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ORIGINAL ARTICLE

The Prevalence of Respiratory Diseases among School Students in Rural Areas and Their Association with Immunological and Physiological Aspects

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ABSTRACT

Respiratory diseases are common health problems among school students, which affect students' health, activity, and learning abilities. These diseases are associated with physiological and immunological markers that affect respiratory efficiency and body's response to infection. This study aimed to assess the prevalence of respiratory diseases among primary school students, identify the most common diseases, and investigate the relationship between respiratory diseases and certain physiological and immunological factors. The cross-sectional study was conducted on 910 infected and non-infected students with respiratory diseases, aged 6–12 years. Physiological and immunological variables were estimated in serum using enzyme-linked immunosorbent assay (ELISA), including zinc and vitamin D, interleukin-8 (IL-8), tumor necrosis factor-alpha (TNF-α), globulin A (IgA), globulin E (IgE), and procalcitonin, in addition to measuring body temperature and heart rate. The results indicated that infected students show elevated in WBC (10.8±2.5), neutrophil (65.9±8.1), IL-8 (54.4±6.3), TNF-α (63.2±3.9), IgA (87±9.7), IgE (144±12.4), and procalcitonin (3.48±98), while decreased in zinc (23.2±2.4), vitamin D (31±4.8), lymphocyte (28.1±5), RBC (10.8±2.5), and Hb (12.4±1.3) compared to non-infected students. Univariate binary logistic regression analysis showed that zinc (OR=0.766), WBC (OR=1.67), lymphocyte (OR=0.739), neutrophil (OR=1.439), IL-8(OR=1.674), and IgA (OR=6.38) were strongly associated with respiratory disease presence. These results confirm that respiratory diseases were a significant health problem among primary school students, and their prevalence is not only associated with pathogens but is also influenced by environmental, physiological, and immunological factors. These results showed decreased levels of zinc, vitamin D, and lymphocyte, while IL-8 and IgA were elevated in students infected with respiratory diseases.

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1- INTRODUCTION

The respiratory system is responsible for supplying the body with oxygen necessary for survival and eliminating carbon dioxide produced by metabolism [1]. However, this vital system is susceptible to numerous diseases that impair its function and disrupt normal breathing, causing shortness of breath and other symptoms [2]. Respiratory diseases are among the most common health problems among school-aged children, representing a major cause of school absenteeism and decreased academic performance [3]. According to the World Health Organization, respiratory diseases are among the leading causes of death and disability, ranking third globally in terms of mortality [4]. Despite their significant impact, these diseases are often overlooked in global health discussions due to insufficient attention and resources allocated to combating them [5]. Influenza viruses and other respiratory pathogens are transmitted via droplets through social interaction, whether through conversation or physical contact [6]. There is clear evidence that schools are fertile social environments that facilitate the transmission of respiratory pathogens through close contact among students [7]. Furthermore, continuous exposure to environmental factors such as dust, air pollution, tobacco smoke, and climate change increases children's susceptibility to respiratory diseases and affects the severity of clinical symptoms [8]. These diseases include upper and lower respiratory tract infections, asthma, bronchitis, and pneumonia, which are more prevalent in school environments due to close proximity among students, poor ventilation, and the increased likelihood of pathogen transmission via respiratory droplets and contaminated surfaces [9]. The occurrence of respiratory diseases is not solely dependent on exposure to pathogens but is also linked to an individual's physiological and immunological state. Changes in certain physiological indicators, such as body temperature and heart rate, as well as changes in blood components play a significant role in the response to infection and in assessing disease severity [10].

Immunological and inflammatory markers, such as interleukin-8 (IL-8), tumor necrosis factor-alpha (TNF-α), procalcitonin, and immunoglobulin antibodies (IgA and IgE), are among the most important biomarkers reflecting immune system activity and the inflammatory response associated with respiratory infections [11]. Several studies have shown that elevated levels of inflammatory cytokines and procalcitonin are associated with increased severity of respiratory infections, while decreased levels of certain immunological markers contribute to increased susceptibility to recurrent infections in children [12]. Evidence also suggests that combining physiological and immunological markers provides a better ability to assess health status, predict disease severity, and identify children most at risk of complications compared to relying on clinical signs alone [13]. Despite the increasing number of studies addressing respiratory diseases in children, research combining the assessment of respiratory disease prevalence with the analysis of physiological and immunological markers in the school setting, particularly in Iraq, remains limited. Furthermore, most studies have focused on epidemiological or clinical aspects in isolation, without examining the integrated relationship between physiological and immunological responses and the risk of respiratory diseases [5, 9, 10]. We hypothesized that infected students with respiratory diseases would have significantly different levels of investigated biomarkers compared with non-infected students. Specifically, inflammatory markers would be associated with the presence of disease and differ according to disease types. Therefore, this study aims to assess the prevalence of respiratory diseases among school students, analyze the relationship between respiratory disease incidence and certain physiological and immunological indicators, and identify factors associated with increased risk. This will contribute to improving early detection and prevention programs and provide a scientific basis for developing health strategies targeting children in the school environment.

