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Impact of Pesticide Exposure on Farmer Metabolism Systems: A Systematic Review

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ABSTRACT

Background: Farmers are informal sector workers exposed to multiple health risks due to the unsafe use or storage of pesticides. Farmer are at high risk of pesticide poisoning, which can affect their metabolic disorders. This review aims to systematically examine the impact of pesticide exposure on health disorders in farmers' metabolic systems.
Subjects and Method: This was a systematic review using the PICO model. The keywords used for the search for the study were "Impact" and "Pesticide" AND "Exposure" AND "Farmers'" AND "Metabolism System" in various databases. The inclusion criteria in this study were studies discussing variables, research articles, and articles published from 2021 onwards, while the exclusion criteria were articles that do not have access or are not full-text. Data were collected using the extraction form, which includes PICO, and assessed using the PRISMA diagram. Data analysis was done descriptively by comparing the research results.
Results: The study found that pesticide exposure can affect the metabolic system, potentially damaging cells and causing oxidative stress by damaging lipids, proteins, and DNA, leading to genetic mutations and cell degeneration. The impact of exposure to glyphosate and arsenic pesticides causes liver and kidney function damage and decreased cardiovascular health. Exposure to paraquat, glyphosate, and oxyfluorophene causes Thyroid Cancer. Exposure to organophosphate and organochlorine pesticides causes Parkinson's. Insecticides, herbicides, and fungicides cause sleep disorders. In addition, herbicide pesticides have a significant relationship with type 2 diabetes.
Conclusion: Based on research findings, pesticide exposure impacts farmers' metabolic systems, including the incidence of Chronic Kidney Disease, decline in cardiovascular health, Thyroid Cancer, Parkinson's Disease, Sleep Disorders, and Type 2 Diabetes.

Keywords: Impact, pesticide, exposure, metabolism system, farmers

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BACKGROUND

Farmers are informal sector workers who are not bound by regulations and often lack social security (Sibagariang et al., 2023). Additionally, farmers face many risks such as injuries, work-related diseases, diseases due to pesticide exposure, cardiovascular issues, and stress disorders (Padaallah et al.,

2021) . The Health and safety of farmers needs to be prioritized based on the Health and Safety Executive, where almost every person per week dies, is injured, or falls ill due to working in the agricultural sector (HSE, 2025), in line with the International Labour Organization (ILO). Work-related accidents in the farming sector cause approximately 170,000 workers to die each year. Pesticide exposure is the leading risk factor for work accidents, accounting for 14% of all agricultural accidents and 10% of fatal accidents. UN reports on pesticide poisoning cases worldwide range from 2 to 5 million workers each year, with 40,000 resulting in fatalities (ILO, 2023). Workplace accidents in agriculture are often not recorded and documented well; legally, only 16% of them are reported, and it is estimated that there are 10,000 unreported work Injures (HSE, 2025)

Farmers are at high risk of pesticide poisoning due to unsafe use or storage (Kumar et al., 2023). The use of pesticides in developing countries continues to increase, which affects farmers, as they often come into contact with or are exposed to pesticides that pose health risks (Karunarathne et al., 2021). Pesticide exposure can enter the lungs and skin, as well as be consumed through food or drinks contaminated with pesticides (Wei et al., 2023). Exposure to pesticides at high concentrations can cause acute poisoning and lead to chronic effects that may become apparent after some time (Pedroso et al., 2022). Pesticides affect the metabolic system of the human body when released into the environment (Shaleha et al., 2023). Metabolic system disorders can cause Diabetes Mellitus, and the occurrence of Diabetes Mellitus in farmers is caused by pesticide spraying activities (Pratama et al., 2021). Pesticide exposure can cause health disorders in farmers, including piperonyl butoxide, which has the potential to cause anemia (Shekhar et al., 2024); organochlorines, which can cause anemia and hyperuricemia (Erkudov et al., 2023; Wen et al., 2024); organophosphorus, which also has the potential to cause hyperglycemia (Lasram et al., 2014), and organophosphates and malathion, which are at risk of affecting insulin resistance (Raafat et al., 2012)

Based on this background, pesticide exposure in farmers is at risk of causing disturbances in their metabolic systems. Therefore, a systematic review is needed to assess the impact of pesticide exposure on farmers' metabolic systems, identify contributing risk factors, and provide recommendations for occupational health, particularly in the agricultural sector, by comparing several studies conducted by previous researchers.

