

Economic Burden of Work-Related Low Back Pain in Indonesia Before and During the COVID-19 Era, 2019–2021: Analysis of Global Burden of Disease Estimates

Abdul Kadir¹, Derren DCH Rampengan², Andrean VH Simanjuntak³, Theresia Anggriani⁴, Muhammad Dharma Nauval⁵, Muhammad Ichsan Adnan⁶, Surna Lastri⁷, Muhammad Iqhrammullah⁵

¹Occupational Health and Safety Department, Faculty of Public Health, Universitas Indonesia, Depok, 16424, Indonesia; ²Faculty of Medicine, Universitas Sam Ratulangi, Manado, 95115, Indonesia; ³Indonesian Agency for Meteorology Climatology and Geophysics (BMKG), Jakarta, 23111, Indonesia; ⁴Department of Physiology, Murni Teguh University, Medan, Sumatera Utara, 23111, Indonesia; ⁵Postgraduate Program of Public Health, Universitas Muhammadiyah Aceh, Banda Aceh, 23123, Indonesia; ⁶Department of Accounting, Faculty of Business and Economics, Universitas Syiah Kuala, Banda Aceh, 23111, Indonesia; ⁷Postgraduate Program of Management, Universitas Muhammadiyah Aceh, Banda Aceh, 23123, Indonesia

Correspondence: Muhammad Iqhrammullah, Email m.iqhram@unmuha.ac.id

Introduction: Occupational ergonomic risk factors are a major contributor to musculoskeletal disorders and productivity loss, yet their welfare implications remain underexplored in low- and middle-income settings. This study aimed to quantify the health and economic burden of ergonomic risks across Indonesian provinces using the Value of Lost Welfare (VLW) framework.

Methods: Disability-adjusted life years (DALYs) attributable to ergonomic risks were obtained from the Global Burden of Disease 2019–2021 estimates. VLW was calculated by multiplying DALYs with the Value of a Statistical Life Year (VSLY), derived from GDP per capita and adjusted for purchasing power parity. Both absolute VLW (International Dollar, Int\$) and the VLW-to-GDP ratio were computed at national and provincial levels. Socioeconomic inequality was assessed using the slope index of inequality (SII) and relative index of inequality (RII).

Results: National VLW increased from Int\$ 44.6 billion in 2019 to Int\$ 48.5 billion in 2021, with the largest contributions observed in East Java (Int\$ 7.3 billion) and West Java (Int\$ 6.1 billion), while smaller provinces such as Gorontalo and North Maluku contributed less than Int\$ 200 million. Despite a steady rise in DALYs, the VLW-to-GDP ratio followed the economic cycle, increasing during the 2020 downturn (1.47%) and declining to 1.36% in 2021 as GDP rebounded. Socioeconomic inequality in the VLW-to-GDP ratio was statistically significant, with SII of -0.00165 (95% CI: -0.00255 to -0.00074) and RII of -0.118 (95% CI: -0.183 to -0.053).

Discussion: Occupational ergonomics imposes a substantial and persistent health–economic burden in Indonesia, amounting to nearly Int\$ 50 billion annually. The observed socioeconomic gradient indicates that lower-GDP provinces experience disproportionately greater welfare losses relative to their economic capacity, underscoring the need for sustained workplace interventions and targeted regional policies, particularly in lower-GDP regions.

Keywords: occupational ergonomics, DALY, value of lost welfare, VLW-to-GDP ratio, economic burden, Indonesia

Introduction

Musculoskeletal disorders (MSDs) remain a leading contributor to disability and economic losses worldwide, affecting workers across multiple sectors and age groups. Global estimates indicate that MSDs impose a macroeconomic burden of over USD 2 trillion annually, equivalent to 1.41% of global GDP, with low back pain alone accounting for nearly half of the total impact.¹ In another study, low back pain (LBP) affected more than 600 million people worldwide and is projected to increase by 36% by 2050.² A substantial proportion of LBP-

attributable years lived with disability is also driven by occupational risk factors.² The prevalence of occupational exposure to ergonomic risk factors is striking, with a recent WHO/ILO systematic review indicating that approximately 76% of workers are exposed, particularly those in younger age groups and manual occupations such as agriculture and construction.³

The broader work-related burden of disease further situates ergonomic risks within a wider occupational health crisis. The WHO/ILO joint estimates for 2019 reported 2.9 million deaths and 180 million DALYs attributable to occupational exposures, corresponding to 5.8% of global GDP losses.⁴ While circulatory diseases, cancers, and respiratory conditions were leading causes of mortality, MSDs emerged as a major contributor to morbidity, particularly in working-age populations. Such findings highlight the multidimensional consequences of occupational risks, linking ergonomic exposures to both direct disability and broader economic inefficiencies. To quantify the macroeconomic losses attributed to ergonomic exposures, Value of Lost Welfare (VLW) framework can be used, which integrates disability-adjusted life years (DALYs) with the Value of a Statistical Life (VSL). In previous studies, the framework has been applied to estimate the burden of cancers such as tracheal, bronchial, and lung cancer. This framework allows researchers to translate DALYs into economic terms adjusted for purchasing power parity (PPP), thus providing internationally comparable estimates.⁵ The VLW framework has become a cornerstone for evaluating not only cancer but also other chronic and occupational conditions, including musculoskeletal disorders.

Indonesia, as the world's fourth most populous country with a rapidly expanding workforce, faces unique vulnerabilities to ergonomic risks.^{6–9} A large proportion of workers remain employed in agriculture, manufacturing, and the informal sector, where ergonomic hazards are often under-recognized and poorly mitigated.^{10–14} At the same time, economic evaluations of occupational health in Indonesia have predominantly focused on communicable diseases and injuries,^{15,16} leaving ergonomic-related welfare losses largely unquantified. Estimating the economic burden of occupational ergonomics is therefore crucial to inform evidence-based policies, guide resource allocation, and urge the improvement on workplace interventions. Despite global attention to occupational health, MSD-related economic losses remain underexplored in low- and middle-income countries. To date, no study has quantified the VLW attributable to occupational ergonomic risk-related low back pain (LBP) at the national and subnational levels in Indonesia. Addressing this evidence gap is essential to design equitable policies and integrate ergonomic risk prevention into Indonesia's broader health and economic agendas. By capturing both the health and macroeconomic impacts, this study aims to provide timely insights for national and provincial policymakers, particularly in the context of post-COVID-19 recovery, where competing priorities risk sidelining long-standing ergonomic challenges.

Methods

Study Design and Perspective

A cost-of-illness analysis was conducted to estimate the VLW attributable to occupational ergonomics-associated LBP in Indonesia for the years 2019–2021. As low back pain is the only musculoskeletal outcome with standardized occupational ergonomic risk attribution available in the GBD framework, the analysis could not be extended to other musculoskeletal disorders. The study period was chosen because, at the time the analysis was conducted, GBD estimates were available only up to 2021. Moreover, extending the analysis to years prior to 2019 was avoided to ensure consistency in economic valuation inputs and prevent temporal distortion of welfare estimates. The study was undertaken from a societal perspective, valuing losses in terms of foregone welfare rather than financial expenditure, and expressed as the share of provincial and national gross domestic product (GDP).

Ethical Considerations

This study analyzed publicly available, aggregated secondary data from the GBD 2021 Study and national statistical sources. No individual-level or identifiable information was used; therefore, ethical approval was not required. In accordance with GBD data use policies, prior notification for subnational analysis was completed before conducting the provincial-level analysis.