2- MATERIALS AND METHODS

2.1 Study Design

This cross-sectional study was conducted to determine the prevalence of respiratory diseases among school students and to investigate their relationship to physiological and immunological markers. The study was carried out from January 2026 to April 2026 in seven public primary schools in rural areas of Anbar Governorate. Biomarkers were measured during acute infection.

2.2 Study Population

The study population consisted of primary school students. Schools were selected using a multi-stage random sampling method. After obtaining approvals from the Directorate of Education in Anbar and the school administrations (No. 560 on January/ 2026), students were randomly selected according to inclusion and exclusion criteria. Seven primary schools participated in the study:

1. Al-Wissam Primary School for Boys
2. Al-Maarifa Primary School for Girls
3. Shaheed Al-Elm Co-educational School
4. Al-Azm Co-educational Primary School
5. Al-Nathim Primary Co-educational School.
6. Al-Harith Primary School for Girls.
7. Sumer Primary School for Boys.

2.3 Sample Size

The sample consisted of 910 male and female students aged between (6–12) years, divided into two groups: 120 students with respiratory disease and 790 students without respiratory disease. Respiratory disease was identification based on a combination of physician assessment, reported respiratory symptoms, relevant findings on clinical examination, available health records, and the study questionnaire and confirmed through clinical assessment. Among the 790 students who were screened and found to be non-infected with respiratory diseases, 120 apparently healthy students were randomly selected to serve as the health control. The selected health students were included for comparison with infected students with respiratory diseases in the subsequent clinical and laboratory analyses.

2.4 Inclusion Criteria

Students age between 6–12 years. Parental consent to participation. Completeness of all clinical and laboratory data.

2.5 Exclusion Criteria

Having a chronic non-respiratory disease. Having an autoimmune or genetic disorder. Using immunosuppressive medications. Refusal to participate in the study.

2.6 Data Collection

Data was collected using a questionnaire specifically designed for this study. The questionnaire included the following information: Age and gender, grade level, weight and height, body mass index (BMI), passive smoking in the home, number of family members, parents' education level, home ventilation, exposure to dust and pollutants, previous medical history, ventilation quality in the classroom and home, class size, type of fuel used in the home, and quality of school infrastructure. The student has any of the symptoms such as cough, runny nose, fever, nasal congestion, frequent sneezing, wheezing, and Headache.

2.7 Blood Sample Collection

Five ml of venous blood was withdrawn from each student using sterile, single-use syringes under sterile conditions. The samples were divided into two parts: (2 ml) was placed in EDTA tubes for complete blood count (CBC) testing. Meanwhile, 3 ml was placed in anticoagulant-free tubes to obtain serum. The samples were allowed to coagulate for 30 minutes and then centrifuged at 3000 rpm for 10 minutes. The serum was stored at -20°C until physiological and immunological testing could be performed.

2.8 Physiological Measurements

2.8.1 Body Temperature

A Rossmax digital thermometer (Switzerland) was used to measure temperature orally and axillary (in °C). The measurement was performed after the participant rested for 5–10 minutes, under similar environmental conditions for all participants.

2.8.2 Heart rate

Measured after the participant rested for 5 minutes in a seated position; using a calibrated Microlife. Switzerland digital pulse oximeter. Results were recorded in beats per minute (bpm).

2.8.3 Blood zinc level

Measured using the colorimetric method as per the manufacturer by Elabscience/USA ELISA kit, Catalog No. E-BC-K137-M. Detection range: 0.748–46.2 µmol/L. Sensitivity: 0.418 µmol/L.