SUBJECTS AND METHOD

1. Study Design

This type of research uses a systematic review that follows PRISMA guidelines. The databases used included Science Direct, Elsevier Scopus, Springer Nature Link, Nature Portfolio, MY EBSCO, Emerald Insight, Oxford Academic, ASCE Library, and Westlaw Classic. The search strategy uses Medical Subject Headings, which areadhusted to the structure of each database. The keywords used for the search were "impact" AND "pesticide" AND "exposure" AND "farmers' and metabolism systems". The inclusion criteria in this study were studies discussing variables, research articles, and articles published from 2021 onwards, while the exclusion criteria were articles that did not have access to full text and research that did not have statistical data. The search focused on studies that assessed pesticide exposure among farmers and the risk of developing health disorders in the metabolic system.

PICO model was used to show strong similarities. Population (P) refers to the number of people involved in agricultural activities and exposed to pesticides. Intervention (I) in the study encompasses various types of pesticides used. Comparator (C) includes comparison groups, such as exposed and unexposed, case groups, and control groups. Outcome (O) is a non-communicable disease/metabolic system disorder such as diabetes mellitus, Parkinson's, etc.

2. Inclusion Criteria

The inclusion criteria for this study were full-text articles and open-access articles that used observational study designs, including cross-sectional or case-control studies. These articles specified that the study population consisted of agricultural workers or farmers, specifically those involved in direct or indirect pesticide exposure. The exposure studied was the use of chemical pesticides, and the primary outcomes examined included metabolic disorders, such as type 2 diabetes mellitus, blood glucose levels, or other related clinical biomarkers.

3. Exclusion Criteria

The exclusion criteria for this study were articles that were not available in full-text versions. Articles in the form of literature reviews, editorials, conference abstracts, or animal studies were excluded. Studies that did not report pesticide exposure data or those that did not report outcomes related to metabolic disorders (e.g., diabetes mellitus) were also excluded from the final synthesis.

4. Operational Definition of Variable

Farmer: refers to the number of people involved in agricultural activities and exposed to pesticides.

Pesticides used: refers to exposed and unexposed various types of pesticides used.

Metabolic system: defined as non-communicable disease or metabolic system disorder such as diabetes mellitus, parkinson, etc.

5. Study Instruments

The Study Instrument used the PRISMA flow diagram for systematic reviews. The Methodological quality assessment of articles included in this systematic review used the Joana Briggs Institute (JBI) Critical Appraisal Checklist, which has Cross-Sectional and Case Control study types. Cross-sectional studies have 8 questions, with a maximum score of 16 poins, and case control studies have 10 questions, with a maximum score of 20 points. Cross-Sectional Studies: There are four articles: two with a score of 15 and two with a score of 16. The shortcomings generally lie in explaining confounding factors. Overall, the four cross-sectional articles are categorized as having high methodological quality and reliability. Case-control studies. There are three articles, with two scoring 18 points and one scoring 17 points. This study shows a fairly strong methodology, according to cases and controls. The shortcomings lie in explaining confounding factors and the duration of exposure. Overall, the included articles had good methodological quality, and most articles scored high based on the JBI criteria, with these results being the basis for ensuring the validity and reliability of the synthesised articles.

6. Data Analysis

Data were analyzed using Excel based on the author, year, location, study design, number of samples, and results. The analysis was conducted narratively by comparing the direction and strength of the relationship between the studies, which explains the method of data analysis.

RESULTS

This research employed the PRISMA method, following a structured four-stage process. Figure 1. shows PRISMA flow diagram of the article selection process.

