Jurnal Info Kesehatan
Vol. 24, No. 1, March 2026, pp. 263-274
P-ISSN 0216-504X, E-ISSN 2620-536X
DOI: *10.31965/infokes.Vol24.Iss1.2432*
Journal homepage: *https://jurnal.poltekkeskupang.ac.id/index.php/infokes*

RESEARCH **Open Access**

Body Mass Index, Blood Glucose, and Physical Activity as Determinants of Lactic Acid Levels among Textile Workers

Rachmawati Prihantina Fauzi[1a], Sumardiyono[1b*], Maria Paskanita Widjanarti[1c], Farhana Syahrotun Nisa Suratna[1d], Bachtiar Chahyadhi[1e], Reni Wijayanti[1f], Yeremia Rante Ada[1g]

[1] Bachelor of Applied Science Programme in Occupational Safety and Health, Vocational School, Universitas Sebelas Maret, Surakarta, Central Java, Indonesia

[a] Email address: rachmawatipfauzi@staff.uns.ac.id
[b] Email address: sumardiyono@staff.uns.ac.id
[c] Email address: maria.paskanita@staff.uns.ac.id
[d] Email address: farhanasyahrotun@staff.uns.ac.id
[e] Email address: bachtiarchahyadhi@staff.uns.ac.id
[f] Email address: reniwijayanti@staff.uns.ac.id
[g] Email address: yeremia_ada@staff.uns.ac.id

Received: 24 February 2026 Revised: 5 March 2026 Accepted: 19 March 2026

Abstract

Textile industry is a labour-intensive industry with repetitive activities and heavy physical workload, thereby likely to cause metabolic fatigue as reflected by high levels of lactic acid. This study aims to examine the independent and combined associations of Body Mass Index (BMI), blood glucose levels, and physical activity with elevated lactic acid levels among textile workers. A cross-sectional analytical study was conducted among 80 textile workers selected using at a textile company in Surakarta between January and March 2023. A series of binary logistic regression analysis were conducted, adjusting for age and sex, with statistical significance set to $p < 0.05$. The overall statistical significance of the model was found to be significant ($p < 0.001$) and the explanatory power of the model was very high (Nagelkerke R^2 = 55.2%). The most dominant factor associated with high levels of lactic acid was found to be the level of blood glucose above 180 mg/dL (aOR = 15.525; 95% CI: 3.003–80.263), followed by BMI over 25 kg/m² (aOR = 9.695; 95% CI: 2.155–43.617). Physical activity was found to be protective (aOR = 0.182; 95% CI: 0.037–0.891), but age and sex were not significant. These results suggest that metabolic behavioural factors are significantly associated with elevated lactic acid levels, which may indicate metabolic fatigue among textile employees. These findings highlight the importance of strengthening metabolic screening and promoting physical activity within occupational health programmes.

Keywords: *Blood glucose, Body mass index, Lactic acid, Occupational fatigue, Physical activity*

Corresponding Author:

Sumardiyono
Bachelor of Applied Science Programme in Occupational Safety and Health, Vocational School, Universitas Sebelas Maret, Surakarta, Central Java, Indonesia
Email: atik.martsiningsih@poltekkesjogja.ac.id

©The Author(s) 2026. This article is distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License, which permits unrestricted use, distribution, and reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made.

1. INTRODUCTION

Textile industry is a very labour intensive sector that makes its contribution to the world economies as well as national economies (Anugrah et al., 2024). The textile and garment sector has over 75 million employees across the world, most of them working in developing nations (Bose, 2024). The textile and textile products industry in Indonesia has around 3.7-3.9 million workers that make it more than 20 percent of the total manufacturing workforce and the fifth-largest contributor to non-oil and gas exports (The Indonesia Textiles & Apparel Community Reference, 2026). The nature of work in this sector can be characterized by repetitive work, long working hours, moderate- Heavy physical loads, and high production goals (Seidu et al., 2024). Occupational fatigue, such as building up of lactic acid as a sign of fatigue during metabolism, can be enhanced by these conditions (Fasching et al., 2020).

The final product of an anaerobic metabolism is lactic acid which rises in cases where there is inadequate oxygen supply to satisfy the demands of muscular energy (Kumar et al., 2025; Lardika et al., 2023; Miaomiao et al., 2023). Higher levels of lactate in the blood are highly applicable as a biomarker of physical fatigue and work capacity; high levels of lactate in the blood (above 4 mmol/L) physiologically reflect an overrepresentation of anaerobic metabolism, which is related to poor work performance (Sumardiyono et al., 2025). Lactic acid was selected as an objective biomarker of metabolic fatigue because it directly reflects anaerobic glycolytic activity and muscular metabolic stress under physical workload. Unlike subjective instruments such as fatigue questionnaires (e.g., KAUPK2), which are influenced by perception, psychological state, and reporting bias, blood lactate concentration provides a quantifiable physiological indicator of acute metabolic strain. Therefore, the use of lactate measurement allows a more precise assessment of metabolic fatigue in relation to individual biological determinants under real working conditions.