2.8.4 Vitamin D3 level

Measured using an Elabscience/USA ELISA kit. Catalog No. E-EL-0012 had a detection range of 6.25–400 ng/mL and a sensitivity of 3.75 ng/mL. Hematological tests: A complete blood count (CBC) was performed using a PE-6100 plus automated hematology analyzer/ China and included: Hemoglobin (Hb), Red Blood Cells (RBC), White Blood Cells (WBC), Neutrophils, and Lymphocytes.

2.9 Immunological Measurements

Immunological markers were estimated in serum using ELISA according to the manufacturer's instructions. These markers are IL-8 was measured using the Human IL-8 ELISA Kit (Cat. No. E-EL-H6008 from Elabscience/USA) with detection range: 7.81–500 pg/mL; Sensitivity: 4.69 pg/mL. TNF-α was measured using the Human TNF-α ELISA Kit (Cat. No. E-EL-H0109 from Elabscience/USA) with detection range: 7.81–500 pg/mL; Sensitivity: 4.69 pg/mL. IgA was measured using the Human IgA ELISA Kit (Cat. No. E-EL-H6071 from Elabscience/USA) with detection range is 1.56–100 ng/mL, and the sensitivity is 0.94 ng/mL. IgE was measured using the Human IgE ELISA Kit (Cat.No. E-EL-H6104) from Elabscience/USA with detection range is 3.13–200 ng/mL, and the sensitivity is 1.88 ng/mL. Procalcitonin was measured using the Human PCT ELISA Kit (Cat.No. E-EL-H1492 from Elabscience/USA) with detection range is 31.2–2000 pg/mL, and the sensitivity is 18.7 pg/mL. A standard curve was generated for each assay, and sample concentrations were calculated from the corresponding standard curve.

2.10 Statistical Analysis

Data were entered into SPSS version 27.0 for statistical analysis. The data were presented as mean ± SD and were compared using Student's t-test. While categorical variables were compared using the chi-square test, one-way ANOVA for comparing more than two groups, and univariate logistic regression analysis to identify indicators predicting the presence of respiratory diseases. The receiver operating characteristic (ROC) curve was used to determine cutoff value, sensitivity and specificity. Results were considered statistically significant when p-value was less than 0.05.

3- RESULTS AND DISCUSSION

3.1 Prevalence of respiratory diseases among students

There was a significant difference in the prevalence of respiratory diseases among students The results indicated that the highest diseases prevalence was in Al-Harith Primary School for Girls, reaching 17.3%, while the lowest prevalence was in Al-Azm Co-educational Primary School, reaching 9.2%. Al-Ma'rifa Primary School for Girls and Sumer Primary School for Boys showed almost equal prevalence rates, at 14.6% and 14% respectively, as shown in Table (1). From 790 non-infected students, 120 were randomly selected to serve as health controls.

Table (1): The prevalence of respiratory diseases among Primary School students

School name	Number of students examined	Infected students	Percent (%)	Non-infected students	Percent (%)	P-value
Al-Wisam Primary School for Boys	120	16	13%	104	87%	0.032*
Al-Ma'rifa Primary School for Girls	130	19	14.6%	111	85.4%	
Shaheed Al-Elm Co-educational School	125	14	11.2%	111	88.8%	
Al-Azm Co-educational Primary School	130	12	9.2%	118	90.8%	
Al-Nathim Primary Co-educational School.	140	18	12.8%	122	87.2%	
Al-Harith Primary School for Girls	115	20	17.3%	95	82.7%	
Sumer Primary School for Boys	150	21	14%	129	86%	
Total	910	120	13.1%	790	86.9%	

*** $p < 0.05$, statistically significant. The chi-square (χ^2) test was used for differences in prevalence among schools.**

3.2 Types of Respiratory Diseases Environmental Factors prevalent among school students

Table 2 show four types of respiratory diseases (upper respiratory tract infections, tonsillitis, asthma, and bronchitis) were identified among students in rural schools. Upper respiratory tract infections recorded the highest incidence rate at both Al-Azm Co-educational School and Al-Nathim Co-educational School (50%), followed by Al-Ma'rifa School for Girls (47%). Tonsillitis had the highest incidence rate (50%) at both Shaheed Al-Elm Co-educational and Al-Harith School for Girls, while Al-Ma'rifa School for Girls recorded the lowest incidence rate (21%). Asthma was the least common disease among schools, with the highest incidence (14.2%) at Sumer School for Boys. Bronchitis recorded the highest incidence rate (25%) at Al-Wisam School for Boys. The environmental characteristics of classrooms, the highest average number of students per class was (43±2) at Sumer School for Boys, while the lowest average was (30±4) at Al-Azm Co-educational School. The highest percentage of satisfactory classroom ventilation was at Al-Wisam School for Boys (85%), and the lowest was at Sumer School for Boys (53%). The highest percentage of exposure to dust and air pollutants was (45%) at Al-Harith School for Girls, and lowest was (32%) at Al-Azm Co-educational School. Exposure to smoking inside the house was 25% at Al-Nathim Co-educational School, while the lowest was at Shaheed Al-Elm Co-educational School.

