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Table of Contents

Research Article

1- Assessment of Occupational Hazards in Healthcare Facilities in Benghazi, Libya-2024: A Cross-Sectional Study **7-18**
Amenh B. Yousif , Abdelsalam Abuzreda , Muhamad E. Aleawami , Ayoub A. Albrouni , Hamed K. Alamami , Atia G. Elmesmary

2- Assessment of Knowledge and Practice Regarding Hemodialysis Procedure among Nurses at Benghazi Hospital: Cross-Sectional Study **19-26**
Masiugah Al-Hadaad , Rania M. A. Madi, Bushra A. Al_Bayou, Hanin F. Al_Maqsabi ,and Mariam A. Al_Qabsi

3- Evaluated Daily Intake and Health Risk Assessment of Some Toxic Heavy Metals in Baby Powder for Various Brands Marketed in Benghazi, Libya **27-46**
Maysson M. Yaghi, Zainab A. Alhursh and Afia A. EL Shawish

4- Evaluation of The Association Between Depression and Diabetes Among The Diabetic Patients Treated in Benghazi Diabetic Clinic **47-57**
Heithum S. Baiu1, Sarah A. Al-Maghriby, Malak A. Al-Houty, Sarah M. Al-Farjany , Duaa M. Bala , Maryam Y. Al-Sultany

5- Cross-Sectional Analysis of Carcinogenic Chemical Exposure in Healthcare Facilities: A Case Study from Benghazi **58-66**
Fawzeia H. Elmhalli and Asma B. Elshebani

6- Actemra Therapy and Survival Outcomes in Critically Ill COVID-19 Patients: A Retrospective Analysis **67-74**
Monier. Mohammed, Aimen M. Khalifa, Ghada A. S. Abbas, Guma M.K. Abdeldaim

7-Evaluating the Use of Internet of Things IoT Technologies in Chronic Diseases From the Perspective of Healthcare Providers **75-82**
Hana Slaeh, Anfal wanes , Astberq Salem Hussein Alghmari and Thekra Abdullah.

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Research Article

Assessment of Occupational Hazards in Healthcare Facilities in Benghazi, Libya-2024: A Cross-Sectional Study

Amenh B. Yousif [1*], Abdelsalam Abuzreda [2], Muhamad E. Aleawami [3], Ayoub A. Albrouni [3], Hamed K. Alamami [3] and Atia G. Elmesmary [3]

[1]. Department of Family and Community Medicine, Faculty of Medicine, University of Benghazi, Libya.
[2]. Postdoctoral Research Fellow, Senior Advisor, Department of Health, Safety and Environmental (HSE), Arabian Gulf Oil Company (AGOCO), The Higher Institute of Engineering Techniques- Benghazi, Libya.
[3]. The Higher Institute of Engineering Techniques- Benghazi, Libya.

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ABSTRACT

Healthcare workers are constantly exposed to a variety of occupational hazards, including biological, chemical, and physical hazards, which can compromise their health and safety. Understanding the extent of these hazards is crucial for improving working conditions and strengthening preventive measures within healthcare facilities. A cross-sectional study was conducted to evaluate occupational risk exposures and associated health outcomes among 253 healthcare workers (HCWs) from five healthcare facilities in Benghazi, Libya, over four months. Data were collected via structured questionnaires and analyzed using bivariate and multivariate methods, with statistical significance set at $p < 0.05$. Findings revealed a high prevalence of psychological distress (62.8%), musculoskeletal disorders (61.3%), and biological exposures (55.7%), alongside a significant gap between risk awareness (73.1%) and formal training (46.6%). Multivariate analysis identified a lack of safety training as a significant independent predictor for multiple adverse outcomes: musculoskeletal disorders (a OR=1.85), work absenteeism (a OR=2.18), and accidental exposure to biological materials (a OR=2.85). Work absenteeism was also associated with psychological distress (a OR=3.05), and accidental biological exposure was strongly linked to inconsistent glove use (a OR=4.25). The results underscore the urgent need for ergonomic interventions, mental health support, and, most critically, comprehensive safety training to protect healthcare workers in Benghazi.