Health Outcomes and Population Data

Health outcomes were measured in DALYs attributable to occupational ergonomics-related LBP. According to the GBD case definition, LBP is defined as pain in the posterior aspect of the body from the lower margin of the 12th ribs to the lower gluteal folds, with or without pain referred into one or both lower limbs, lasting for at least one day.² DALYs were extracted from the GBD 2019, which synthesizes multiple sources of epidemiological and demographic data, including vital registration systems, household surveys, censuses, hospital records, and published studies.¹⁷ GBD employs Bayesian meta-regression (DisMod-MR 2.1) to estimate prevalence, incidence, and mortality, reconciles these with covariates, and then derives DALYs as the sum of years of life lost (YLLs) and years lived with disability (YLDs).^{17,18} In GBD analysis, attribution of LBP to occupational ergonomic risk factors is performed using comparative risk assessment, in which relative risks and modeled exposure distributions are combined to estimate population attributable fractions (PAFs). Thereafter, these PAFs are then applied to total LBP DALYs to quantify the burden attributable to occupational ergonomic exposures, as described in the GBD risk assessment methodology.¹⁹ Uncertainty intervals are propagated at each stage of modeling, and we collected the corresponding 95% uncertainty intervals (95% UI) for all estimates. Population counts by province and year were also obtained from GBD, ensuring consistency between the denominators for DALY rates and the scaling of economic indicators. Provincial life expectancy at birth was extracted from Statistics Indonesia (*Badan Pusat Statistik*, BPS).²⁰

Economic Indicators

Provincial GDP per capita in Indonesian rupiah (IDR, reported in thousand rupiah) was sourced from BPS.²¹ These figures were scaled to full rupiah and converted into purchasing power parity (PPP)-adjusted international dollars using annual PPP conversion factors for Indonesia provided by the World Bank World Development Indicators (WDI).^{22,23} Corresponding US GDP per capita (PPP, international \$) was also taken from WDI.²⁴ The US Department of Transportation (US DOT) value of a statistical life (VSL) served as the benchmark for welfare valuation.²⁵

Valuation of Outcomes

Provincial VSLs were derived by transferring the US DOT VSL to Indonesian provinces according to relative income levels. Specifically, provincial VSL was calculated as the US DOT VSL multiplied by the ratio of provincial GDP per capita (PPP) to US GDP per capita (PPP), raised to the power of the income elasticity of VSL. We adopted an elasticity of one ($\epsilon = 1$), consistent with the published guideline from the Organisation for Economic Co-operation and Development (OECD).²⁶ The formula was:

$$VSL_{prov,t} = VSL_{US,t} \times \left(\frac{GDP_{pcppp,prov,t}}{GDP_{pcppp,US,t}} \right)^{\epsilon} \quad (1)$$

To estimate the value of a statistical life year (VSLY), provincial VSLs were annualized over life expectancy at birth using a constant 3% annual discount rate, in accordance with WHO recommendations and the Indonesian Ministry of Health's economic evaluation guidelines.²⁷ Discounting was applied to assign a lower present value to health losses occurring further in the future. Thus, the formula to estimate the VSLY was:

$$VSLY_{prov,t} = \frac{VSL_{prov,t}}{\sum_{a=1}^{LE_{prov,t}} \frac{1}{(1+r)^a}} \quad (2)$$

where LE denotes provincial life expectancy at birth and $r = 0.03$.

Value of Lost Welfare and VLW-to-GDP Ratio

The VLW was estimated by multiplying the provincial VSLY by the number of DALYs attributable to occupational ergonomics-associated LBP (Equation 3). This approach quantifies the monetary value of population-level health losses by assigning a welfare value to each year of healthy life lost, consistent with established welfare-based economic burden frameworks.

$$VLW_{prov,t} = VSLY_{prov,t} \times DALY_{prov,t} \quad (3)$$

To facilitate comparison across provinces with different economic sizes, VLW was further expressed relative to total provincial economic output. Provincial GDP (PPP-adjusted) was calculated as GDP per capita multiplied by the corresponding provincial population estimate. The VLW-to-GDP ratio (Equation 4) therefore reflects the proportion of total economic output that is equivalent to welfare losses attributable to occupational ergonomic risks.

$$\text{Ratio of VLW to GDP}_{prov,t} = \frac{VLW_{prov,t}}{GDP_{pcppp,prov,t} \times Population_{prov,t}} \quad (4)$$

This normalized measure allows assessment of the relative economic burden of occupational low back pain across provinces, independent of absolute economic scale. All input data and intermediate calculations are provided in the [Supplementary File](#).

Spatiotemporal Analysis

Spatiotemporal analyses were performed to characterize the provincial distribution and temporal variation of the burden attributable to occupational ergonomics-associated low back pain (LBP) in Indonesia between 2019 and 2021. All analyses and visualizations were conducted using Python (version 3.12) with libraries including geopandas, matplotlib, seaborn, and pandas for geospatial processing, data manipulation, and mapping. DALYs were depicted as choropleth maps, the VLW was represented using graduated color maps, and VLW-to-GDP ratios were visualized with intensity gradients to emphasize inter-provincial disparities. Temporal dynamics were examined by calculating percentage shifts for each indicator between 2019–2020 and 2020–2021, displayed through comparative bar charts to highlight increases and decreases across provinces.

Estimation of Socioeconomic Inequalities

Absolute and relative socioeconomic inequalities were estimated using regression-based inequality indices, namely the Slope Index of Inequality (SII) and the Relative Index of Inequality (RII), respectively. Provinces were ranked by GDP from lowest to highest and assigned a relative socioeconomic rank based on rdit scores. The SII was estimated by regressing the outcome of interest (y_i ; DALY count, value of lost welfare, or VLW–GDP ratio) on the relative socioeconomic rank of each province (R_i). The following formula was used:

$$y_i = \alpha + \beta R_i + \varepsilon_i \quad (4)$$

where β represents the SII and quantifies the absolute difference in the outcome between provinces at the lowest and highest ends of the GDP distribution. Standard errors (SEs) were obtained from the regression model, and 95% confidence intervals (CIs) were calculated as:

$$CI_{95\%} = \beta \pm t_{n-2,0.975} \times SE(\beta) \quad (5)$$

Meanwhile, the RII was derived by normalizing the SII to the overall mean of the outcome (μ):

$$RII = \frac{\beta}{\mu} \quad (6)$$

The RII represents the relative difference in the outcome across the socioeconomic hierarchy. Standard errors and 95% confidence intervals for the RII were estimated using error propagation based on the variance of the SII. Negative SII and RII values indicate a disproportionate burden among lower-GDP provinces, consistent with provinces being ranked from lowest to highest GDP.

Assumptions

We assumed no differentiation by sex, applied a uniform income elasticity of one, and valued DALYs proportionally to welfare loss without age-weighting. All monetary values were expressed in current PPP-adjusted international dollars. The analysis was limited to the years 2019–2021 and did not extrapolate beyond this period.

Table 1 Disability-Adjusted Life years Attributable to Occupational Ergonomics–Associated Low Back Pain in Indonesia and Its Provinces

Province	DALY (95% UI), Count			DALY Shift (%)	
	2019	2020	2021	2019 to 2020	2020 to 2021
Indonesia	65.17 (89.18–45.41)	65.96 (90.29–46.26)	67.39 (92.77–46.71)	1.21	2.18
Aceh	1.24 (1.71–0.83)	1.26 (1.78–0.84)	1.3 (1.84–0.87)	2.02	3.16
North Sumatra	3.41 (4.79–2.22)	3.46 (4.82–2.29)	3.54 (4.98–2.32)	1.49	2.53
Jambi	0.87 (1.23–0.59)	0.89 (1.26–0.6)	0.91 (1.3–0.6)	1.83	2.42
West Sumatra	1.33 (1.83–0.9)	1.35 (1.85–0.9)	1.38 (1.93–0.93)	0.98	2.74
Riau	1.41 (2.03–0.96)	1.44 (2.07–0.98)	1.47 (2.1–1)	1.65	2.30
Riau Islands	0.43 (0.61–0.29)	0.45 (0.62–0.3)	0.46 (0.66–0.31)	2.99	4.21
South Sumatra	2.04 (2.85–1.38)	2.07 (2.88–1.41)	2.12 (2.91–1.44)	1.22	2.61
Bengkulu	0.52 (0.73–0.35)	0.52 (0.74–0.36)	0.54 (0.76–0.37)	1.69	2.87
North Kalimantan	0.15 (0.21–0.1)	0.16 (0.22–0.1)	0.17 (0.23–0.11)	3.13	4.48
Lampung	2.29 (3.2–1.48)	2.34 (3.28–1.52)	2.4 (3.44–1.56)	1.84	2.79
Bangka-Belitung Islands	0.37 (0.5–0.25)	0.37 (0.52–0.26)	0.38 (0.53–0.26)	2.07	2.90
Yogyakarta	0.92 (1.34–0.63)	0.92 (1.34–0.63)	0.92 (1.36–0.62)	–0.50	0.92
Jakarta	2.02 (2.88–1.37)	2.04 (2.85–1.35)	2.08 (2.97–1.4)	0.91	1.99
East Java	10.3 (14.32–6.92)	10.27 (14.33–6.86)	10.38 (14.65–6.89)	–0.26	1.11
West Java	11.26 (15.64–7.66)	11.42 (15.9–7.69)	11.62 (16.09–7.79)	1.43	1.79
Banten	2.63 (3.7–1.75)	2.69 (3.84–1.77)	2.76 (3.94–1.82)	1.97	2.76
Central Java	9.26 (12.9–6.2)	9.33 (12.86–6.27)	9.5 (13.08–6.38)	0.73	1.76
West Kalimantan	1.34 (1.84–0.9)	1.37 (1.92–0.93)	1.41 (1.95–0.97)	2.71	2.95
Bali	1.09 (1.53–0.73)	1.09 (1.55–0.73)	1.11 (1.59–0.73)	0.30	1.48
Central Kalimantan	0.67 (0.95–0.45)	0.69 (0.98–0.46)	0.71 (0.99–0.48)	2.47	3.30
West Nusa Tenggara	1.3 (1.77–0.88)	1.32 (1.83–0.9)	1.36 (1.87–0.92)	1.86	2.91
South Kalimantan	0.98 (1.37–0.66)	0.99 (1.39–0.66)	1 (1.41–0.67)	0.57	1.31
East Nusa Tenggara	1.38 (1.91–0.94)	1.41 (1.95–0.95)	1.45 (2.03–0.99)	2.00	2.75
Central Sulawesi	0.75 (1.05–0.51)	0.76 (1.06–0.52)	0.78 (1.13–0.54)	1.35	2.58
East Kalimantan	0.79 (1.11–0.52)	0.81 (1.14–0.53)	0.83 (1.17–0.55)	2.11	2.94
South Sulawesi	2.3 (3.27–1.57)	2.33 (3.25–1.58)	2.38 (3.37–1.64)	1.24	2.22
Southeast Sulawesi	0.65 (0.9–0.45)	0.66 (0.91–0.45)	0.68 (0.96–0.46)	2.22	3.20
North Sulawesi	0.68 (0.95–0.47)	0.69 (0.96–0.47)	0.7 (0.98–0.48)	0.90	2.10
Maluku	0.5 (0.69–0.34)	0.51 (0.71–0.35)	0.53 (0.74–0.37)	2.88	4.32
Gorontalo	0.32 (0.43–0.21)	0.32 (0.44–0.22)	0.33 (0.45–0.22)	1.01	2.34
North Maluku	0.34 (0.46–0.22)	0.35 (0.47–0.23)	0.36 (0.49–0.24)	3.07	4.43
West Sulawesi	0.36 (0.49–0.24)	0.37 (0.5–0.25)	0.38 (0.52–0.25)	2.35	3.73
West Papua	0.26 (0.36–0.18)	0.27 (0.38–0.19)	0.29 (0.4–0.2)	5.26	6.55
Papua	1 (1.35–0.67)	1.05 (1.46–0.7)	1.12 (1.52–0.76)	5.18	5.92