Table (2): Comparison of respiratory diseases types and Environmental Factors prevalent among school students

Variables	Al-Wisam School for Boys (16)	Al-Ma'rifa School for Girls (19)	Shaheed Al-Elm Co-educational School(14)	Al-Azm Co-educational School(12)	Al-Nathim Co-educational School(18)	Al-Harith School for Girls(20)	Sumer School for Boys(21)	P-value
Upper respiratory tract infections	5(31.2%)	9(47.3%)	4(28.5%)	6(50%)	9(50%)	5(25%)	8 (38%)	0.024*
Tonsillitis	6(37.5%)	4(21%)	7(50%)	4(33.3%)	7(38.8%)	10 (50%)	8(38%)	0.033*
Asthma	1(6.2%)	2(10%)	1(7.1%)	0 (0)	1(5.5%)	2(10%)	3(14.2%)	0.014*
Bronchitis	4(25%)	4(21%)	2 (14.2%)	2 (14.2%)	1(5.5%)	3(15%)	2(9.5%)	0.028*
Average number of students per class	35 ±4	38±3	36±5	30 ±4	37±5	40 ±2	43± 2	0.012*
Classroom ventilation	85%	62%	73%	77%	65%	56%	53%	0.043*
Exposure to dust and air pollutants	27%	34%	38%	23%	37%	45%	42%	0.038*
Exposure to smoking	32%	37%	25%	27%	46%	34%	44%	0.041*

*** $p < 0.05$, statistically significant.**

3.3 Demographic Characteristics of School Students

The results showed no difference in age and gender between infected students and uninfected. There was difference in BMI between infected students and uninfected students. Students were divided into three groups based on their BMI: underweight, normal weight, and overweight. The highest percentage of both students with and without respiratory disease were within the normal weight, while the lowest percentage of students were in the overweight category, as in Table 3.

Table (3): Demographic Characteristics of School Students

Parameters		Infected (120)	Non-infected (120)	P-value
Age (years)		9.8±1.7	9.2 ±2.1	0.164
Gender (N/%)	**Boys**	61 / 50.8%	62/ 51.5%	0.255
	Girls	59/ 49.2%	58/ 48.5%	
BMI (N/%)	**Under weight**	30/ 25%	28/ 23.3%	0.034*
	Normal weight	66/ 55%	67/ 55.8%	
	Over weight	24/ 20%	25/ 20.8%	

*** $p < 0.05$, statistically significant.**

3.4 Physiological and Immunological indicators between Students with and without Respiratory Diseases

Table (4) shows the significant differences between the two groups with respect to physiological factors. Temperature and heart rate showed the highest mean in students with respiratory diseases (38.2± 0.6°C and 91.3 ± 5.5 beats/minute, respectively). The levels of both zinc and vitamin D3 were decreased in the students with respiratory diseases (23.2±2.4 and 31±4.8, respectively) compared to the students without respiratory diseases (42 ± 2.6 and 5.5±64, respectively). Similarly, Hb, RBC, and lymphocytes were decreased in the students with respiratory diseases (12.4±1.3, 4.41±0.45, and 28.1±5.0, respectively) compared to the students without respiratory diseases. WBC count and neutrophil % were higher in students with respiratory disease (10.8± 2.5 and 65.9±8.1, respectively) compared to students without respiratory disease. There are significant differences in immunological indicators between the two groups. The mean levels of IL-8, TNF-α, IgA, IgE, and procalcitonin were significantly higher in the students with respiratory diseases group (54.4±6.3, 3.9± 63.2 , 87±9.7, 144±12.4, and 98±3.48 respectively) compared to the students without respiratory diseases group.