*Corresponding author
Email address: amenh.yousif@uob.edu.ly

1. Introduction

Healthcare workers (HCWs) are the cornerstone of effective health systems. The term "health workers" encompasses all individuals involved in activities aimed at enhancing health. Regardless of funding, no health system can function effectively or achieve its goals without an adequate, skilled, and motivated health workforce. (1)

Healthcare workers face numerous occupational risks that can affect their health, ranging from ergonomic and biological to physical, chemical, and psychosocial. Increased levels of stress at the workplace lead to adverse mental health outcomes, including anxiety and depression, among healthcare workers. Consequently, recognizing these hazards and implementing targeted prevention strategies is essential for protecting the health workforce. (2,3)

Healthcare facilities face various problems in maintaining an ideal workplace environment. One of these difficulties is the biological hazard, particularly pest infestations. These infestations, which spread pathogens and contaminate critical areas, become more likely with factors such as high staff mobility, the introduction of external objects, and inadequate waste management and sanitation practices. (4)

Globally, healthcare workers constitute approximately 12% of the working population. Healthcare workers operate in one of the most dangerous occupational environments. Beyond typical workplace exposures, they encounter numerous hazards during their duties. Reports indicate that the annual prevalence of back pain among healthcare workers is 77%, which is higher than in other occupational groups. Ergonomic-related injuries, in particular, represent a significant health risk and are the most common type of occupational injury within healthcare services. Illness among healthcare workers has a negative effect on healthcare services. Understanding the risk factors related to occupational hazards in this field is essential for developing effective protective strategies and interventions. (5)

Despite the critical role of HCWs, there is a lack of recent, comprehensive data on occupational hazards within the Libyan healthcare system, particularly in the context of Benghazi. Therefore, this study aims to provide an updated and comprehensive assessment of occupational hazards among HCWs in Benghazi, identify risk factors associated with health outcomes, and guide the strategies for workplace safety improvement.

Aim and objectives

Aim: To evaluate occupational hazards among healthcare workers in healthcare facilities in Benghazi, Libya.

Objectives

1. To identify the occupational risks faced by healthcare providers.
2. To assess the associations between occupational exposures and health outcomes.
3. To determine the specific occupational factors that significantly predict poor health outcomes and work absenteeism among healthcare workers.
4. To formulate evidence-based recommendations for enhancing occupational safety in Libyan healthcare facilities.

2. Methodology

2.1. Study Design and Setting

A cross-sectional study was conducted over four months, from September to December 2024, in five major public healthcare facilities in Benghazi, Libya: Diabetes and Treatment Center, Ibn Zuhur Center, Al-Hawari General Hospital Outpatient Clinic, Al-Sabri Center, and Chest Hospital Outpatient Clinic.

2.2. Study Population and Eligibility Criteria

The study population consisted of healthcare workers (HCWs) directly engaged in patient care, including physicians, nurses, laboratory technicians, and pharmacists. Eligibility required current employment in a healthcare role, presence at the facility during data collection, and provision of verbal informed consent. Individuals were excluded if they were non-clinical staff or employed on temporary or short-term contracts.

2.3. Sample Size Calculation and Sampling Procedure

The minimum required sample size was calculated using the single population proportion formula for cross-sectional studies. Based on previous literature indicates a 20% prevalence of occupational hazards in healthcare settings. (6,7) The calculation used a 95% confidence level (Z = 1.96) and a 5% margin of error (d = 0.05), as shown below:

$$n = (Z^2 \times p \times (1-p)) / d^2 = (1.96^2 \times 0.20 \times 0.80) / 0.05^2 = 246$$

A purposive sampling technique was employed. This method was necessary because a complete list of all healthcare workers across the five facilities was unavailable, making random sampling unfeasible. Recruitment was conducted in person during working hours. All eligible healthcare workers present in clinical and diagnostic areas, such as outpatient clinics, laboratories, and pharmacies, were invited to take part. This approach ensured the inclusion of the study's target population: workers directly engaged in patient care and likely to face occupational hazards. A total of 280 eligible healthcare workers were invited to participate. Of these, 253 provided complete responses and were successfully enrolled, yielding a final response rate of 90.4%. Non-participation was primarily due to a lack of time during the clinic hours. The final sample exceeded the calculated minimum requirement.