Recurring lactate build-up can be associated with the risk of chronic fatigue, poor productivity, and elevated risk of occupational accidents among industrial workers who are exposed to repetitive and moderately high to high-intensive tasks (Sumardiyono et al., 2025). Despite the high prevalence of physically demanding and repetitive tasks in the textile industry, the extent of metabolic fatigue risk attributable to individual metabolic profiles has not been adequately quantified. Although ergonomic workload has been widely investigated, variations in lactate accumulation between workers indicate that individual metabolic characteristics, particularly adiposity status measured by Body Mass Index, glycaemic control, and habitual physical activity, may substantially influence physiological responses to comparable workloads. Nevertheless, empirical studies that simultaneously integrate these determinants within an actual industrial setting remain scarce, especially in developing countries where metabolic disorders are increasing rapidly.

Body Mass Index (BMI) is a measure of nutritional status that is highly related to metabolic capacity and efficiency in energy utilisation (Muscogiuri et al., 2023; Ramadhania et al., 2024). Obesity and overweight are so prevalent in the world that 43 percent of adults are overweight (Pillai et al., 2025). In Indonesia, obesity prevalence among adults aged ≥18 years increased to 23.4% in 2023 according to the Survei Kesehatan Indonesia 2023, up from 21.8% reported in Riskesdas 2018 (Safitri et al., 2025). Earlier national data also showed a rise from 23.0% in 2007 to 50.1% in 2018, highlighting a substantial long-term escalation of adult obesity (Ferdina et al., 2024). Patients with high BMI have a higher risk of becoming insulin-resistant, less efficient glucose metabolism, and less efficient fat oxidation that leads to a faster transition of the metabolism towards a more anaerobic one during physical work (Chen et al., 2025). This situation, theoretically, can amplify the lactic acid production in the workplace state of affairs, but limited empirical data exists in the industrial workforce population.

Besides the BMI, the level of blood glucose is important in the regulation of energy metabolism (Jones, 2023; Sohn & Ho, 2020). Chronic hyperglycaemia relates to the organ dysfunction of the mitochondria and oxidative stress that can affect glycolytic events and the production of lactate (Qin et al., 2025). The global burden of diabetes continues to rise substantially. In 2024, an estimated 589 million adults aged 20–79 years were living with diabetes, representing a global prevalence of 11.1%. This increasing trend is also evident in Indonesia, where the age-standardised prevalence in the same age group has reached 11.3%, affecting approximately 20.4 million individuals. These figures position Indonesia among the top five countries worldwide in terms of total diabetes burden, highlighting the escalating metabolic health challenges faced by developing economies (Genitsaridi et al., 2024; Soeatmadji et al., 2023). In a factory, prediabetes or mild hyperglycaemia can go unexamined but could potentially change the metabolism to physical workload (Meo et al., 2020). Even though the interrelationship between glucose metabolism and lactate production has been extensively studied in clinical population and athletic population, little evidence exists in manufacturing worker population.

Another determinant that warrants consideration is habitual physical activity. Globally, it is estimated that 27.5% of adults do not meet the recommended levels of physical activity, and WHO reports indicate that one in five adults and four in five adolescents are insufficiently active (Kapoor et al., 2022). In Indonesia, recent national data indicate that 37.4% of individuals aged ≥10 years do not meet the recommended levels of physical activity (Public Relations of BKPK, 2025). Insufficient physical activity is associated with reduced aerobic capacity (VO_2max) and a lower lactate threshold, thereby accelerating lactate accumulation during physical exertion. Surakarta was selected as the study setting because it is located in Central Java, a province that hosts approximately 671 textile manufacturing enterprises, representing one of Indonesia's major textile production hubs (Disperindag Jateng, 2026). This industrial concentration makes Surakarta a relevant and representative context for examining metabolic fatigue among textile workers.

While structured recreational physical activity has been shown to improve aerobic capacity (VO_2max) and increase lactate threshold, thereby delaying lactate accumulation during physical exertion (Meyer et al., 2024), evidence from occupational settings suggests a contrasting pattern. Several studies describe the "physical activity paradox," in which repetitive and prolonged work-related physical activity does not necessarily enhance cardiorespiratory fitness and may even increase cardiovascular strain due to its static, monotonous, and non-recovery-based characteristics (Ekblom-bak et al., 2024). Consequently, occupational physical activity may differ substantially in its metabolic effects compared to leisure-time physical activity, which consistently demonstrates protective cardiometabolic benefits. These inconsistencies indicate that the role of physical activity in influencing lactate production cannot be examined in isolation and should be analyzed simultaneously with nutritional status (BMI) and glycaemic regulation to better understand its net effect on lactate accumulation under real industrial working conditions.

According to the literature review, there are a number of gaps in research. To begin with, research done to determine lactic acid in industrial workers has extensively been done in terms of ergonomic workload or work intensity, but not on individual metabolic determinants. Second, there is a lack of literature that has combined and tested nutritional condition (BMI), metabolic (blood glucose) health and physical activities habits within a determinant analysis of lactic acid concentrations among textile employees. Third, the setting of developing nations where the incidence of obesity and metabolic disorders is increasing has not been well represented in the literature with a high impact.