Table (4): Comparison of physiological and Immunological indicators between students with and without disease

Parameters	Groups		P-value
	Infected student	Non-infected students	
Temperature (°C)	38.2 ±0.6	36.8 ± 0.3	<0.001
Heart rate (beats/minute)	91.3±5.5	76.4 ± 4.2	<0.001
Zinc (µmol/L)	23.2 ± 2.4	42±2.6	<0.001
Vitamin D3 (ng/mL)	31 ± 4.8	64 ± 5.5	<0.001
Hb (g/dL)	12.4 ± 1.3	13.6 ± 1.1	<0.001
RBC ($\times10^6$/µL)	4.41±0.45	4.82 ±0.39	<0.001
WBC ($\times10^3$/µL)	10.8 ± 2.5	6.7 ± 1.3	<0.001
Lymphocytes %	28.1 ±5	38.6 ± 6.4	<0.001
Neutrophil %	65.9± 8.1	52.4 ± 7.2	<0.001
IL-8 (pg/mL)	54.4 ± 6.3	36 ± 4.3	<0.001
TNF-α (pg/mL)	63.2 ±3.9	38.2 ±3.2	<0.001
IgA (ng/mL)	87 ± 9.7	41.5 ±4.1	<0.001
IgE (ng/mL)	144 ±12.4	64.8 ±6.3	<0.001
Procalcitonin (pg/mL)	98 ± 3.48	41 ± 2.3	<0.001

*** $p < 0.05$, statistically significant.**

3.5 Identifying Respiratory Disease Predictors Using Univariate Logistic Regression Analysis

Univariate binary logistic regression analysis was performed to estimate the association between the study markers and the occurrence of respiratory disease. The regression analysis showed no significant association between body temperature, heart rate, vitamin D level, Hb concentration, RBC, TNF-α, IgE, and procalcitonin with the occurrence of respiratory disease, as the $p > 0.05$. The odds ratio (OR) and 95% confidence interval were estimated for each variable. However, Univariate binary logistic regression analysis showed that zinc, WBC, lymphocyte, neutrophil, IL-8, and IgA were strongly associated with the presence of respiratory disease, as the $p < 0.05$. Elevated levels of WBC, neutrophils, IL-8, and IgA were associated with an increased probability of respiratory infections, while elevated zinc levels and lymphocyte% were associated with a decreased probability of respiratory infections, in table (5).

Table (5): Univariate Bivariate Logistic Regression of Markers associated with respiratory infection

Variable	B	SE	Wald	P-value	OR	95% CI for OR
Temperature (°C)	1.557	0.704	4.887	0.057	4.743	1.193 – 8.860
Heart rate (beats/minute)	0.876	0.534	2.687	0.101	2.401	0.842 – 6.845
Zinc(μmol/L)	-0.366	0.100	7.094	0.018*	0.766	0570 – 0.932
vitamin D3 ng/mL)	-0.425	0.282	2.264	0.132	0.654	0.376 – 1.137
Hb (g/dL)	-1.389	0.634	4.803	0.068	0.249	0.072 – 0.863
RBC ($\times 10^6$/μL)	0.965	0.376	6.602	0.779	1.625	0.857 –2.481
WBC ($\times 10^3$/μL)	0.514	0.280	3.37	0.050*	1.67	0.337 – 3.791
Lymphocytes %	-0.303	0.122	6.198	0.013*	0.739	0.582 – 0.938
Neutrophil %	0.434	0.143	6.464	0.021*	1.439	0.387 – 1.904
IL-8 (pg/mL)	0.516	0.254	4.117	0.044*	1.674	1.018 – 2.755
TNF-α (pg/mL)	0.467	0.250	3.493	0.062	1.595	0.977 – 2.604
IgA (ng/mL)	1.851	0.788	5.52	0.019*	6.38	1.367 - 9.981
IgE (ng/mL)	0.105	0.041	6.401	0.061	1.110	1.024 – 1.204
Procalcitonin (pg/mL)	0.119	0.049	6.059	0.062	1.127	1.25 – 1.239

3.6 Multivariate logistic regression analysis identified independent marker associated with respiratory disease

In multivariate logistic regression analysis, zinc (OR=0.671, P=0.001), WBC (OR=4.599, P=0.04), IL-8 (OR=1.757, P=0.003), and IgA (OR=1.204, P=0.005) remained independent factors associated with respiratory disease among infected students after adjustment of other variables included in this model. In contrast, neutrophil and lymphocyte were no longer statistically significant independent predictors of respiratory disease ($p > 0.05$), in Table (6).