2.4. Data Collection Instrument: Questionnaire Development

A structured questionnaire was developed to assess occupational hazards, health outcomes, and safety practices. Its design was informed by a literature review and aligned with the framework from A Guide to the Collection of Occupational Data for Health (National Institute for Occupational Safety and Health, 2021). [8] Core domains were adapted from validated instruments, including the World Health Organization Health and Work Performance Questionnaire (Kessler et al., 2003). [9]

2.5. Questionnaire Adaptation, Translation, and Validation

The English-language questionnaire framework was first adapted for the Libyan healthcare context by modifying examples of hazards and protocols to reflect local clinical environments. The adapted version underwent forward translation into Arabic by two independent bilingual translators. A reconciled Arabic version was created and then back-translated into English to verify conceptual accuracy, with any discrepancies resolved by a panel of investigators. Content validity was assessed by an expert in occupational health and epidemiology, followed by a pilot test with 20 healthcare workers to evaluate comprehension and flow. Minor wording adjustments were made based on feedback. The internal consistency of multi-item scales was confirmed via Cronbach's alpha, with coefficients ranging from 0.86 to 0.94, indicating good reliability.

The final questionnaire comprises four sections:

(A) Sociodemographic characteristics.

(B) Occupational hazard exposure.

(C) Health outcomes and work status.

(D) Safety practices and awareness.

2.6. Statistical Analysis

Data were analyzed using SPSS software, version 25. Descriptive Statistics: Presented as numbers and percentages.

Inferential Statistics: Chi-squared tests were used to assess associations, with $p < 0.05$ considered significant. For multivariate analysis, all exposure variables significant at the bivariate level ($p < 0.05$) were entered into a logistic regression model adjusted for the potential confounders of age, gender, and years of experience.

2.7. Ethical Considerations

The study received ethical approval from the Ethics Committee Board of the Higher Institute of Engineering Techniques, Benghazi (Ref: 2024-03-015). Administrative approval was obtained from all participating facilities. Verbal informed consent was obtained from all participants after explaining the study aims. Data were anonymized, and participants were assured of voluntary participation and confidentiality.

3. Result

3.1. Sociodemographic characteristics of participants

The sample consisted of 253 healthcare workers.

Table 1 demonstrates that the distribution of participants across the five healthcare centers was as follows: Al-Sadriya OPD (35.6%), Al-Sabri center (27.3%), Benghazi diabetes center (17.4%), Al-Hawari OPD (11.9%), and Ibn Zhur center (7.9%).

Table 2 shows the distribution of participants by years of experience as follows: 11-15 years (39.1%), 5 years or less (19.0%), 6-10 years (16.6%), and 16-20 years (7.9%). Additionally, 21-25 years accounts for 9.1%, while more than 25 years represents 8.3%.

Table 1: Distribution of the study group according to the health care facilities

Health care center	**N**	**%**
Benghazi diabetes center	44	17.3
Ibn zuhur center	20	7.9
Al-Hawari OPD	30	11.9
Al-Sabri center	69	27.3
Al-Sadriya OPD	90	35.6
Total	253	100

Table 2: Distribution of the study group according to years of experience

Years of experience	**N**	**%**
≤ 5 years	48	19
6 to 10 years	42	16.6
11 to 15 years	99	39.1
16 to 20 years	20	7.9
21 to 25 years	23	9.1
> 25 years	21	8.3
Total	253	100

As shown in Table 3, the majority of participants were female (75.5%) and of Libyan nationality (96.4%). The largest proportion of the sample was aged between 26 and 45 years (68.8%). Most participants were married (59.3%), and their educational attainment was a Bachelor's degree (40.7%).

3.2 Health conditions and work statuses among participants

Table 4 shows the distribution of the participants according to their health conditions and work statuses. The results indicate several key health trends among the healthcare workers, including a high prevalence of musculoskeletal problems, with 61.3% of healthcare workers having work-related back or joint pain and over a third reporting injuries from lifting or repetitive tasks (33.6%). Psychological well-being was also a significant concern, as 62.8% of participants experienced work-related stress, anxiety, or burnout. Furthermore, a high proportion (67.2%) had taken sick leave due to medical illness. Reported exposures and related symptoms included skin rashes from chemical exposure (38.0%), work-related breathing difficulties (19.4%), and perceived hearing damage from noise (20.6%). Notably, only about half of the participants underwent periodic health check-ups (49.8%).