The novelty of this study lies in its simultaneous and integrative analysis of BMI, blood glucose levels, and habitual physical activity as independent and interacting determinants of elevated lactate levels within a live industrial setting. Rather than examining these variables

separately, this study applies a multivariable determinant model to estimate their adjusted contributions under actual workplace exposure conditions, thereby bridging metabolic epidemiology and occupational physiology in a real-world context. This model integrates work physiological, metabolic epidemiological and occupational health to form an individual risk based determinant model that can be used during promotion and preventive measures at the workplace.

This study aims to analyze the independent and combined effects of Body Mass Index (BMI), blood glucose levels, and physical activity on elevated lactic acid levels among textile workers using multivariable logistic regression analysis, and to identify the most dominant determinant contributing to metabolic fatigue risk. It is anticipated that the findings will contribute to evidence-based occupational health interventions and support metabolism-based to increase the work capacity and productivity in the textile industry.

2. RESEARCH METHOD

This study employed an analytical observational design with a cross-sectional approach, in which exposure and outcome variables were measured simultaneously. This design was selected due to its effectiveness in examining associations between risk factors and outcomes within a working population during a specific period, as well as its efficiency in utilising company secondary data. Cross-sectional approaches are widely applied in occupational epidemiology to identify metabolic determinants of physiological indicators among workers, as they provide robust preliminary evidence of associations prior to conducting longitudinal investigations.

The study was conducted at PT Iskandar Indah Printing Textile, Surakarta, Central Java, Indonesia. The study population comprised all employees who underwent the company's periodic medical check-up (MCU) during the study year. A total of 92 workers underwent the periodic MCU during the study year. A census (total population sampling) technique was applied, in which all eligible workers meeting the inclusion criteria were included in the study. Following the screening process, 80 workers fulfilled the eligibility criteria and were analysed. The inclusion criteria were: (1) permanent employees who completed the full MCU examination; (2) availability of complete data on blood glucose levels, BMI, and lactic acid; and (3) consent for their data to be used for research purposes. The exclusion criteria were: (1) documented history of severe metabolic diseases, such as chronic kidney failure or severe hepatic disorders; (2) workers experiencing acute illness at the time of examination; and (3) incomplete or invalid laboratory data. Following the selection process, 80 eligible workers were included as study participants.

The study utilised secondary data derived from company MCU records. The analysed variables included Body Mass Index (BMI), blood glucose levels, physical activity, lactic acid levels, and covariates (age and sex), all of which were categorised according to established international clinical and epidemiological guidelines (American Diabetes Association Professional Practice Committee, 2024). Body weight was measured using a calibrated digital weighing scale (Yanhui®, China; accuracy ±0.05 kg), and height was measured using a portable stature meter (GEA®, China; accuracy ±0.1 cm). BMI was subsequently calculated as body weight (kg) divided by the square of height (m^2). Blood glucose and lactic acid measurements were conducted by a certified clinical laboratory appointed by the company using an automated clinical chemistry analyzer (e.g., Roche Cobas C311, Roche Diagnostics, Germany). Blood glucose levels were measured using the enzymatic hexokinase photometric method, while lactic acid concentrations were determined using an enzymatic colorimetric method based on lactate oxidase. All laboratory procedures followed standardized operating protocols in accordance with clinical biochemistry guidelines and internal quality control procedures. All variables were

categorised for the purpose of multiple binary logistic regression analysis. Physical activity was classified as no regular exercise or engagement in structured exercise at least once per week, referring to the minimum activity recommendation framework for adult populations (Bull et al., 2020). Blood glucose was classified in >180 mg/dL and ≤180 mg/dL, according to the clinical cut off at which postprandial hyperglycaemia surpassed the renal glucose reuptake threshold and was indicative of a significant acute glycaemic disregulation and potentially affect the anaerobic glycolytic activity and lactate output. This has been a popular cut-off used to explain clinically significant hyperglycaemia in metabolic and occupational health research. BMI was categorised as >25 kg/m² and ≤25 kg/m² based on the World Health Organization classification for overweight among adult populations (World Health Organization, 2025). The dependent variable, lactic acid level, was dichotomised using the sample mean as the cut-off point (≤ mean vs. > mean) to facilitate binary logistic regression modelling, a common approach when no universally established clinical threshold exists (Erees, 2022). Age was categorised as ≤40 years and >40 years to reflect early and late productive-age groups, considering that metabolic risk profiles tend to increase after the fourth decade of life in occupational populations (Cao et al., 2022), and sex as male or female.

Chronologically, the study commenced with obtaining permission to access MCU data from company management, followed by participant selection based on inclusion and exclusion criteria. Variable coding and categorisation were performed according to operational definitions, followed by data verification and entry into statistical software. Statistical analyses were conducted using IBM SPSS Statistics version 27. Univariable analysis was used to describe the frequency distribution of study variables. Before multiple binary logistic regression analysis was carried out, multicollinearity diagnostics was carried out to determine possible overlaps between the independent variables especially BMI and blood glucose levels. The values of Variance Inflation Factor (VIF) and tolerance have been checked and the VIF was below 10 and the tolerance was above 0.1, which means that there is no significant multicollinearity. The outcome proved that no multicollinearity was found among predictors and supported the validity of multivariable model. The association between the BMI, blood glucose levels, and physical activity with lactic acid level was then analysed with multiple binary logistic regression with adjustment on the age and sex. This method was selected because the dependent variable was dichotomous and allowed estimation of event probability based on multiple predictors (Hosmer et al., 2013). Statistical significance was set at $p < 0.05$ with a 95% confidence interval (CI), and results were presented as adjusted odds ratios (AORs) with 95% CIs.