Results

Disability-Adjusted Life Years

National DALY counts attributable to occupational ergonomics–associated low back pain are presented in Table 1. The estimates increased steadily from 65.17 (95% UI: 45.41–89.18) thousand in 2019 to 67.39 (46.71–92.77) thousand in 2021, representing a cumulative rise of 3.4%. Most provinces followed this upward trend, with the largest absolute DALY counts observed in West Java (11.62 thousand in 2021), East Java (10.38 thousand), and Central Java (9.5 thousand). Provinces with smaller populations, such as Riau Islands, Gorontalo, and North Kalimantan, showed lower counts (<0.5 thousand each year) but often registered higher percentage increases, exceeding 4% in some years. Papua and West Papua displayed the sharpest year-to-year increases, with DALYs rising by more than 5% annually between 2019 and 2021. In contrast, Yogyakarta and East Java showed minimal or negative shifts during 2019–2020 before modest increases in 2021.

Value of Lost Welfare

The estimated VLWs attributable to occupational ergonomics-associated low back pain in Indonesia and its provinces are presented in Table 2. Nationally, VLW rose from Int\$ 44.57 billion in 2019 to Int\$ 48.53 billion in 2021, reflecting a 2-year increase of 8.9%. Provincially, the largest absolute welfare losses were concentrated in East Java (Int\$ 7.16–7.32 billion), Jakarta (Int\$ 6.34–6.83 billion), and West Java (Int\$ 5.70–6.30 billion). Several provinces experienced sharp increases between 2019 and 2020, notably North Kalimantan (+16.3%), Riau Islands (+16.1%), and Central Sulawesi (+19.8%). From 2020 to 2021, Central Sulawesi (+16.1%), North Maluku (+16.7%), and Papua (+12.8%) recorded the steepest gains. Conversely, declines were observed in some provinces, including Bali (−9.4%), Lampung (−2.3%), and Jakarta (−2.4%), despite stable or increasing DALYs.

Table 2 Value of Lost Welfare Attributable to Occupational Ergonomics–Associated Low Back Pain in Indonesia and Its Provinces

Province	VLW (Million Int\$)			VLW Shift (%)	
	2019	2020	2021	2019 to 2020	2020 to 2021
Indonesia	44571.30	47,555.03	48,532.24	6.69	2.05
Aceh	452.39	515.48	533.52	13.94	3.50
North Sumatra	2212.47	2463.37	2414.16	11.34	−2.00
Jambi	626.88	663.05	694.52	5.77	4.75
West Sumatra	709.80	762.68	739.67	7.45	−3.02
Riau	1848.31	2102.20	2236.46	13.74	6.39
Riau Islands	611.46	709.70	722.67	16.07	1.83
South Sumatra	1292.68	1438.51	1448.53	11.28	0.70
Bengkulu	223.69	247.85	250.00	10.80	0.87
North Kalimantan	249.44	290.17	303.66	16.33	4.65
Lampung	1142.12	1181.15	1153.90	3.42	−2.31
Bangka-Belitung Islands	225.85	250.26	264.56	10.81	5.71
Yogyakarta	389.84	437.23	434.07	12.16	−0.72
Jakarta	6341.88	6834.25	6670.90	7.76	−2.39
East Java	7157.83	7468.64	7319.07	4.34	−2.00
West Java	5704.45	6295.17	6131.91	10.36	−2.59
Banten	1622.57	1828.21	1805.83	12.67	−1.22
Central Java	4246.98	4376.10	4251.74	3.04	−2.84
West Kalimantan	663.55	700.07	703.38	5.50	0.47
Bali	738.48	727.08	658.82	−1.54	−9.39
Central Kalimantan	452.78	510.54	530.71	12.76	3.95
West Nusa Tenggara	401.02	435.78	423.62	8.67	−2.79
South Kalimantan	501.48	570.29	566.88	13.72	−0.60
East Nusa Tenggara	325.73	367.08	356.34	12.70	−2.93
Central Sulawesi	548.84	657.43	763.11	19.79	16.08
East Kalimantan	1660.01	1658.60	1767.38	−0.08	6.56
South Sulawesi	1554.78	1670.42	1669.92	7.44	−0.03
Southeast Sulawesi	370.35	422.67	421.04	14.13	−0.39
North Sulawesi	419.58	446.88	446.58	6.51	−0.07
Maluku	156.68	168.91	168.02	7.81	−0.53
Gorontalo	133.17	149.61	145.55	12.34	−2.71
North Maluku	128.54	148.63	173.41	15.63	16.67
West Sulawesi	147.67	158.48	161.14	7.32	1.68
West Papua	273.80	265.28	258.91	−3.11	−2.40
Papua	685.64	644.27	726.94	−6.03	12.83

VLW-to-GDP Ratio

The ratio of VLW-to-GDP attributable to occupational ergonomics-associated low back pain is presented in Table 3. At the national level, the VLW-to-GDP ratio rose from 1.36% in 2019 to 1.47% in 2020 before declining back to 1.36% in 2021, reflecting a rebound of GDP following the COVID-19 economic slowdown. Meanwhile in provincial level, similar patterns were observed with nearly all provinces showing increases of 7–9% between 2019 and 2020 and subsequent decreases of 6–8% from 2020 to 2021. The highest relative burdens in 2021 were noted in Maluku (1.59%), North Maluku (1.56%), and East Nusa Tenggara (1.53%), all exceeding the national average. In contrast, Jakarta (1.09%) and East Kalimantan (1.20%) consistently showed the lowest ratios.