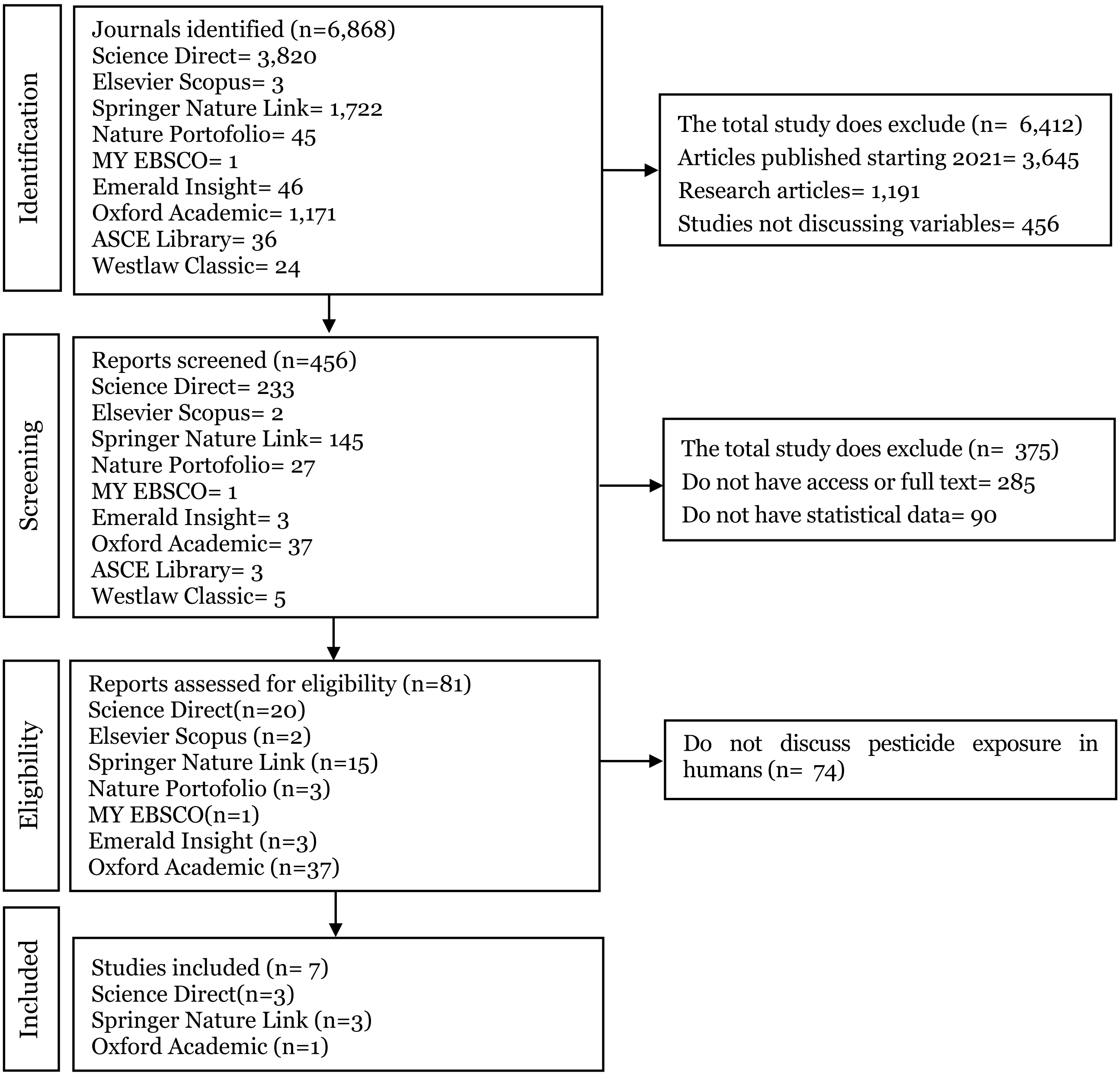

Figure 1. PRISMA-ScR Flow Diagram of the article selection process

In the identification stage, a comprehensive literature search was conducted across multiple databases, including Science Direct, Elsevier, Scopus, Springer, Nature Link, Nature Portfolio, MY EBSO, Emerald Insight, Oxford Academic, ASCE Library, and Westlaw Classic. The search strategy utilized a combination of keywords and Medical Subject Headings (MeSH), specifically: Impact AND Pesticide AND Exposure AND Farmers' AND Metabolic. This initial search yielded a total of 6,868 articles.