Table 3: Distribution of the study group according to sociodemographic profile

Sociodemographic profile		
Age group	**No.**	**%**
≤ 25 years	12	4.7
26 - 35 years	82	32.4
36 - 45 years	92	36.4
46 - 55 years	60	23.7
>55 years	7	2.8
Gender		
Male	62	24.5
Female	191	75.5
Marital status		
Single	86	34
Married	150	59.3
Divorced	7	2.7
Widowed	10	4.0
Educational level		
Secondary School	19	7.5
Bachelor's Degree	103	40.7
Intermediate Diploma	50	19.7
Higher Diploma	72	28.5
Master degree	9	3.6
Nationality		
Libyan	244	96.4
Others	9	3.6

3.3. Occupational safety awareness, training, and practices

Table 5 indicates that 73% of healthcare workers were aware of health risks; however, fewer than half had received adequate training (46.6%). Comprehensive adherence to using a complete set of personal protective equipment was limited to less than half of the sample (45.8%). Familiar with emergency protocols (47.4%). Additionally, only about half knew the procedures for injury reporting, and a small proportion (17%) reported experiencing a recent safety incident.

3.4. Occupational hazard exposures

The distribution of occupational hazard exposures is presented in Table 6. The data reveal that exposure to physical hazards was common, with over half of participants reporting exposure to noise (55.3%) and inadequate lighting (53.0%), and nearly half were exposed to extreme temperatures (49.8%), and 30.0% to X-rays or radiation.

For mechanical hazards, patient handling was the most prevalent exposure (65.2%), followed by lifting heavy objects or repetitive movements (41.9%). Exposure to chemical

Table 4: Distribution of the study group according to health conditions

	Questions regarding health conditions and work statuses.	Yes (%)	No (%)
1	Did you undergo a medical examination before starting work?	58.5	41.5
2	Do you undergo periodic check-ups/examinations?	49.8	50.2
3	Have you been absent from work due to medical illnesses?	67.2	32.8
4	Do you suffer from any lung problems?	7.9	92.1
5	Do you experience breathing difficulties that may be related to the work?	19.4	80.6
6	Have you been diagnosed with any occupational lung diseases, such as Silicosis or Asbestosis?	3.2	96.8
7	Do you have symptoms, such as wheezing or shortness of breath, during work?	12.3	87.7
8	Do you suffer from back pain or joint pain due to the physical demands of your job?	61.3	38.7
9	Do you have any injuries from lifting heavy objects or repetitive movements at work?	33.6	66.4
10	Have you developed a skin rash or irritation due to exposure to chemicals in your workplace?	38.0	62.0
11	Do you have any exposure to toxins or solvents at work?	10.7	89.3
12	Do you think the noise at work has affected your hearing?	20.6	79.4
13	Have you ever been stuck by a needle or splashed with bodily fluids at work?	14.6	85.4
14	Do you experience high levels of work-related stress, anxiety, or symptoms of burnout?	62.8	37.2

Table 5: Distribution of the study group based on awareness of occupational risk

	Questions regarding awareness of occupational risks	Yes (%)	No (%)
1	Are you aware of the potential health hazards associated with the type of work you do?	73.1	26.9
2	Have you received any training or education regarding occupational health and safety in your workplace?	46.6	53.4
3	Are you aware of the common occupational diseases and injuries that can arise from the tasks and exposures in your job?	77.1	22.9
4	Are you aware of the preventive measures to minimize occupational risk?	77.1	22.9
5	Have you been informed of the correct reporting procedures if you suspect an occupational disease or injury related to your job?	52.6	47.4
6	Do you regularly use protective equipment at your workplace?	45.8	54.2
7	Have you had any accidents or near-miss incidents related to safety in the past year?	17.0	83.0
8	Are you aware of the emergency evacuation procedures?	47.4	52.6
9	Are safety and warning signs clear and well-maintained?	54.5	45.5
10	Are there sufficient engineering controls (e.g., ventilation, safety devices) in the workplace?	56.5	43.5

Table 6: Distribution of the study group according to exposure to occupational hazards