Table (6): Multivariate logistic regression analysis identified independent markers associated with respiratory disease

Variable	B	SE	P-value	OR	95% CI for OR
Zinc(μmol/L)	0.698-	0.116	0.001*	0.671	0.535 – 0.842
WBC ($\times 10^3$/μL)	1.664	0.530	0.04*	4.599	1.626 – 13.006
Lymphocytes %	0.440-	0.139	0.085	0.787	0.398 – 1.034
Neutrophil %	0.575	0.217	0.073	1.777	0.161 – 2.719
IL-8 (pg/mL)	0.564	0.189	0.003*	1.757	0.214 – 2.544
IgA (ng/mL)	0.185	0.066	0.005*	1.204	0.161 - 1.370

3.7 Receiver Operating Characteristics (ROC) Curve of Biomarkers Predicting Respiratory Diseases

ROC curve analysis showed good discriminatory performance of the studied biomarkers in distinguishing between students with respiratory diseases and health students. Cutoff value was derived from the study data using ROC curve analysis and interpreted as a study-specific predictive threshold. IgA showed the highest discriminatory power, with AUC=0.991, a sensitivity of 100%, and a specificity of 96% at a cutoff value ≥72.0. Also, WBC demonstrated excellent performance, with an AUC =0.969, a sensitivity of 86.7%, and a specificity of 100% at a cutoff value ≥ 8.54×10^9/μL. Followed by IL-8 with an AUC=0.954, a sensitivity of 90.0%, and a specificity of 92.0% at a cutoff value ≥44.0. Neutrophil with AUC = 0.912, with a sensitivity of 93.3% and a specificity of 76.0% at a cutoff value ≥57.0%. In contrast, zinc and lymphocyte levels were lower. In students with respiratory diseases compared to healthy students, the ROC curves for these two indicators are reversed. Zinc showed AUC= 0.967, with a sensitivity of 90.0% and a specificity of 96.0% at cutoff value ≤35.5 μmol/L, while the lymphocyte with AUC= 0.876, with a sensitivity of 73.3% and a specificity of 88.0% at cutoff value ≤33.5%, as shown in Table (7) and Figure (1).

Table (7): ROC curve of indicators that distinguish between infected students and healthy students

Parameters	AUC	Sensitivity	Specificity	cutoff value
Zinc (µmol/L)	0.967*	90%	96%	≤35.5
WBC (×10^3/µL)	0.969	86.7%	100%	≥8.54
Lymphocytes %	0.876*	73.3%	88%	≤33.5
Neutrophil %	0.912	93.3%	76%	≥57.0
IL-8 (pg/mL)	0.954	90%	92%	≥44.0
IgA (ng/mL)	0.991	100%	96%	≥72.0