Next, during the filtering stage, articles were screened based on inclusion criteria: studies must align with the research variables, be primary research articles, and have been published after 2021. Following this, the eligibility stage involved reviewing articles against exclusion criteria. Studies were excluded if they were not available in full-text format or if they were literature reviews, editorials, conference abstracts, or animal studies. Additionally, articles that did not report data on pesticide exposure or did not include outcomes related to metabolic disorders, such as diabetes mellitus, were also excluded. In the final selection stage, 50 articles were assessed for methodological quality using the JBI Critical Appraisal Tool. Based on this appraisal, 7 high-quality articles were selected for synthesis, focusing on the effects of pesticide exposure on metabolic system disorders. Figure 2. shows the map of the distribution of articles included in the systematic-review

Figure 2. Map of the distribution of articles included in the Systematic review

The articles were assessed for methodological quality using the JBI Critical Appraisal Tool. Based on this appraisal, 7 high-quality articles were selected for synthesis, focusing on the effects of pesticide exposure on metabolic system disorders. Tables 1 and 2 show the results of the critical appraisal assessment study included.

Table 1. The results of the critical appraisal assessment for cross-sectional study

Author (Year)	Criteria										
	1	2	3	4	5	6	7	8	9	10	Total
Sharafi et al. (2021)	2	2	2	2	2	1	2	2	0	0	15
Sung et al. (2021)	2	2	2	2	2	1	2	2	0	0	15
Juntarawijit et al. (2025)	2	2	2	2	2	2	2	2	0	0	16
Zhu et al. (2025)	2	2	2	2	2	2	2	2	0	0	16

Description of the question criteria for the Cross-sectional:

1 = Were the criteria for inclusion in the sample clearly defined?
2 = Were the study subjects and the setting described in detail?
3 = Was the exposure measured in a valid and reliable way?
4 = Were objective, standard criteria used for measurement of the condition?
5 = Were confounding factors identified?
6 = Where did strategies to deal with confounding factors start?

7 = Were the outcomes measured in a valid and reliable way?
8 = Was appropriate statistical analysis used?

Answer score description:

0 = No
1 = Can't tell
2 = Yes

Table 2. The results of the critical appraisal assessment for case control study

Author (Year)	Criteria										
	1	2	3	4	5	6	7	8	9	10	Total
Omidakhsh etal. (2022)	2	2	2	2	2	2	0	2	2	2	18
Wei et al. (2023)	2	2	2	2	2	2	0	2	1	2	17
Samareh et al. (2024)	2	2	2	2	2	2	0	2	2	2	18

Description of the question criteria for Case Control:

1 = Were the groups comparable other than the presence of disease in cases or the absence of disease in controls?
2 = Were cases and controls matched appropriately?
3 = Were the same criteria used for the identification of cases and controls?
4 = Was exposure measured in a standard, valid, and reliable way?
5 = Was exposure measured in the same way for cases and controls?
6 = Were confounding factors identified?
7 = Where did strategies to deal with confounding factors start?
8 = Were outcomes assessed in a standard, valid, and reliable way for cases and controls?
9 = Was the exposure period of interest long enough to be meaningful?
10 = Was appropriate statistical analysis used?

Answer score description:

0 = No
1 = Can't tell
2 = Yes

Table 3 shows the summary of studies included in the systematic review examining the impact of pesticide exposure on metabolic disorders among farmers. Based on the results of the analysis, as many as five articles reported that pesticides were associated with chronic kidney disease, thyroid cancer, Parkinson's disease, type 2 diabetes, and prediabetes. The associated pesticides were Glyphosate, organophosphate, paraquat, and oxyfluorfen. One study stated that there was no significant association with diabetes; however, diabetes was significantly associated with age, sex, BMI, education level, and physical activity.