Table 3 Ratio of Value of Lost Welfare to Gross Domestic Product Attributable to Occupational Ergonomics–Associated Low Back Pain in Indonesia and Its Provinces

Province	VLW-to-GDP			VLW-to-GDP Shift (%)	
	2019	2020	2021	2019 to 2020	2020 to 2021
Indonesia	0.0136	0.0147	0.0136	7.74	−7.18
Aceh	0.0137	0.0148	0.0139	8.44	−6.42
North Sumatra	0.0132	0.0143	0.0133	7.91	−7.02
Jambi	0.0141	0.0153	0.0143	8.58	−6.83
West Sumatra	0.0137	0.0147	0.0137	7.16	−6.97
Riau	0.0127	0.0138	0.0129	8.63	−6.76
Riau Islands	0.0115	0.0124	0.0115	8.01	−6.67
South Sumatra	0.0139	0.0150	0.0140	7.92	−6.61
Bengkulu	0.0147	0.0159	0.0148	8.01	−6.75
North Kalimantan	0.0126	0.0137	0.0128	8.26	−6.40
Lampung	0.0146	0.0157	0.0146	7.94	−7.00
Bangka-Belitung Islands	0.0144	0.0155	0.0145	8.23	−6.86
Yogyakarta	0.0138	0.0147	0.0136	6.64	−7.62
Jakarta	0.0109	0.0117	0.0109	7.56	−7.20
East Java	0.0142	0.0151	0.0140	6.66	−7.68
West Java	0.0131	0.0141	0.0131	8.21	−7.37
Banten	0.0127	0.0138	0.0129	8.62	−6.59
Central Java	0.0140	0.0151	0.0139	7.22	−7.52
West Kalimantan	0.0141	0.0153	0.0142	8.46	−7.22
Bali	0.0141	0.0151	0.0139	6.97	−7.60
Central Kalimantan	0.0145	0.0158	0.0147	8.51	−6.65
West Nusa Tenggara	0.0143	0.0155	0.0145	8.23	−6.68
South Kalimantan	0.0139	0.0151	0.0138	8.76	−8.71
East Nusa Tenggara	0.0151	0.0163	0.0153	7.70	−6.05
Central Sulawesi	0.0146	0.0157	0.0147	7.98	−6.65
East Kalimantan	0.0120	0.0130	0.0120	7.87	−7.24
South Sulawesi	0.0143	0.0154	0.0143	7.75	−7.18
Southeast Sulawesi	0.0142	0.0154	0.0144	8.52	−6.47
North Sulawesi	0.0147	0.0157	0.0145	7.07	−7.50
Maluku	0.0157	0.0170	0.0159	8.47	−6.16
Gorontalo	0.0155	0.0167	0.0156	8.03	−6.65
North Maluku	0.0153	0.0166	0.0156	8.69	−6.02
West Sulawesi	0.0149	0.0161	0.0151	8.30	−6.35
West Papua	0.0138	0.0150	0.0141	8.65	−6.06
Papua	0.0131	0.0142	0.0133	8.72	−6.45

Spatiotemporal Distribution

DALY attributable to occupational ergonomics-related low back pain increased at the national level between 2019 and 2021, with higher absolute values in populous provinces such as West Java, East Java, and Central Java (Figure 1). VLW also increased over the same period, rising nationally from 2019 to 2021. Provinces with large populations, such as East Java, West Java, and Jakarta, contributed the largest shares of the total VLW, while smaller provinces such as Gorontalo, North Maluku, and West Sulawesi accounted for much lower values (Figure 2). The VLW-to-GDP ratio showed a different pattern. At the national level, the ratio rose from 2019 to 2020 and returned to the 2019 level in 2021. Provinces such as Maluku, Gorontalo, North Maluku, and East Nusa Tenggara consistently exhibited the highest ratios,

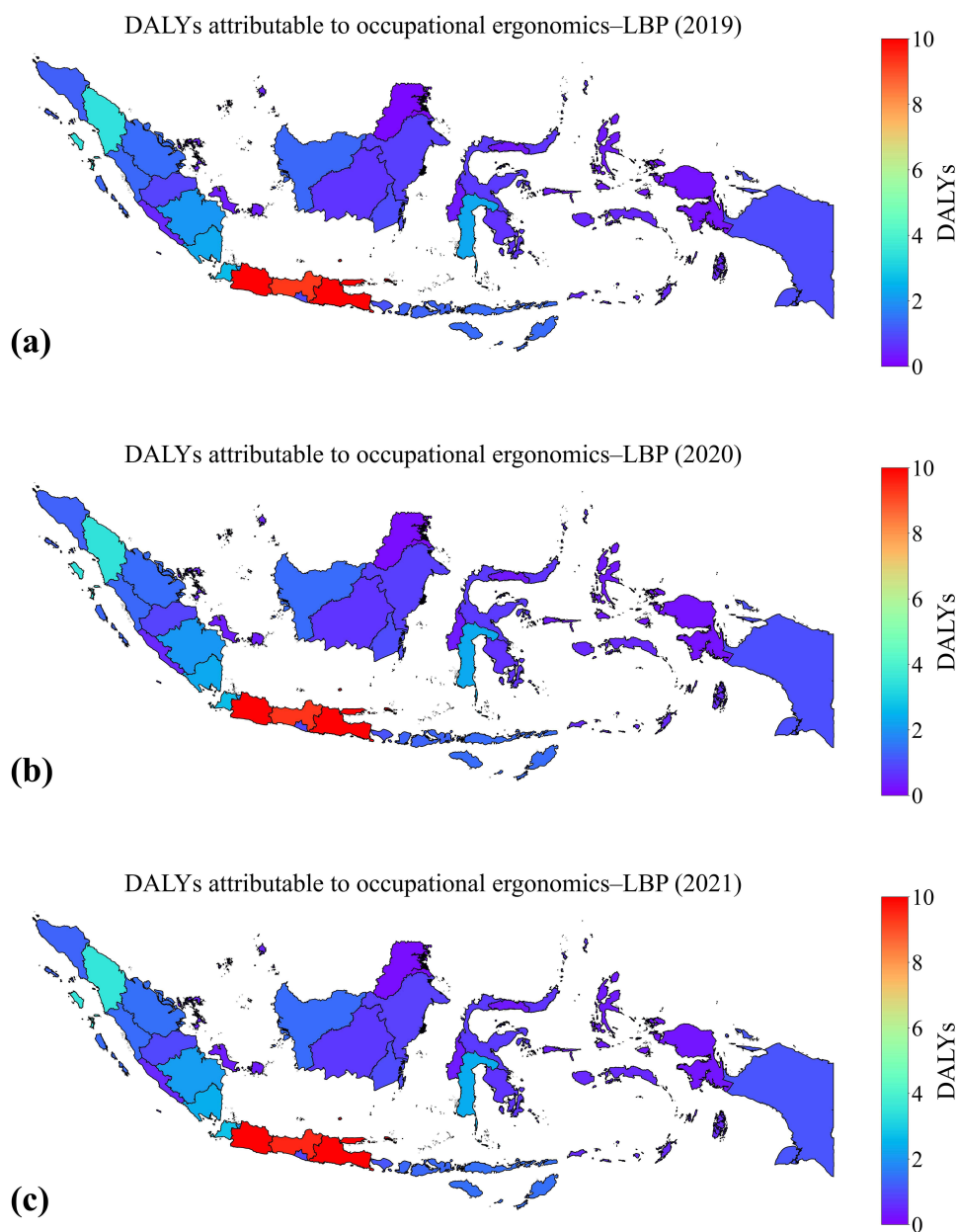


Figure 1 Disability-adjusted life years (DALYs) attributable to occupational ergonomics-associated low back pain in Indonesia, 2019–2021, showing national DALY estimates across the three study years (a), the provincial distribution of DALYs in 2021 (b), and the temporal change in DALYs from 2019 to 2021 across provinces (c).