This study received ethical approval from the Health Research Ethics Committee of Dr Moewardi Regional General Hospital, Surakarta (Approval No. 147/II/HREC/2026). All data were anonymised to ensure the confidentiality of worker identities.

3. RESULTS AND DISCUSSION

The analysis included 80 textile workers who were eligible to take part in the analysis. Altogether, most of the workers were considered non-overweight and have blood glucose levels not more than 180 mg/dL. Nonetheless, the percentage of workers who never exercised was relatively large when compared with individuals who exercised at least once in a week. The balance of sexes was rather equal, and the number of female workers was a little higher. Majority of the respondents were above 40 years. Lactate levels were categorised based on the sample mean of 12.23 mmol/L, with >12.23 mmol/L classified as elevated and ≤12.23 mmol/L as lower levels. Blood lactate was measured from venous samples collected at rest during the morning MCU session using an automated enzymatic method in a certified laboratory. All respondent characteristics are shown in Table 1.

Table 1. Characteristics of Textile Workers (N = 80)

Variable	Category	n	%
Body Mass Index (BMI)	> 25 kg/m²	31	38.8
	≤ 25 kg/m²	49	61.2
Blood Glucose Level	> 180 mg/dL	16	20.0
	≤ 180 mg/dL	64	80.0
Physical Activity	No exercise	49	61.2
	≥1 time per week	31	38.8
Sex	Male	37	46.3
	Female	43	53.8
Age	≤ 40 years	5	6.2
	> 40 years	75	93.8
Lactate Level	> 12.23 mmol/L	25	31.2
	≤ 12.23 mmol/L	55	68.8

The worker characteristics distribution is a sign of possible metabolic vulnerability, especially in the terms of an increased percentage of overweight people as well as a very low degree of organized physical activity. This observation is correlated with the increasing rates of obesity in the working-age population in developing nations (GBD 2021 Adolescent BMI Collaborators, 2025; Mahumud et al., 2021; UNICEF, 2025), where lifestyle transitions and occupational sedentariness contribute to metabolic disorders. The percentage of employees with high blood glucose levels is also remarkable because hyperglycaemia, even at the subclinical level, can decrease the efficiency of energy metabolism and elevate the oxidative stress of cells (González et al., 2023). Moreover, the age of the workers which is mostly above 40 years can be linked to lower aerobic capacity and lactate threshold because of the age-related deterioration of mitochondrial activities and muscle mass (Grevendonk et al., 2021). Despite the fact that the high percentage of lactic acid was not prevalent among the population, the percentage is still appropriate in an occupational health setting as it shows a transition to anaerobic metabolism that is linked with fatigue and possible declines in work performance.

The significant Omnibus test ($\chi^2 = 39.910$; df = 5; $p < 0.001$) indicates that the inclusion of independent variables significantly improved model prediction compared with the null model, demonstrating that the predictors jointly contribute to distinguishing workers with elevated lactate levels. The model demonstrated a −2 Log Likelihood of 59.464, with Cox & Snell $R^2 = 0.393$ and Nagelkerke $R^2 = 0.552$, indicating that approximately 55.2% of the variance in elevated lactate levels was explained by the included predictors. This value indicates a moderate explanatory contribution, which provides preliminary evidence of association but does not imply causal inference due to the cross-sectional design. The Hosmer–Lemeshow test indicated acceptable model fit ($\chi^2 = 11.922$; df = 6; $p = 0.064$), suggesting no significant discrepancy between observed and predicted values.

The table 2 shows the regression parameter estimates. Three variables such as the BMI, blood glucose levels and exercise habits had significant associations with high levels of lactic acid but not sex and age when they were adjusted by other variables.

Table 2. Binary Logistic Regression Analysis of Determinants of Elevated Lactate Levels

Variable	B	SE	p	aOR (Exp(B))	95% CI
Body Mass Index (>25 kg/m²)	2.272	0.767	0.003	9.695	2.155–43.617
Blood Glucose (>180 mg/dL)	2.742	0.838	0.001	15.525	3.003–80.263

Physical Activity (≥1 time/week)	-1.705	0.811	0.036	0.182	0.037–0.891
Male	-1.104	0.691	0.110	0.332	0.086–1.285
Age >40 years	1.494	1.181	0.206	4.454	0.440–45.066
Constant	-6.289	3.109	0.043	0.002	—

The strongest influence was adjusted odds ratio (aOR) of blood glucose >180 mg/dL (aOR=15.525; p=0.001), then BMI >25 kg/m² (aOR = 9.695; p = 0.003), and exercise habits (aOR = 0.182; p = 0.036). Workers who performed regular exercise (≥1 time per week) had significantly lower odds (aOR = 0.182; 95% CI: 0.037–0.891) of elevated lactate levels compared with workers who did not exercise, confirming the protective effect of habitual physical activity.