Table 3. Summary of Studies Included in the Systematic Review Examining the Impact of Pesticide Exposure on Metabolic Disorders among Farmers

Author (Year)	Study Design	Country	P	I	C	O	Result	View
Sharafi et al.	Cross-Sectional	Iran	9,088 Adults over 30	Pesticide exposure	People without	Prevalence of Type 2	Age (OR= 3.73; 95% CI= 3.30 to 4.22), Gender	Diabetes is significantly

Author (Year)	Study Design	Country	P	I	C	O	Result	View
(2021)			years old	by employment status	pesticide exposure/ not working in agriculture	Diabetes Mellitus	(OR= 1.21; 95% CI= 1.06 to 1.39), BMI (OR= 1.82; 95%CI= 1.57 to 2.11), Educational level - High School (OR= 0.74; 95% CI= 0.64 to 0.85), Academic (OR= 0.53; 95%CI= 0.43 to 0.67), Physical activity Medium (OR= 0.83; 95 % CI= 0.73 to 0.94), High (OR= 0.61; 95 % CI= 0.53 to 0.705), Pesticide exposure (OR= 0.98; 95% CI= 0.91 to 1.05).	related to age, gender, BMI, educational level, and physical activity, but there is no significant relationship between pesticide exposure and the risk of Type 2 Diabetes.
Sung et al. (2021)	Cross-Sectional	Taiwan	55 Patients with Kidney Disease and 100 participants without kidney disease	Glyphosate, Arsenic, Cadmium Exposure in Urine	People with Chronic Kidney Disease and Healthy People	Chronic Kidney Disease	Kidney disorder: high Cd concentration >1mg/g creatinine (OR= 7.57; 95% CI= 1.90 to 29.95), High Glyphosate concentration >1 mg/g creatinine (OR= 1.39; 95% CI= 0.90 to 2.15). Normal kidney: high CD concentration >1mg/g creatinine (OR= 1.85; 95% CI= 0.83 to 4.11), glyphosate >1 mg/g creatinine (OR= 1.57; 95% CI= 1.13 to 2.16), as >1 mg/g creatinine (OR= 1.00; 95% CI= 1.00 to 1.02).	Exposure to pesticides Cd, Glyphosate, and as has a significant relationship with the incidence of Chronic Kidney Disease
Omidakhsh et al. (2022)	Case Control	California	2,067 cases and 1,003 control	Exposure to 29 types of agricultural pesticides	People exposed to pesticides and people with low pesticide exposure	Thyroid Cancer	Paraquat dichloride (OR= 1.46; 95% CI= 1.23 to 1.73), Glyphosate (OR= 1.33; 95% CI= 1.12 to 1.58), Oxyfluorfen (OR= 1,21 95% CI= 1.02 to 1.43)	Pesticide exposure to Paraquat, Glyphosate, and Oxyfluorfen from agriculture is significantly associated with the incidence of thyroid

Author (Year)	Study Design	Country	P	I	C	O	Result	View
								cancer.
Wei et al. (2023)	Case Control	China	2,626 residents of Henan Village	Exposure to herbicide mixture, oxadiazone	People with Prediabetes and Normal Blood Sugar Levels	Risk of Prediabetes and Type 2 Diabetes	Oxadiazon and Prediabetes (OR= 1.00; 95%CI= 1.03 to 1.13), Herbicides and type 2 DM (OR= 1.09; 95% CI= 1.04 to 1.15), Risk exposure type 2 DM (OR= 1.13; 95% CI= 1.10 to 1.15), Prediabetes (OR= 1.06; 95% CI= 1.01 to 1.11).	Exposure to herbicides has a significant relationship with the incidence of type 2 diabetes and prediabetes.
Samareh et al. (2024)	Case Control	Iran	29 patients and 51 healthy subjects	Organo-chlorine and Organo-phosphate Exposure	People with parkinson's disease and healthy people	Parkinson	Organochlorine levels in the Parkinson's atient group were significantly higher compared to the control group ($p<0.050$). AChE and PON-1 enzyme activities in the Parkinson's patient group were significantly lower compared to the control group. A decrease AChE and PON-1 enzymactivities characterizes increased organophosphate exposure.	Research shows that exposure to organophosphate and organochlorine pesticides is possibly contributing to the risk of developing Parkinson's disease.
Juntarawijit et al. (2025)	Cross-Sectional	Thailand	27,334 farmers aged 20 years or older, with a minimum of 5 years of work experience	History of use of 38 types of pesticides	Farmers without pesticide exposure versus farmers with lower exposure	Sleep Disorders	Type of pesticide, which has a significant relationship: Organochlorine Insecticide (Chlorpyrifos, Chlordane, dieldrin, DDT), Organophosphate Insecticid (EPN, Parathion, Methamidophos), Carbamate Insecticides (Carbaryl, Carbofuran, Methonyl), Other Insecticide (Imidacloprid), Herbicide (Alachlor, Ametryn, Diuron, Glyphosate, Paraquat, Fungicide	1. This study shows a positive relationship between pesticides (twelve insecticides, five herbicides, and five fungicides) and sleep disturbances. 2. The dose-response pattern has a significant relationship. 3. Women have a higher risk of sleep disorders.