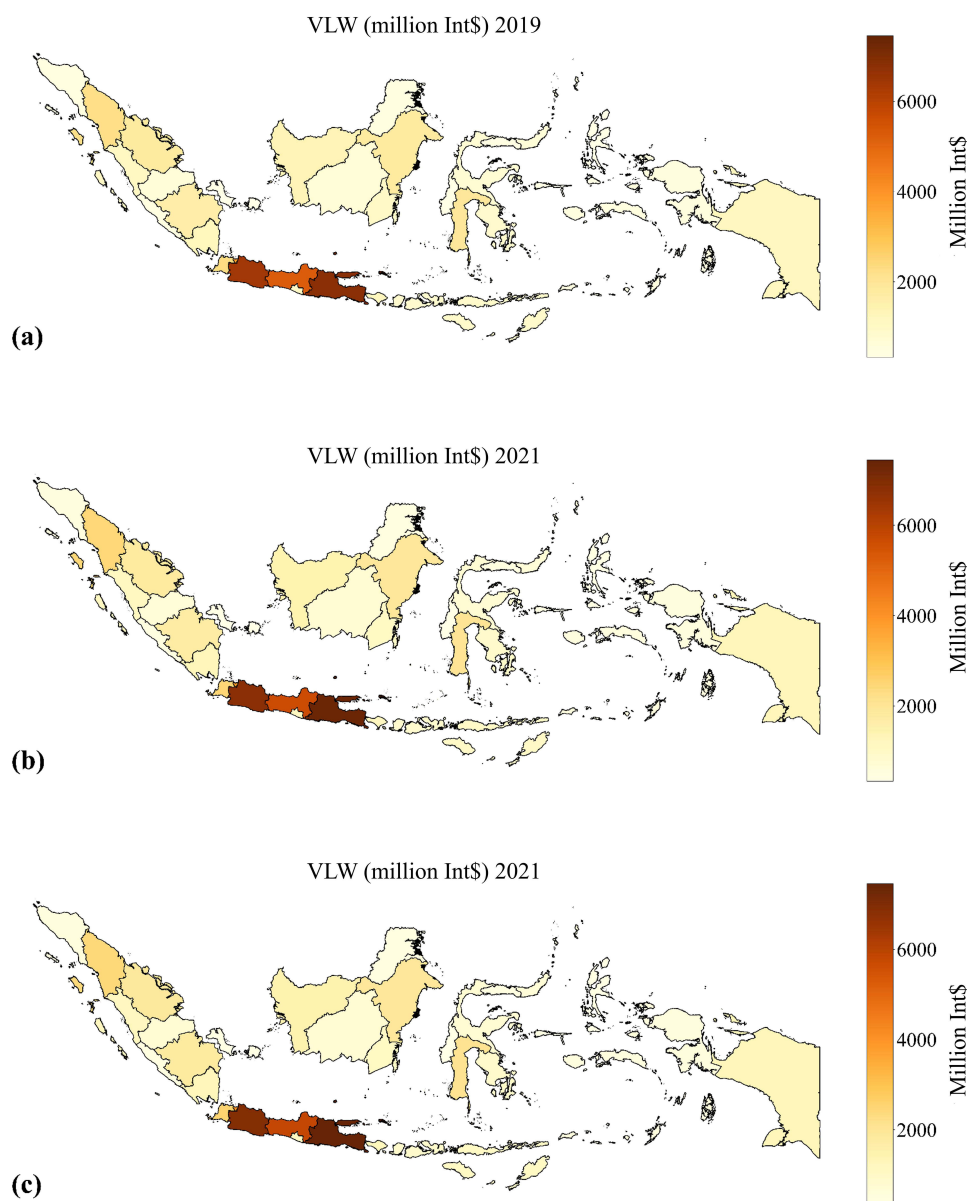


Figure 2 Value of lost welfare (VLW, million Int\$) attributable to occupational ergonomics-associated low back pain in Indonesia and its provinces, 2019–2021, illustrating national VLW estimates across the three study years (a), the provincial distribution of VLW in 2021 (b), and temporal shifts in VLW from 2019 to 2021 across provinces (c).

while Jakarta, Riau Islands, and East Kalimantan remained at the lowest levels (Figure 3). In terms of their year-to-year changes, the trends are uneven as presented in Figure 4. From 2019 to 2020, the onset of the COVID-19 pandemic and the associated economic shock coincided with negative or minimal DALY shifts in several Java provinces, while many eastern provinces showed increases. From 2020 to 2021, as the economy began to rebound, DALY growth was observed in most provinces, with the largest increases again in the east, while provinces in Java remained stable VLW also rose nationally, with some eastern provinces showing stronger gains, while Bali, Jakarta, and West Java experienced stagnation or declines. A similar shift was observed for the VLW-to-GDP ratio: during 2019 to 2020, when GDP contracted, the ratio increased across nearly all provinces, with the sharpest rises in smaller economies such as Maluku, Gorontalo, North Maluku, and East Nusa Tenggara. From 2020 to 2021, as GDP rebounded, most provinces saw the ratio

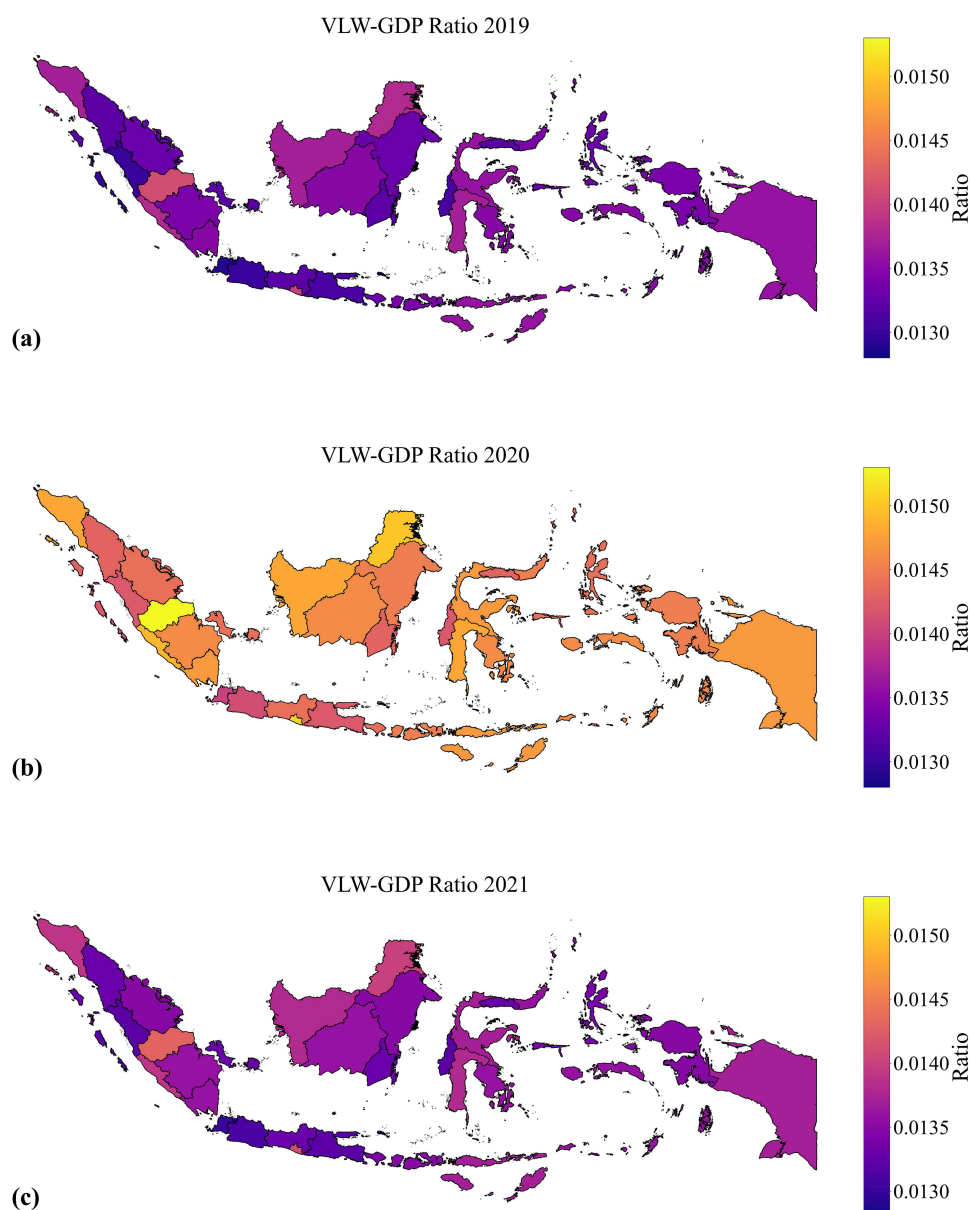


Figure 3 Ratio of VLW-to-GDP attributable to occupational ergonomics–associated low back pain in Indonesia and its provinces, 2019–2021, showing national VLW-GDP ratios across study years (a), the provincial distribution of VLW-GDP ratios in 2021 (b), and temporal changes in VLW-GDP ratios across provinces from 2019 to 2021 (c).

decline toward pre-pandemic levels, although the relative ranking persisted, with eastern provinces highest and Jakarta, Riau Islands, and East Kalimantan lowest.

Socioeconomic Inequalities

Before the COVID-19 pandemic, DALY counts exhibited a positive concentration toward higher-GDP provinces (Table 4). In 2020, this pattern shifted toward lower-GDP provinces, before reverting to a positive concentration in 2021. For absolute VLW, concentration indices remained positive throughout 2019–2021. However, none of the absolute or relative inequality estimates for DALY counts or absolute VLW were statistically significant, as the corresponding confidence intervals crossed the null. In contrast, the VLW–GDP ratio demonstrated statistically significant and consistently negative inequality indices across all years. Absolute inequality estimates indicated a consistent GDP gradient in the VLW–GDP ratio, with SII values of