All the findings taken together prove that metabolic and behavioural aspects play a significant role in increasing lactic acid levels as a signifier of metabolic fatigue in textile workers. Blood glucose exhibited the highest regression coefficient (B = 2.742), which means that it has the most significant increase in log odds of high lactate levels. Hyperglycaemia, physiologically, can provoke the dysfunction of the mitochondria and increased anaerobic glycolysis, increasing lactate (Darshi et al., 2024). This observation is in line with a study conducted by Blagov et al. (2024) who also found that compromised glucose metabolism is a resultant factor of low cellular bioenergetic efficiency even in the prediabetic stage before the manifestation of clinical complications.

Although BMI >25 kg/m² was significantly associated with elevated lactate levels (aOR = 9.695; 95% CI: 2.155–43.617), the relatively wide confidence interval indicates limited precision of the estimate, likely due to the modest sample size and distribution imbalance, and therefore warrants cautious interpretation. Beyond insulin resistance and reduced oxidative capacity, excess adipose tissue functions as an active endocrine organ that releases pro-inflammatory cytokines such as TNF- α and IL-6, contributing to chronic low-grade systemic inflammation. This inflammatory milieu may impair mitochondrial function and skeletal muscle oxidative phosphorylation efficiency, thereby accelerating the shift toward anaerobic glycolysis during occupational workload and increasing lactate production. The results agree with those of Kościuszko et al. (2024), who reported that insulin resistance and decreased muscular oxidative capacity contribute to the earlier shift to anaerobic metabolism during occupational activity in overweight individuals. The findings are also consistent with Owesny & Grune (2023), who revealed that obesity is associated with poor energy metabolism and reduced oxidative efficiency among working-age adults.

There was a negative regression coefficient (B = -1.705) between exercise habits and high levels of lactate, which implies that exercise habits are protective against high levels of lactate. Physiologically, routine physical training improves the aerobic capacity and elevates the lactate threshold, thus regulating the lactate build-up during physical exercise (Mandadzhiev, 2025). This indicates that workers who did not exercise had a higher likelihood of accumulating lactate during work compared with physically active workers. These findings should also be interpreted within the framework of the "physical activity paradox." Although textile work involves repetitive physical tasks, such occupational physical activity (OPA) may not provide adequate aerobic conditioning because it is often static, prolonged, and performed without sufficient recovery periods. In contrast, structured leisure-time physical activity (LTPA) is typically dynamic, progressive, and designed to improve cardiorespiratory fitness, mitochondrial density, and lactate threshold. Therefore, regular planned exercise outside working hours appears to confer metabolic protection that routine occupational activity alone does not provide, explaining why habitual exercise demonstrated a protective association in this study.

The multivariate model included the sex (p = 0.110) and age (p = 0.206) that were not found to be significant. The effect of ageing is theoretically related to the decreased aerobic

capacity, but in this case, it was negated once corrected with respect to BMI and blood glucose level (Zhuang et al., 2020). This implies that metabolic causes are more influential as compared to demographic causes in the determination of levels of lactate in this population of workers.

In general, the level of determinants by aOR values was as follows: blood glucose, BMI, exercise habits, age, and sex. Although the regression model demonstrated moderate explanatory capacity (Nagelkerke $R^2 = 0.552$) and acceptable fit, the findings should be interpreted with caution due to the cross-sectional nature of the study, reliance on secondary MCU data, and limited sample size. Nonetheless, the results suggest that metabolic and behavioural factors are important correlates of elevated lactate levels in textile workers and may inform targeted occupational health interventions.

Study Limitations

This study has several limitations. First, the cross-sectional design limits the ability to establish causal relationships between metabolic determinants and elevated lactate levels. The observed associations cannot definitively confirm temporal directionality. Second, the use of secondary MCU data restricted control over certain potential confounders, such as dietary intake prior to blood sampling, hydration status, and recent physical exertion, which may influence lactate and glucose measurements. Third, the relatively small sample size from a single textile company may limit generalisability to other industrial populations. Despite these limitations, the study provides important preliminary evidence regarding integrative metabolic determinants of occupational fatigue in a real-world industrial setting.

4. CONCLUSION

The research determines that body mass index, level of blood glucose and physical activity are highly linked with the high levels of lactic acid among the employees in the textile industry. Blood glucose surpassing 180 mg/dL of blood proved to be the most widely occurring factor, with BMI surpassing 25 kg/m2 before regular exercise was found to be protective against high levels of lactate. Such results show that the metabolic and behavioural aspects are significantly linked to the risk of metabolic fatigue in the labour-intensive textile settings.

From an occupational health perspective, textile companies are recommended to implement risk-based metabolic surveillance, including periodic fasting and postprandial glucose testing, BMI-based risk stratification, and targeted counselling for metabolically vulnerable employees. Operational strategies may include structured aerobic exercise sessions (2–3 times/week), active rest breaks between shifts, task rotation to reduce continuous anaerobic workload, and annual metabolic profiling as part of regular medical check-ups to reduce elevated lactate levels and mitigate metabolic fatigue risk.