Author (Year)	Study Design	Country	P	I	C	O	Result	View
							(Benomyl, Carbendazim, Bordeaux mixture, Copper sulfate, Metalaxyl) Dose respon: fungi cide Q3 (116 to 442.5 day) (OR= 4.18; 95% CI= 1.39 to 12.59). Klorpirfos Q4 (245.1 to 9030 day) (OR= 5.19; 95% CI= 1.46 to 18.46), Abamectin Q4 (245.1 to 9030 day) (OR= 11.55; 95% CI= 1.51 to 88.26) Q2 (37.6 to 105 day) (OR= 11.55; 95% CI= 1.38 to 83.4) Gender: Man (OR= 0.98; 95% CI= 0.29 to 3.33) pada, Women (OR= 3.52; 95% CI= 1.41 to 8.75)	
Zhu et al. (2025)	Cross-Sectional	United States	2,842 American Adults	Glyphosate Exposure in Urine	Individuals with high exposure and individuals with low exposure /not exposed	Cardio-vascular risk	Decrease in cardio-vascular Health (CI = -2.25 to 0.41). The negative relationship between glyphosate and cardiovascular health p < 0.050, Non-Linear relationship between glyphosate and cardiovascular health p < 0.001	Glyphosate exposure is associated with a decline in cardio-vascular health.

Most literature studies show a positive relationship between pesticide exposure and metabolic system disorders. The research designs used include Cross-sectional and Case-Control studies. Most of the literature studies come from Asian countries, namely five articles, and from African countries, two articles, where these countries still use many pesticides. Pesticides that have the risk of causing metabolic system disorders include Cd, Glyphosate, As, Paraquat, Oxyfluorphen, Organophosphates, Carbamate Insecticides, and Organochlorines. In addition to pesticide exposure that can affect the metabolic system include age, gender, BMI, education level, and physical activity. Metabolic disorders that occur include Diabetes, Parkinson's, sleep disorders, cardiovascular disease, and chronic kidney disease.

PICO of the included studies has a fairly strong dtrength, with the main population (P) being farmers and individuals exposed to pesticides, with the main factor (I) pesticide exposure, the comparison group (C) includeing the exposed group, low exposure group, case group and control group, and outcomes in the form of metabolic system disorders/Non-Communicable Diseases/such as diabetes, sleep disorders, Parkinson's, kidney disease, thyroid cancer, decreased cardiovascular health.

The Synthesis results showed a consistent relationship between pesticide exposure and metabolic system disorders, especially those using biomarkers to measure pesticide exposure. Quality assessment using the JBI checklist showed relatively high results, with scores of 15-16 for cross-sectional studies and 17-18 for case-control studies, thus strengthening the strength and robustness of the findings.

Important implications for occupational health protection in the agricultural sector, especially farmer education on the safe use of pesticides, as well as the need for long-term exposure monitoring, with these findings requiring further longitudinal research.

DISCUSSION

Pesticides are hazardous chemical substances that, if not used properly, can negatively affect health(Nurhayati and Wardani, 2021). This study found that pesticide exposure can affect the metabolic system, potentially damaging body cells and leading to oxidative stress by damaging lipids, proteins, and DNA, leading to genetic mutations and cell degeneration (Keman, 2020). Pesticide exposure can also decrease metabolic enzymes and accumulate toxins in tissues, which can trigger extensive cell damage.