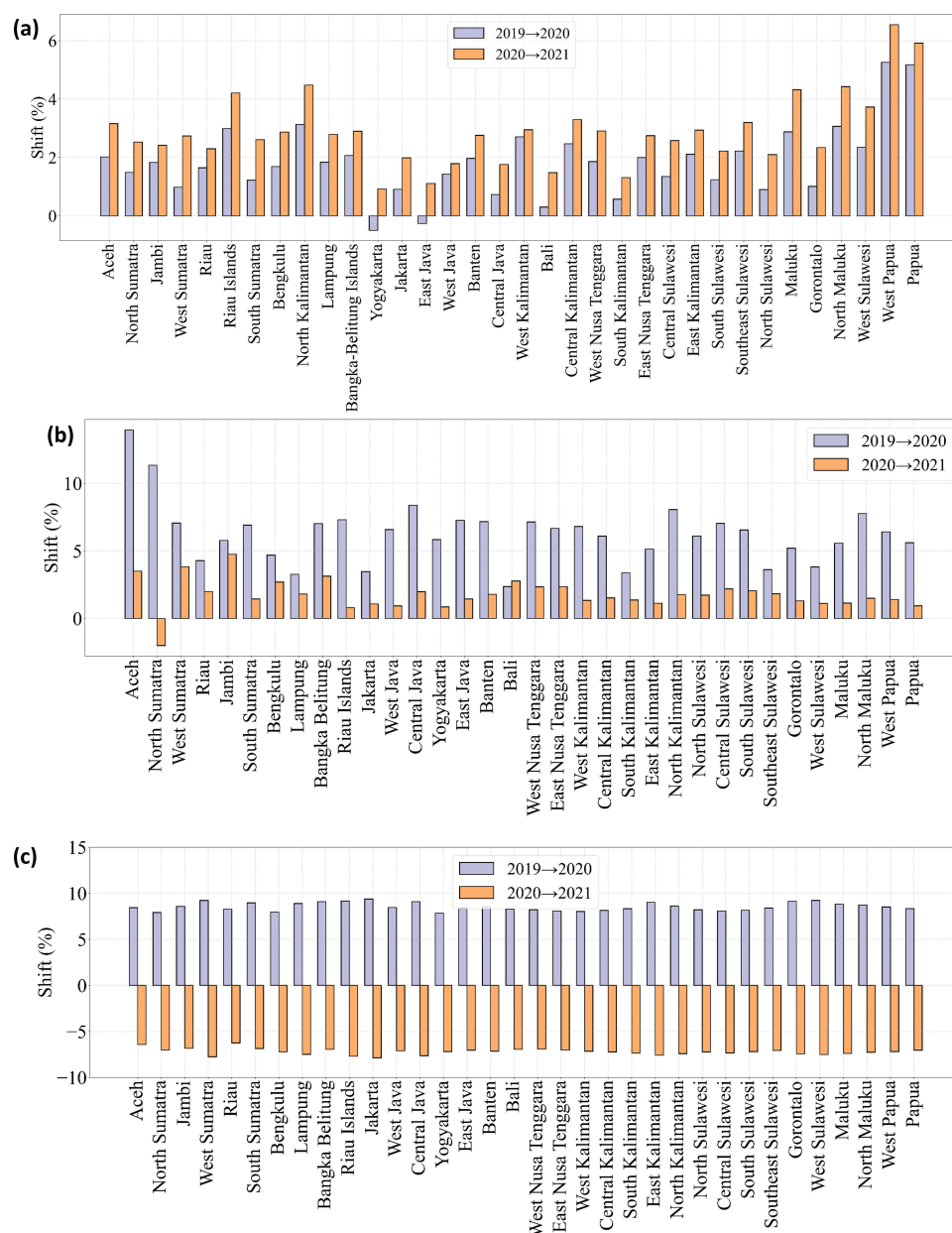


Figure 4 Year-to-year shifts of DALYs (a), VLWs (b), and VLW-to-GDP ratios (c) attributable to occupational ergonomics-associated low back pain provinces in Indonesia.

−0.00162 (95% CI: −0.00249 to −0.00075) in 2019, −0.00173 (95% CI: −0.00268 to −0.00078) in 2020, and −0.00165 (95% CI: −0.00255 to −0.00074) in 2021. Correspondingly, relative inequality estimates were also statistically significant, with RII values of −0.117 (95% CI: −0.179 to −0.054), −0.115 (95% CI: −0.178 to −0.052), and −0.118 (95% CI: −0.183 to −0.053), respectively (Table 4).

Discussion

This present study quantified the economic burden of occupational ergonomics across Indonesian provinces using the VLW framework. At the national level, VLW reached Int\$ 48.5 billion in 2021, rising from Int\$ 44.6 billion in 2019 and Int\$ 47.6 billion in 2020. This steady increase reflects the persistent and cumulative nature of musculoskeletal and ergonomic disorders, which continue to add disability and premature mortality even as other acute health shocks subside.

Table 4 Absolute and Relative Health Inequality Estimates for Disease and Economic Burdens Attributable to Occupational Low Back Pain in Indonesia

Estimates	Slope Index of Inequality	Relative Index of Inequality
DALY		
2019	-2,701.58 (-29,382.45 to 23,979.30)	-0.14 (-1.53 to 1.25)
2020	-5,373.39 (-32,198.95 to 21,452.16)	-0.28 (-1.66 to 1.11)
2021	-8,219.10 (-31,504.05 to 23,065.84)	-0.21 (-1.59 to 1.16)
VLW		
2019	1,090.49 (-622.11 to 2,803.10)	0.84 (-0.48 to 2.16)
2020	1,034.56 (-806.72 to 2,875.85)	0.74 (-0.58 to 2.06)
2021	1,136.60 (-647.52 to 2,920.72)	0.82 (-0.47 to 2.10)
VLW-GDP ratio		
2019	-0.00162 (-0.00249 to -0.00075)	-0.117 (-0.179 to -0.054)
2020	-0.00173 (-0.00268 to -0.00078)	-0.115 (-0.178 to -0.052)
2021	-0.00165 (-0.00255 to -0.00074)	-0.118 (-0.183 to -0.053)

At the provincial scale, the burden was unevenly distributed. East Java recorded the highest VLW (Int\$ 7.3 billion in 2021), followed closely by West Java and Jakarta, provinces characterized by dense populations and concentrated labor forces where ergonomic risks are magnified by industrial and service-sector activity. In contrast, smaller or less industrialized regions such as Gorontalo (Int\$ 145.6 million) and North Maluku (Int\$ 173.4 million) contributed only a fraction of the national burden, illustrating the strong influence of both population size and economic structure on VLW estimates. As a comparison, the recently published estimates indicate that MSDs caused a worldwide VLW of USD 2,099.84 billion in 2021, equivalent to 1.41% of global GDP, with LBP alone accounting for 43% of the total burden.¹

In interpreting the findings of the present study, it is important to consider the mechanisms underlying the observed trajectories. The increase in absolute VLW was primarily shaped by the rise in DALY attributable to occupational ergonomics-related low back pain, with additional influence from the annual adjustment of national VSL benchmarks. By contrast, the spike and normalization of the VLW-to-GDP ratio closely tracked the national economic cycle, with GDP growth of 5.0% in 2019, a contraction of -2.1% in 2020, and a rebound of 3.7% in 2021.²⁸ Notably, the rise in DALY during 2020 in the present study coincided with the onset of the COVID-19 pandemic, when large segments of the workforce shifted to remote work in non-ergonomic environments. Reviews on evidence from multiple countries suggest that work-from-home arrangements were associated with increased prevalence of low back, neck, and shoulder pain due to prolonged sitting, inadequate furniture, and limited physical activity.^{29,30} In Indonesia, a descriptive study reported that two-thirds of workers experienced musculoskeletal complaints during home-based work, particularly in the lower back and neck.³¹ These patterns suggest that pandemic-driven changes in work environments may have exacerbated ergonomic risks, amplifying the musculoskeletal burden even as economic activity slowed. However, it is important to emphasize that the present study does not infer a causal relationship between pandemic-related changes in work environments and the observed trajectories of DALYs or VLW, and these associations are discussed only in relation to evidence reported in the existing literature.

In the present study, the SII and RII estimated from the VLW-GDP ratio suggests that provinces with lower GDP may significantly experience a disproportionate welfare impact from occupational LBP, even when absolute burdens are lower. This pattern is consistent with the structural characteristics of labor markets in lower-GDP provinces, where employment is more likely to involve physically demanding tasks, informal arrangements, and limited access to ergonomic safeguards. Empirical evidence from Indonesian settings consistently highlights the pervasiveness of MSDs

across such sectors.^{32,33} For example, factory workers reported extremely high prevalence of low back, shoulder, and neck pain, with LBP affecting 94.4% of workers.³² Similarly, ergonomic risk assessments among informal welding workers found that 75% experienced high-level MSD complaints, with physical fitness and posture emerging as dominant predictors.³³ In particular, traditional weavers in East Nusa Tenggara, one of the lowest-ranked provinces by GDP, have been reported to face a high risk of low back pain.³⁴ Similarly, seven out of ten harbor porters in Southeast Sulawesi were found to experience LBP.³⁵

Regardless of provincial socioeconomic status, previous studies have reported that healthcare workers are particularly prone to MSDs, with risks strongly associated with workload and posture.^{7,36} Nurses, in particular, frequently reported frequent LBP and tension neck syndrome.^{7,36} More than 70% of dentists report poor ergonomic practices, and nearly all experience work-related MSDs, predominantly affecting the back, waist, and neck.^{8,37} Systematic reviews have consistently confirmed age, gender, workload, and posture as key determinants of MSDs among healthcare workers.^{9,38} Among health students, LBP has been frequently associated with body mass index, prolonged sitting duration, and poor posture.³⁹