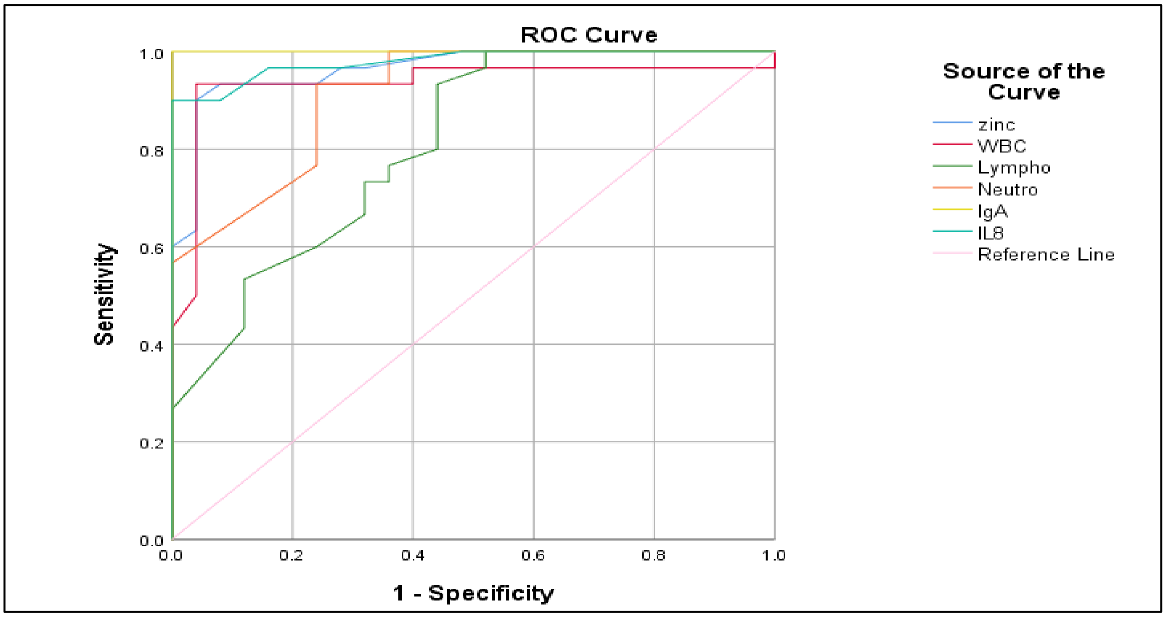

Fig (1): Shows the ROC curve that evaluates the diagnostic performance of physiological and immunological markers to distinguish students with respiratory diseases from healthy students

These results showed a high prevalence of respiratory disease among primary school students in rural areas, due to a combination of social and environmental factors that increase children's exposure to respiratory pathogens. Primary school students are among the most vulnerable to respiratory infections due to their immature immune systems and the close contact in classrooms, which facilitates the transmission of viral and bacterial infections [9, 10]. This study also revealed poor ventilation in classrooms leads to increased concentrations of airborne pollutants and germs, raising the likelihood of respiratory infections. Furthermore, rural environments are exposed to pollen and pesticides, which are respiratory irritants and can contribute to an increase in allergies, asthma, and recurrent respiratory infections among children [5]. These findings are consistent with many studies indicating that exposure to dust, poor ventilation, overcrowded classrooms, and environmental pollution are among the most significant risk factors associated with the increased prevalence of respiratory diseases among children in rural areas compared to urban areas [9, 14]. These results indicated that upper respiratory tract infections were the most common respiratory disease among primary school students, followed by tonsillitis, then bronchitis, while asthma was the least common [15]. Upper respiratory tract infections are the most common infectious disease because they are often associated with viral infections such as rhinovirus, adenovirus, and respiratory syncytial virus (RSV) [16]. These viruses are easily transmitted through respiratory droplets or contact with contaminated surfaces, which is exacerbated in crowded classrooms, especially with poor ventilation [3, 14]. Tonsillitis is the second most common disease because the tonsils are the first line of defense against microbes entering through the mouth and nose and are therefore frequently exposed to inflammation due to viral or bacterial infections, especially Streptococcus pyogenes [17]. Furthermore, repeated upper respiratory tract infections increase the likelihood of tonsillitis, which explains its high prevalence among school students [2]. Bronchitis is frequent occurrence as a complication of upper respiratory tract infections or as a result of continuous exposure to environmental pollutants prevalent in rural areas [18]. While these factors are common, bronchitis requires the infection to reach the lower airways, making it less frequent than upper respiratory tract infections. Asthma, on the other hand, was the least common respiratory disease among students, due to asthma being a chronic inflammatory disease largely dependent on genetic predisposition and allergic factors, rather than a contagious disease transmitted among students as is the case with respiratory tract infections [10, 14].

This study indicated that students with respiratory infections exhibited elevated body temperature, which is a clinical sign of infections. Fever results from the release of pro-inflammatory cytokines such as IL-1β, IL-6, and TNF-α by immune cells, which act on the thermoregulatory center in the hypothalamus, leading to an increase in body temperature [19]. Fever represents a defensive response that helps limit microbial proliferation and enhances the efficiency of immune cells [13, 20]. The increased heart rate in infected students can be explained by the elevated temperature, which increases metabolic rate and oxygen consumption, prompting the heart to beat faster to maintain tissue perfusion and meet the increased metabolic demands during infection [2, 21]. The results indicated an increase in WBC and neutrophils, reflecting activation of the innate immune system in response to infection, particularly in cases of bacterial infection or acute inflammation [22]. Neutrophils represent the first line of defense against pathogens, migrating rapidly to the site of inflammation, engulfing microorganisms, and secreting enzymes and oxidants to eliminate them. Therefore, an elevated neutrophil is an important indicator of the severity of the inflammatory response [23]. Conversely, the results showed a significant decrease in zinc in infected students, due to zinc being an essential element for immune regulation, lymphocyte proliferation, and cytokine production [24]. During acute infection, zinc is redistributed from the blood to the liver and damaged tissues as part of the acute phase response is a normal and leading to a decrease in its blood level that may not indicate true deficiency. Zinc deficiency also impairs immune cell function and the integrity of the respiratory tract mucous membranes, increasing students' susceptibility to infections and prolonging the duration of disease [25]. Infected students also experience lower levels of vitamin D, this vitamin is crucial for regulating both innate and adaptive immunity, as it stimulates the production of antimicrobial peptides and regulates the production of inflammatory cytokines. Therefore, low vitamin D levels can weaken immune defenses and increase the risk and severity of respiratory infections, a finding supported by numerous studies linking vitamin D deficiency to an increased incidence of respiratory infections in children [26]. Also, these results showed a decrease in RBC and Hb in infected students because of the chronic inflammation on iron metabolism and RBC formation, in addition to the accompanying malnutrition and deficiencies in iron, zinc, and certain vitamins essential for hematopoiesis [27]. Furthermore, inflammatory cytokines, especially IL-6, stimulate the production of hepcidin, which reduces iron absorption and limits its availability for hemoglobin formation. The decrease in hemoglobin contributes to a reduced oxygen-carrying capacity of the blood, which may exacerbate respiratory symptoms and delay patient recovery [28].