To conduct future studies, longitudinal or quasi-experimental study designs were suggested to assess the variation in lactate levels prior to and subsequent to the interventions of structured exercise or metabolic control to enhance the causal inference on the effects of BMI reduction, glycaemic control, and improved aerobic fitness on metabolic fatigue on industrial workers.

REFERENCES

American Diabetes Association Professional Practice Committee. (2024). Diagnosis and Classification of Diabetes: Standards of Care in Diabetes—2024. Diabetes Care, 47(January), 20–42. https://doi.org/10.2337/dc24-S002

Anugrah, A., Mohamad, H. H., Otniel, J., Fahrezi, R., Radian, M., & Siswajanthy, F. (2024). Analisis Industri Tekstil di Jawa Barat Sebelum dan Setelah Krisis Ekonomi. Doktrin: Jurnal Dunia Ilmu Hukum Dan Politik, 2(2), 118–135. https://doi.org/10.59581/Doktrin-widyakarya.v2i1.2579

Blagov, A., Nedosugova, L., Kirichenko, T., Sukhorukov, V., Melnichenko, A., & Orekhov, A. (2024). Mitochondrial Dysfunction as a Factor of Energy Metabolism Disorders in Type 2 Diabetes Mellitus. Frontiers in Bioscience-Scholar, 16(1), 1–10. https://doi.org/10.31083/j.fbs1601005

Bose, M. B. (2024). Introduction Stitching Together Gender, Textile and Garment Labor, and Heritage in Asia. In Threads of Globalization: Fashion, Textiles, and Gender in Asia in the Long Twentieth Century (pp. 1–22). Manchester University Press. https://doi.org/10.7765/9781526163417.00005

Bull, F. C., Al-Ansari, S. S., Biddle, S., Borodulin, K., Buman, M. P., Cardon, G., Carty, C., Chaput, J.-P., Chastin, S., Chou, R., Dempsey, P. C., DiPietro, L., Ekelund, U., Firth, J., Friedenreich, C. M., Garcia, L., Gichu, M., Jago, R., Katzmarzyk, P. T., … Willumsen, J. F. (2020). World Health Organization 2020 Guidelines on Physical Activity and Sedentary Behaviour. British Journal of Sports Medicine, 54(September), 1451–1462. https://doi.org/10.1136/bjsports-2020-102955

Cao, Q., Zheng, R., He, R., Wang, T., Xu, M., Lu, J., Dai, M., Zhang, D., Chen, Y., Zhao, Z., Wang, S., Lin, H., Wang, W., Ning, G., Yufang Bi, Xu, Y., & Li, M. (2022). Age-Specific Prevalence, Subtypes and Risk Factors of Metabolic Diseases in Chinese Adults and the Different Patterns from Other Racial/Ethnic Populations. BMC Public Health, 22(November), 1–11. https://doi.org/10.1186/s12889-022-14555-1

Chen, M., Deng, Q., Kang, H., Li, K., Wu, Y., Zhang, J., Zhu, J., Zheng, T., Zhang, A., Sheng, J., & Liu, X. (2025). Association of Body Composition with Insulin Resistance in a Middle-Aged Population. Hormone and Metabolic Research, 57(9), 520–528. https://doi.org/10.1055/a-2691-0442

Darshi, M., Kugathasan, L., Maity, S., Sridhar, V. S., Fernandez, R., Limonte, C. P., Grajeda, B. I., Saliba, A., Zhang, G., Drel, V. R., Darshi, M., Kugathasan, L., Maity, S., Sridhar, V. S., Fernandez, R., Limonte, C. P., Grajeda, B. I., Saliba, A., Zhang, G., … Wang, J. (2024). Glycolytic Lactate in Diabetic Kidney Disease. JCI Insight, 9(11), 1–15. https://doi.org/10.1172/jci.insight.168825

Disperindag Jateng. (2026). Sebaran Jumlah Perusahaan Tekstil di Jawa Tengah. Disperindag Jateng. https://disperindag.jatengprov.go.id/v3/publik/berita_baca/MDIxZDE1MmY4MjBkZjEyYjg3MWQwOGYyZmUyMzQ2NDFlNmViYzNkNDY3NTljZjllZmU3YjM4NDc0ZTE0ZTMz

Ekblom-bak, E., Ekblom, B., Paulsson, S., Wallin, P., & Väisänen, D. (2024). Revisiting the Physical Activity Paradox: the Role of Cardiorespiratory Fitness in Workers with High Aerobic Demands. Scandinavian Journal of Public Health, 52(December 2022), 123–127. https://doi.org/10.1177/14034948221151137

Erees, S. (2022). Effects of Dichotomizing Continuous Outcome on Efficiencies of Measures of Explained Variation in Logistic Regression: Simulation Study and Application. Communications in Statistics: Case Studies, Data Analysis and Applications, 8(1), 1–19. https://doi.org/10.1080/23737484.2022.2139019

Fasching, P., Rinnerhofer, S., Wultsch, G., Birnbaumer, P., & Hofmann, P. (2020). The First Lactate Threshold Is a Limit for Heavy Occupational Work. Journal of Functional Morphology and Kinesiology, 5(66), 1–13. https://doi.org/10.3390/jfmk5030066