In the informal sector, such as agriculture, LBP risk is similarly influenced by posture, working conditions, and gender.^{10,12,39} Online motorcycle taxi drivers in Jakarta have demonstrated early signs of carpal tunnel syndrome attributable to prolonged awkward postures.¹¹ Garment and batik workers exhibit high ergonomic risks associated with age, body mass index, and posture.^{13,14,40} In heavy industries, compounded exposures are particularly pronounced, with coal mining workers facing combined physical and psychosocial risks for neck and shoulder pain,⁴¹ and construction workers experiencing markedly elevated odds of neck pain under similar conditions.⁴²

Innovative approaches are beginning to demonstrate potential solutions to reduce the burden of work-related LBP. Digital Human Modeling (DHM) applied in horticultural workstations reduced RULA scores by 75% after replacing manual valves with motor-operated systems.⁴³ Such computer-aided ergonomics methods demonstrate how technology can substantially reduce musculoskeletal risks in manual labor settings. Beyond prevention, ergonomic challenges also influence recovery. A previous study of hip fracture patients identified low grip strength, arm muscle area, calf circumference, serum albumin, and muscle fiber diameter as predictors of walking inability six weeks post-surgery.⁴⁴ It is worth noting that the WHO/ILO joint estimates of the work-related burden of disease and injury reported that 2.9 million deaths and 180 million DALYs in 2019 were attributable to occupational exposures worldwide.⁴ Work-related DALYs accounted for 5.8% of global GDP, with musculoskeletal disorders contributing 9% of the total burden.⁴ Thus, occupational risks, including ergonomic hazards, not only impose severe health consequences but also translate into substantial macroeconomic losses, reinforcing the urgency for national and global action.

This study has several limitations that should be considered when interpreting the findings. First, the estimation of VLW relies on the VSLY, which is derived from GDP per capita and PPP adjustments. This approach assumes a uniform relationship between income and the valuation of health across provinces, potentially overlooking cultural, demographic, and labor market differences that influence the true willingness to pay for risk reduction. The structure of income elasticity and discounting can influence the magnitude of the estimates; however, the estimation in the present study followed internationally accepted guidelines for health economic evaluation. Second, the analysis used aggregated DALY estimates from the GBD framework, which may mask within-province heterogeneity and could be subject to modeling uncertainties, particularly for work-related MSDs. In Indonesia, where occupational health surveillance remains limited and informal employment predominates, ergonomic risk exposures are likely underreported. As a result, the estimation herein may represent a conservative approximation of the true impact. Third, the time frame of 2019–2021 coincides with the COVID-19 pandemic, and interpretation of the findings should not extend beyond the study window. Finally, this study did not incorporate other economic components such as productivity losses, direct healthcare costs, employer-related expenditures, or caregiver burden. Consequently, the estimated value of lost welfare reflects health-related welfare losses rather than the full economic cost of occupational LBP.

Conclusion

Occupational ergonomics imposes a substantial and rising health burden in Indonesia, with welfare losses amounting to nearly Int\$ 50 billion in 2021. While the VLW-to-GDP ratio declined due to rapid economic recovery following the

COVID-19 downturn, this should not be interpreted as a reduction in ergonomic risk. The steady increase in DALYs during the pandemic may partly reflect changes in work behaviour, particularly remote working in non-ergonomic environments. Moreover, the economic weight of this burden is unevenly distributed across provinces, with lower-GDP regions experiencing disproportionately higher welfare losses relative to their economic capacity. These findings underscore the importance of prioritizing systematic ergonomic risk assessment and monitoring, particularly in lower-GDP provinces that are more vulnerable to the economic consequences of occupational health burdens. Strengthening occupational health surveillance, expanding routine ergonomic risk assessments, and integrating ergonomic indicators into provincial labor and health monitoring systems could support earlier identification of high-risk work settings and inform targeted preventive actions.

Data Sharing Statement

Data available in a publicly accessible repository: The data presented in this study are openly available in FigShare at <https://doi.org/10.6084/m9.figshare.30218182>, reference number.⁴⁵

Acknowledgments

The authors acknowledge the Global Burden of Disease (GBD) Study collaborators and Statistics Indonesia (*Badan Pusat Statistik*, BPS) for providing access to the data used in this analysis. The interpretation and reporting of these data are the sole responsibility of the authors and do not necessarily represent the views of the Institute for Health Metrics and Evaluation (IHME), the GBD collaborators, or BPS.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Funding

This study is fully funded by Directorate of Research Funding and Ecosystem (DPER) Universitas Indonesia under Publikasi Terindeks Internasional (PUTI) Grant, grant number: NKB-667/UN2.RST/HKP.05.00/2024.

Disclosure

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

1. Qiu K, Wang C, Mo X, et al. The global macroeconomic burden of musculoskeletal disorders. *Int J Surg*. 2025;111(11):7857–7866. doi:10.1097/JS9.0000000000003072
2. Ferreira ML, de Luca K, Haile LM, GBD 2021 Low Back Pain Collaborators. Global, regional, and national burden of low back pain, 1990–2020, its attributable risk factors, and projections to 2050: a systematic analysis of the Global Burden of Disease Study 2021. *Lancet Rheumatol*. 2023;5(6):e316–e329. doi:10.1016/S2665-9913(23)00098-X
3. Hulshof CTJ, Pega F, Neupane S, et al. The prevalence of occupational exposure to ergonomic risk factors: a systematic review and meta-analysis from the WHO/ILO joint estimates of the work-related burden of disease and injury. *Environ Int*. 2021;146:106157. doi:10.1016/j.envint.2020.106157
4. Takala J, Hämäläinen P, Sauni R, et al. Global-, regional- and country-level estimates of the work-related burden of diseases and accidents in 2019. *Scand J Work Environ Health*. 2024;50(2):73–82. doi:10.5271/sjweh.4132
5. Liu G, Liu Y, Jing H, et al. Global, regional, and national economic consequences of tracheal, bronchial, and lung cancer. *Lung Cancer*. 2025;207:108685. doi:10.1016/j.lungcan.2025.108685
6. Kamijantono H, Sebayang MM, Lesmana A. Risk factors and ergonomic influence on musculoskeletal disorders in the work environment. *J La Medihaltico*. 2024;5(3):660–670. doi:10.37899/journallamedihaltico.v5i3.1413
7. Nuraisyah F. Ergonomic hazards and musculoskeletal disorders among healthcare workers. *J Envir Occupat Health Safety*. 2025;1(1):01–16.
8. Setiawati F, Hapsari EM, Khairinisa S, et al. Factors related to dental ergonomics practice among Indonesian dentists. *Int J Dental Hygiene*. 2025;23(2):346–352. doi:10.1111/idh.12850