This study indicated that elevated IL-8 level is due to its crucial role in attracting neutrophils to the site of inflammation. The epithelial cells lining the respiratory tract, phagocytes, and other immune cells produce IL-8 in response to infection or inflammatory stimuli [29]. IL-8 acts as a chemotactic for neutrophils, leading to their accumulation in respiratory tissues and an increased inflammatory response. Thus, the elevated IL-8 levels in patients are consistent with the elevated neutrophil and WBC and indicate activation of innate immunity during respiratory infection [23, 30]. TNF-α levels were also elevated in patients compared to healthy students. TNF-α is a key cytokine associated with acute inflammation [31]. It is primarily produced by phagocytes and other immune cells in response to infection and contributes to the activation of inflammatory cells, increased vascular permeability, and the stimulation of other cytokine production. Therefore, its elevation reflects the severity of the inflammatory response in the respiratory tract and may be associated with the onset of clinical symptoms such as fever, fatigue, increased secretions, and congestion [29]. The elevated IgA in infected students is due to the crucial role of this immunoglobulin in protecting the respiratory tract mucosa or due to a compensatory immune response to microbes present on the respiratory tract mucosa. IgA is a key component of mucosal immunity, helping to prevent viruses and bacteria from adhering to epithelial cells and restricting pathogens before they reach the tissues [32]. The results also showed elevated IgE levels in infected students, which could be linked to an allergic component or an overactive immune response in some children, particularly in cases associated with asthma or allergic rhinitis. IgE is associated with the activation of mast cells and eosinophils, leading to the release of inflammatory mediators that may cause bronchoconstriction, increased mucus production, and the appearance of respiratory symptoms. Furthermore, continuous exposure to dust and air pollutants in rural areas may be a contributing factor to the allergic response and the elevated IgE levels [33]. Procalcitonin levels were elevated in infected students, which can be explained by its association with the systemic response to bacterial infection and inflammation. During infection, extra-thyroidal procalcitonin production can increase due to the influence of inflammatory cytokines and microbial toxins [34]. Therefore, its elevation in patients reflects an infection-related inflammatory response, particularly in bacterial causative agent [29].

This study has some limitations. First, the study included a limited number of schools, which may restrict the generalizability of results to all primary schools in the region. Second, some information regarding exposure to house smoking, dust, and other environmental factors was obtained through questionnaires not quantified using direct measurements of air pollutants. Third, Seasonal variation was not considered in the study. Respiratory disease may vary according to season because of differences in respiratory pathogens, temperature and environmental exposures, and other seasonal factors. Fourth, the prevalence of respiratory diseases may vary depending on the season, humidity, temperature, and dust levels; therefore, data collected over a specific period may not reflect the true annual prevalence. Therefore, future longitudinal studies should involve a larger number of schools.

4- CONCLUSION

These results confirm that respiratory diseases were a significant health problem among primary school students, and their prevalence is not only associated with pathogens but is also influenced by environmental, physiological, and immunological factors. These results showed elevated WBC, neutrophils, IL-8, TNF-α, IgA, IgE, and procalcitonin in infected students with respiratory diseases, reflecting an inflammatory and immune response associated with respiratory infections. The decreased levels of zinc, vitamin D, Hb, RBC, and lymphocyte percentage in infected students are attributed to inflammation or malnutrition.

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