The impact of pesticide exposure on the farmers' metabolic system, namely liver and kidney function damage (Iskandar et al., 2025), is supported by the theoretical review that we analyzed, which states that exposure to Glyphosate and Arsenic pesticides is associated with the occurrence of Chronic Kidney Disease (Sung et al., 2022). Arsen exposure in the body can occur through contaminated water, soil, and rocks contaminated with Arsen (Wicaksana and Rachman, 2018). Pesticides can also cause lipid metabolism disorders and blood clotting, leading to atherosclerosis and increased heart attacks (Iskandar et al., 2025), in consistent with a theoretical review stating that glyphosate-type pesticides cause a decline in cardiovascular health (Zhu et al., 2025). In addition to these disorders, pesticide exposure can cause genetic mutations, leading to uncontrolled cell growth and, in the long term, cancer (Iskandar et al., 2025). This is consistent with the literature, which indicates that exposure to paraquat, glyphosate, and oxyfluorfen pesticides can cause Thyroid Cancer (Omidakhsh et al., 2022). This literature review showed that exposure to organophosphate and organochlorine pesticides is involved in the onset of Parkinson's disease (Samareh et al., 2024). Pesticide exposure can cause oxidative stress, which can lead to genetic mutations and damage to the central and peripheral nervous systems. If this occurs over a long period, it can cause brain damage, which has the potential to lead to Parkinson's disease (Iskandar et al., 2025).

Pesticide exposure can cause neurobehavioral (NB) effects, also known as neurotoxic symptoms on health, characterized by sleep disturbances and difficulty concentrating (Mustakim and Kas, 2022; Sari and Juananda, 2024). Our literature review indicates that pesticides, such as insecticides, herbicides, and fungicides, also affect farmers' metabolic systems, causing sleep disturbances (Juntarawijit et al., 2025).

Prolonged pestici (Dyck et al., 2013)de application adversely affects human health by elevating the risk of type 2 diabetes and obesity (Xiao et al., 2017). Previous research on men in rural Kandam has found that insecticide exposure is an independent risk factor for diabetes (Dyck et al., 2013). In line with our theoretical review, pesticide exposure can cause metabolic system disturbances such as diabetes, where there is a significant relationship between herbicide-type pesticides and the incidence of type 2 diabetes (Wei et al., 2023). However, this does not align with previous research, which found no significant relationship between pesticide exposure and type 2 diabetes (Sharafi et al., 2021).

Health disorders due to pesticide exposure can be prevented by using personal protective equipment such as long pants, long-sleeved clothing, head coverings, masks, gloves, and boots to avoid entry of pesticide particles into the body through the skin and respiratory system. Spraying activities should be conducted in the afternoon by moving backward (Ahyanti et al., 2022). When mixing pesticides, it is advisable to take less than 15 minutes and follow the instructions on the label, and it is not recommended to mix more than two types of pesticides. The use of pesticides on a single plant is recommended to be of only one type (Ahyanti et al., 2022).

The Result of the analyzed articles show a positive relationship between pesticide exposure and an increased risk of metabolic system disorders. Most of the study results indicate that exposure to glyphosate, paraquat, Organochlorine, Organophosphate, and Oxadiazone pesticides has a higher risk of causing metabolic disorders. The Study results also show that exposure levels with a longer duration have a greater potential for metabolic system disorders. However, studies report that pesticide exposure does not strongly correlate with the occurrence of metabolic system disorders, namely diabetes, but is influenced by gender, BMI, education, and physical activity (Sharafi et al., 2021).

This study found differences in the type of pesticide used, exposure assessment methods, differences in interfering factors, and the duration of exposure to health impacts (Omidakhsh et al., 2022). This synthesis shows that despite differences, the study results state that pesticide exposure impacts metabolic system disorders. Shows the importance of monitoring chemical exposure in the agricultural sector and more in-depth longitudinal research in the future.

AUTHOR CONTRIBUTION

Triyani selected the topic and searched for articles. Collected articles, analyzed data, and wrote the manuscript. Hanifa Maher Denny assessed the quality of the articles, analyzed data, and wrote the manuscript. Suroto supervised, Validated, and revised the manuscript critically. All authors have read and approved the final version of the manuscript.

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CONFLICT OF INTEREST

The authors declare no conflicts of interest. This systematic literature review was conducted independently, and the authors were solely responsible for all findings and interpretations.

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