9. Surya H, Handayani S. Individual and ergonomic risk factors for musculoskeletal disorders among health workers in Indonesia: a literature review. *Hearty*. 2025;13(2):409–419. doi:10.32832/hearty.v13i2.17541
10. Juli Suarbawa I, Yusuf M, Sudiajeng L. Ergonomic factors which affect the work productivity of clove flower harvesters. *Int J Advance Sci Engineer Informat Technol*. 2024;14(2):675–682.
11. Mariyamah T, Handoko Y, Eliana M, et al. The carpal tunnel syndrome and ergonomic risk factor profile in online motorcycle taxi drivers (ojol) in Jakarta. In: *In SHS Web Conf*. Vol. 189. 2024:01047.
12. Pawitra TA, Al Khairi R, Widada D. The ergonomic risk evaluation of work posture for oil palm harvest workers in East Kalimantan using SNI 9011:2021. *J Integrated Sys*. 2024;7(2):211–222. doi:10.28932/jis.v7i2.10152
13. Prabarukmi GS, Widajati N. The correlation of ergonomic risk factor with musculoskeletal complaints in batik workers. *Indonesian J Occupational Safety Health*. 2020;9(3):269–278. doi:10.20473/ijosh.v9i3.2020.269-278
14. Pristianto A, Naufal AF, Dewangga MW, et al. Age and ergonomic position as determinants of musculoskeletal disorders among Batik workers. *Phys Therap J Indonesia*. 2025;6(1):64–69. doi:10.51559/ptji.v6i1.282
15. Andrastea KDP, Lienderiwati NM. Mechanical injury predominates in rural Bali, Indonesia: implications for prevention and treatment of ocular trauma. *Bioscientia Medicina*. 2025;9(2):6209–6222.
16. Kurnianto AA, Khatatbeh H, Prémusz V, et al. Managing disabled workers due to occupational accidents in Indonesia: a case study on return to work program. *BMC Public Health*. 2023;23(1):943. doi:10.1186/s12889-023-15930-2
17. Naghavi M, Ong KL, Aali A, et al. Global burden of 288 causes of death and life expectancy decomposition in 204 countries and territories and 811 subnational locations, 1990–2021: a systematic analysis for the Global Burden of Disease Study 2021. *Lancet*. 2024;403(10440):2100–2132.
18. Ferrari AJ, Santomauro DF, Aali A, et al. Global incidence, prevalence, years lived with disability (YLDs), disability-adjusted life-years (DALYs), and healthy life expectancy (HALE) for 371 diseases and injuries in 204 countries and territories and 811 subnational locations, 1990–2021: a systematic analysis for the Global Burden of Disease Study 2021. *Lancet*. 2024;403(10440):2133–2161.
19. GBD 2021 Risk Factors Collaborators. Global burden and strength of evidence for 88 risk factors in 204 countries and 811 subnational locations, 1990–2021: a systematic analysis for the Global Burden of Disease Study 2021. *Lancet*. 2024;403(10440):2162–2203.
20. BPS. Angka Harapan Hidup (AHH) menurut provinsi dan jenis kelamin (Tahun). Available from: <https://www.bps.go.id/statistics-table/2/NTAXLZlF=angka-harapan-hidup-ahh-menurut-provinsi-dan-jenis-kelamin.html>. Accessed: September 9, 2025.
21. BPS. Produk domestik regional bruto atas dasar harga berlaku menurut provinsi (miliar rupiah). Available from: <https://www.bps.go.id/statistics-table/3/WkdVMWRYVnBkMnBvVEhKSVkyWXhNblZtTjJSbmR6MDkMw==/produk-domestik-regional-bruto-atas-dasar-harga-berlaku-menurut-provinsi-miliar-rupiah-2022.html?year=2023>. Accessed: September 9, 2025.
22. World Bank. GDP per capita, PPP (current international \$) - Indonesia. Available from: <https://data.worldbank.org/indicator/NY.GDP.PCAP.PP.CD?locations=ID>. Accessed: September 9, 2025.
23. UN Data. GDP, PPP (current international \$). Available from: https://data.un.org/Data.aspx?d=WDI&f=Indicator_Code%3ANY.GDP.MKTP.PP.CD. Accessed: September 9, 2025.
24. World Bank. GDP per capita, PPP (current international \$) - United States. Available from: https://data.worldbank.org/indicator/NY.GDP.PCAP.PP.CD?end=2024&locations=US&most_recent_year_desc=false&start=2008. Accessed: September 9, 2025.
25. US Department of Transportation. Departmental guidance on valuation of a statistical life in economic analysis. Available from: <https://www.transportation.gov/office-policy/transportation-policy/revised-departmental-guidance-on-valuation-of-a-statistical-life-in-economic-analysis>. Accessed: September 9, 2025.
26. OECD. Mortality risk valuation in policy assessment: a global meta-analysis of value of statistical life studies. Available from: https://www.oecd.org/en/publications/mortality-risk-valuation-in-policy-assessment_76ca89a2-en.html. Accessed: December 17, 2025.
27. Suryawati S, Nadjib M, Hidayat B, et al. General guideline for health technology assessment in Indonesia. Available from <https://www.badankebijakan.kemkes.go.id/general-guideline-for-health-technology-assessment-in-indonesia/> Accessed: September 9, 2025.
28. World Bank. GDP growth (annual %) - Indonesia. Available from: <https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG?locations=ID>. Accessed: August 29, 2025.
29. Gomez IN, Suarez CG, Sosa KE, et al. Work from home-related musculoskeletal pain during the COVID-19 pandemic: a rapid review. *Int J Osteopath Med*. 2023;47:100654. doi:10.1016/j.ijosm.2022.12.001
30. Fadel M, Bodin J, Cros F, et al. Teleworking and musculoskeletal disorders: a systematic review. *Int J Environ Res Public Health*. 2023;20(6):4973. doi:10.3390/ijerph20064973
31. Condrowati, Bachtiar F, Maharani FT, et al. Musculoskeletal disorder of workers during work from home on COVID-19 pandemic: a descriptive study. In: *International Conference of Health Development. Covid-19 and the Role of Healthcare Workers in the Industrial Era (ICHD 2020)*. Atlantis Press;2020:153–160
32. Viatina K, Tejamaya M, Widanarko B. Musculoskeletal disorders risk assessment among small tofu factory workers in Tangerang city: an Indonesian case study. *Indonesian J Public Health*. 2024;19(1):183–195. doi:10.20473/ijph.v19i1.2024.183-195
33. Suherdin S, Kartadarma S. Ergonomic hazard control modeling for informal welding workers in Greater Bandung: a study on Musculoskeletal Disorders (MSDs). *Jurnal Ilmu Kesehatan Masyarakat*. 2025;16(1):18–31. doi:10.26553/jikm.2025.16.1.18-31
34. Ones M, Sahdan M, Tira DS. Faktor yang berhubungan dengan keluhan nyeri punggung bawah (low back pain) pada penenun di Desa Letneo Selatan Kecamatan Insana Barat Kabupaten Timor Tengah Utara. *Media Kesehatan Masyarakat*. 2021;3(1):72–80. doi:10.35508/mkm.v3i1.2958
35. Tonda WOJ, Lestari H, Rezal F. Hubungan posisi kerja, lama kerja, dan beban kerja dengan keluhan low back pain (LBP) pada pekerja buruh pelabuhan Nusantara Kendari. *J Health Sci Leksia*. 2025;3(3):22–34.
36. Lataoso R, Saptaputra SK. Analisis faktor risiko ergonomi dengan kemungkinan timbulnya keluhan musculoskeletal disorders pada perawat di Rumah Sakit Bhayangkara TK. III Tahun 2024. *Medika Alkhairaat*. 2024;6(2):479–495.
37. Kholinne E, Azalia X, Rahayu EP, et al. The prevalence and risk factors of musculoskeletal disorders among Indonesian dental professionals. *Front Rehab Sci*. 2025;6:1513442. doi:10.3389/fresc.2025.1513442
38. Hartono FD, Madinah FI, Yusmar MR, et al. Faktor resiko nyeri muskuloskeletal akibat masalah ergonomis pada dokter di instalasi ruang operasi. *CoMPHI J*. 2024;4(3):185.
39. Kristanto A, Malkab AM, Ma'ruf F, et al. Analysis of the prevalence and risk factors for malalignment of the lower limbs in rice farmers in Indonesia. *J Curr Sci Technol*. 2025;15(2):96. doi:10.59796/jcst.V15N2.2025.96

40. Kurniawan EA, Muzakir H. Faktor-faktor yang berhubungan dengan MSDs pada penjahit di PT. Andria Fesyen Indonesia Tekstile. *Indones J Sci.* 2024;1(3):890–895.
41. Widanarko B, Legg S, Devereux J, et al. Interaction between physical and psychosocial risk factors on the presence of neck/shoulder symptoms. *Ergonomics.* 2015;58(9):1507–1518. doi:10.1080/00140139.2015.1019936
42. Kusmasari W, Sutarto AP, Dewi NS, et al. Exploring the interaction between physical, psychosocial, and neck pain symptoms in construction workers. *J Occupational Health.* 2024;66(1):uia010. doi:10.1093/joccuh/uiae010
43. Nugraha MH, Widyantoro W, Luthfi AM, et al. Digital human modeling for computer-aided ergonomics analysis in horticulture. *Sintek J.* 2023;17(1):44–49.
44. Savio SD, Kawiya IK, Wiratnaya IG, et al. Low hand grip strength, muscle area, calf circumference, serum albumin, and fiber diameter as risk factors for walking inability post-Hip fracture surgery. *Clin Orthopaedics Surg.* 2024;16(2):230. doi:10.4055/cios23256
45. Iqhrammullah M. Dataset for “economic burden of work-related musculoskeletal disorders in Indonesia before and during the COVID-19 era: analysis of Global Burden of Disease Estimates (2019–2021)”. *Figshare.* 2025.

ClinicoEconomics and Outcomes Research

Publish your work in this journal

ClinicoEconomics and Outcomes Research is an international, peer-reviewed open-access journal focusing on Health Technology Assessment, Pharmacoeconomics and Outcomes Research in the areas of diagnosis, medical devices, and clinical, surgical and pharmacological intervention. The economic impact of health policy and health systems organization also constitute important areas of coverage. The manuscript management system is completely online and includes a very quick and fair peer-review system, which is all easy to use. Visit <http://www.dovepress.com/testimonials.php> to read real quotes from published authors.

Submit your manuscript here: <https://www.dovepress.com/clinicoeconomics-and-outcomes-research-journal>

Dovepress

Taylor & Francis Group