Ferdina, A. R., Arfines, P. P., & Aryastami, N. K. (2024). Obesity in Urban Indonesia: Evidence from the 2007 and 2018 Basic Health Research. Medical Journal of Indonesia, 33(May), 119–127. https://doi.org/10.13181/mji.oa.247183

GBD 2021 Adolescent BMI Collaborators. (2025). Global, Regional, and National Prevalence of Child and Adolescent Overweight and Obesity, 1990–2021, with Forecasts to 2050: A Forecasting Study for the Global Burden of Disease Study 2021. The Lancet, 405(March), 785–812. https://doi.org/10.1016/S0140-6736(25)00397-6

Genitsaridi, I., Salpea, P., Salim, A., Sajjadi, S. F., Tomic, D., James, S., Thirunavukkarasu, S., Issaka, A., Chen, L., Basit, A., Luk, A. O. Y., Ma, R. C. W., Mbanya, J., Ramachandran, A., Wild, S. H., Duncan, B. B., Boyko, E. J., & Magliano, D. J. (2024). 11th Edition of the IDF Diabetes Atlas: Global, Regional, and National Diabetes Prevalence Estimates for 2024 and Projections for 2050. THE LANCET Diabetes & Endocrinology, 14(2), 149–156. https://doi.org/10.1016/S2213-8587(25)00299-2

González, P., Lozano, P., Ros, G., & Solano, F. (2023). Hyperglycemia and Oxidative Stress: An Integral, Updated and Critical Overview of Their Metabolic Interconnections. International Journal of Molecular Sciences, 24(May), 1–35. https://doi.org/10.3390/ijms24119352

Grevendonk, L., Connell, N. J., Mccrum, C., Fealy, C. E., Bilet, L., Bruls, Y. M. H., Mevenkamp, J., Jörgensen, J. A., Schaart, G., Havekes, B., Bosch, J. D. V. Den, Bragt, M. C. E., Meijer, K., Schrauwen, P., & Hoeks, J. (2021). Impact of Aging and Exercise on Skeletal Muscle Mitochondrial Capacity, Energy Metabolism, and Physical Function. Nature Communications, 12(August), 1–17. https://doi.org/10.1038/s41467-021-24956-2

Jones, J. M. (2023). Glucose: Metabolism and Homeostasis. In Encyclopedia of Human Nutrition (Fourth Edition) (Issue March, pp. 70–78). https://doi.org/10.1016/B978-0-12-821848-8.00130-X

Kapoor, G., Chauhan, P., Singh, G., Malhotra, N., & Chahal, A. (2022). Physical Activity for Health and Fitness: Past, Present and Future. Journal of Lifestyle Medicine, 12(1), 9–14. https://doi.org/10.15280/jlm.2022.12.1.9

Kościuszko, M., Buczyńska, A., Łuka1, K., Duraj, E., Żuk-Czerniawska, K., Adamska, A., Siewko, K., Wiatr, A., Krętowski, A. J., & Popławska-Kita, A. (2024). Assessing the Impact of Body Composition, Metabolic and Oxidative Stress Parameters on Insulin Resistance as a Prognostic Marker for Reactive Hypoglycemia: A Cross-Sectional Study in Overweight, Obese, and Normal Weight Individuals. Frontier in Pharmacology, 15(April), 1–13. https://doi.org/10.3389/fphar.2024.1329802

Kumar, S., Sahu, N., Jawaid, T., Chellammal, H. S. J., & Upadhyay, P. (2025). Dual Role of Lactate in Human Health and Disease. Frontiers in Physiology, 81(August), 1–18. https://doi.org/10.3389/fphys.2025.1621358

Lardika, R. A., Tarigan, B., Ray, H. R. D., & Yudiana, Y. (2023). Lactic Acid and Cognitive Function: An Investigation Among Female Volleyball Athletes. Journal Sport Area, 8(2), 281–290. https://doi.org/10.25299/sportarea.2023.vol8(2).12707

Mahumud, R. A., Sahle, B. W., Owusu-Addo, E., Chen, W., Morton, R. L., & Renzaho, A. M. N. (2021). Association of Dietary Intake, Physical Activity, and Sedentary Behaviours with Overweight and Obesity Among 282,213 Adolescents in 89 Low and Middle Income to High-Income Countries. International Journal of Obesity, 45(May), 2404–2418. https://doi.org/10.1038/s41366-021-00908-0

Mandadzhiev, N. (2025). The Contemporary Role of Lactate in Exercise Physiology and Exercise Prescription – A Review of the Literature. Folia Medica, 67(1), 1–7. https://doi.org/10.3897/folmed.67.e144693

Meo, S. A., Muneif, Y. A. Bin, BenOmran, N. A., AlSadhan, M. A., Hashem, R. F., & Alobaisi, A. S. (2020). Prevalence of Pre Diabetes and Type 2 Diabetes Mellitus Among Cement Industry Workers. Pakistan Journal of Medical Sciences, 36(2), 32–36. https://doi.org/10.12669/pjms.36.2.1266

Meyer, A., Dowd, J., Kim, N., Nguyen, M., Misch, M., Marmo, K., Will, C., Janosevic, M., & Stephenson, E. J. (2024). Inactivity-Mediated Molecular Adaptations: Insights from a

Preclinical Model of Physical Activity Reduction. Physiological Reports, 12(November), 1–16. https://doi.org/10.14814/phy2.70140

Miaomiao, Z., Fanming, K., & Qian, Z. (2023). Exercise Regulates Lactic Acid Metabolism. Chinese Journal of Tissue Engineering Research, 27(2), 322–328. https://doi.org/10.12307/2022.1028

Muscogiuri, G., Verde, L., & Colao, A. (2023). Body Mass Index (BMI): Still be Used? European Journal of Internal Medicine, 117(August), 50–51. https://doi.org/10.1016/j.ejim.2023.09.002

Owesny, P., & Grune, T. (2023). The Link Between Obesity and Aging - Insights Into Cardiac Energy Metabolism. Mechanisms of Ageing and Development, 216(July), 1–21. https://doi.org/10.1016/j.mad.2023.111870

Pillai, G. P., Varghis, J. S., Binu, S., & James, R. T. (2025). Assessing The Rising Tide: A Comprehensive Analysis of Overweight and Obesity Prevalence Among Adults. International Journal for Multidisciplinary Research, 7(2), 1–6. https://doi.org/10.36948/ijfmr.2025.v07i02.42715

Public Relations of BKPK. (2025). Physical Activity of Indonesian Population. Kemenkes BKPK. https://www.badankebijakan.kemkes.go.id/en/aktifitas-fisik-penduduk-indonesia/

Qin, B., Wang, Y., & Ding, J. (2025). The Role of Mitochondrial Function in the Pathogenesis of Diabetes. Frontier in Endocrinology, 16(August), 1–16. https://doi.org/10.3389/fendo.2025.1607641

Ramadhania, A. R., Hasna, A. N., Winata, R. K., Ridwan, H., & Sopiah, P. (2024). Hubungan Aktivitas Fisik dan Pola Makan terhadap Status Indeks Masa Tubuh Normal. SEHATMAS (Jurnal Ilmiah Kesehatan Masyarakat), 3(1), 58–66. https://doi.org/10.55123/ sehatmas.v3i1.3057

Safitri, N. H., Sabilu, Y., & Lestari, H. (2025). Analisis Faktor Perilaku Sedentari, Pemesanan Makanan Online dan Faktor Genetik Terhadap Kejadian Obesitas di Wilayah Kerja BLUD UPTD Puskesmas Benu-Benua Kecamatan Kendari Barat. Indonesian Journal of Health Science, 5(3), 441–454. https://doi.org/10.54957/ijhs.v5i3.1502

Seidu, R. K., Ofori, E. A., Eghan, B., Fobiri, G. K., Afriyie, A. O., & Acquaye, R. (2024). A Systematic Review of Work-Related Health Problems of Factory Workers in the Textile and Fashion Industry. Journal of Occupational Health, 66(1), 1–9. https://doi.org/10.1093/JOCCUH/uiae007

Soeatmadji, D. W., Rosandi, R., Saraswati, M. R., Sibarani, R. P., & Tarigan, W. O. (2023). Clinicodemographic Profile and Outcomes of Type 2 Diabetes Mellitus in the Indonesian Cohort of DISCOVER: A 3-Year Prospective Cohort Study. Journal of the ASEAN Federation of Endocrine Societies, 38(1), 68–74. https://doi.org/10.15605/jafes.038.01.10

Sohn, J.-W., & Ho, W.-K. (2020). Cellular and Systemic Mechanisms for Glucose Sensing and Homeostasis. European Journal of Physiology, 472(September), 1547–1561. https://doi.org/10.1007/s00424-020-02466-2

Sumardiyono, S., Widjanarti, M. P., Suratna, F. S. N., Wijayanti, R., Fauzi, R. P., Ada, Y. R., Setyawan, H., Puspitasari, Y. D., & Agathara, R. A. (2025). Lactic Acid as a Biomarker of Occupational Fatigue in Textile Industry Workers. Malaysian Journal of Medicine and Health Sciences, 21(5), 78–84. https://doi.org/10.47836/mjmhs.21.5.10

The Indonesia Textiles & Apparel Community Reference. (2026). Menjahit Ulang Daya Saing: Jalan Panjang Kebangkitan Industri Tekstil Indonesia. https://indotextiles.com/joomla30/3196-menjahit-ulang-daya-saing-jalan-panjang-kebangkitan-industri-tekstil-indonesia

UNICEF. (2025). Obesity Exceeds Underweight for the First Time among School-Age Children and Adolescents Globally – UNICEF. UNICEF. https://www.unicef.org/press-

releases/ obesity-exceeds-underweight-first-time-among-school-age-children-and-adolescents

World Health Organization. (2025). Obesity and Overweight. https://www.who.int/en/news-room/fact-sheets/detail/obesity-and-overweight?utm_source=chatgpt.com

Zhuang, H., Karvinen, S., Zhang, X., Ojanen, X., & Törmakangas, T. (2020). Interactive Effects of Aging and Aerobic Capacity on Energy Metabolism-Related Metabolites of Serum, Skeletal Muscle, and White Adipose Tissue. BioRxiv, July, 1–41. https://doi.org/10.1101/2020.07.16.207746