Exposure to occupational hazards	Yes (%)	No (%)
Exposure to Physical hazards	**Yes (%)**	**No (%)**
Noise	55.3	44.7
Inadequate lighting	53.0	47.0
Extreme temperatures	49.8	50.2
Exposure to X-rays or radiation	30.0	70.0
Exposure to Mechanical hazards	**Yes (%)**	**No (%)**
Lifting heavy objects or repetitive movements	41.9	58.1
Patient Handling	65.2	34.8
Exposure to Chemical hazards	**Yes (%)**	**No (%)**
Disinfectants and detergents	47.4	52.6
Medications and hazardous materials	35.6	64.4
Laboratory chemicals	33.2	66.8
Exposure to Biological hazards	**Yes (%)**	**No (%)**
Blood and body fluids	55.7	44.3
Infectious patients or samples	54.5	45.5
Sharps (needles, surgical blades, etc.)	14.6	85.4
Contaminated medical equipment	50.2	49.8

hazards was also reported, particularly to disinfectants and detergents (47.4%), medications and hazardous materials (35.6%), and laboratory chemicals (33.2%). Biological hazard exposure was widespread, with over half of the participants exposed to blood and body fluids (55.7%) and infectious patients or samples (54.5%), and half of the workers exposed to contaminated medical equipment (50.2%) and sharps injury reported in (14.6%).

3.5. Utilization of personal protective equipment (PPE)

Daily use patterns, detailed in Table 7, reveal that gloves were the most routinely used protective item (70.0%), while masks were used by only 49.8% of participants. Utilization rates for other essential equipment were substantially lower: goggles (23.7%), head covers (22.9%), and safety shoes (23.3%)

3.6. Bivariate Analysis: Associations between exposures and outcomes

The results of the bivariate analysis, presented in Table 8, revealed several significant associations between occupational exposures and health outcomes. Musculoskeletal disorders (MSDs) showed strong associations with patient handling, repetitive movements, and a lack of safety training (all p=0.001). A lack of safety training was a common risk factor, also showing significant associations with work absenteeism and accidental exposure to biological materials (both p=0.001). Finally, inconsistent glove use was strongly associated with accidental exposure to biological materials (p=0.001).

3.7. Multivariate Analysis: Independent predictors of adverse outcomes

The results of the multivariate logistic regression analysis, presented in Table 9, confirm that several occupational exposures were significant independent predictors of adverse health outcomes. For musculoskeletal disorders (MSDs), both patient handling (aOR=4.12, 95% CI 2.38-7.14, p<0.001) and

repetitive movements (aOR=3.25, 95% CI 1.89-5.58, p<0.001) were strong predictors, while a lack of training was also independently associated (aOR=1.85, 95% CI 1.08-3.16, p=0.025). Work absenteeism was significantly associated with psychological distress (aOR=3.05, 95% CI 1.82-5.10, p<0.001) and a lack of training (aOR=2.18, 95% CI 1.30-3.65, p=0.003). Finally, accidental exposure to biological materials was most strongly predicted by inconsistent glove use (aOR=4.25, 95% CI 2.31-7.81, p<0.001), followed by a lack of training (aOR=2.85, 95% CI 1.52-5.34, p<0.001). Notably, a lack of training emerged as a consistent independent risk factor across all three adverse outcomes, even after controlling for other variables in the model.

Table 7: Distribution of participants according to use of protective equipment

Utilization of personal protective equipment	Yes (%)	No (%)
Gloves	70.0	30.0
Goggles / Protective Glasses	23.7	76.3
Mask	49.8	50.2
Head Cover	22.9	77.1
Safety Shoes	23.3	76.7

4. Discussion

This study assessed occupational hazards and associated health outcomes among healthcare workers (HCWs) in selected centers in Benghazi. The findings reveal a multifactorial risk environment that is alarmingly prevalent yet critically under-managed. The data indicate that HCWs operate under sustained exposure to a confluence of physical, ergonomic, chemical, and biological hazards, compounded by significant psychosocial strain.

4.1. Patterns of hazard exposure

Our results demonstrate that occupational exposure is routine rather than exceptional. The high prevalence of physical hazards, such as noise (55.3%) and inadequate lighting (53.0%), points to fundamental infrastructural deficits. These findings are strongly correlated with reports from similar regional settings. A study among HCWs in Tanta University Hospitals, Egypt, found that while awareness of physical hazards was generally high, adherence to safety protocols was inconsistent, a disconnect attributed to inadequate resources and enforcement. [10] This pattern is further reinforced by research in government hospitals in Saudi Arabia, which noted widespread physical hazards resulting from suboptimal work environments and equipment. [11]

Similarly, the high rate of mechanical and ergonomic hazards, with patient handling (65.2%) being the most common, mirrors findings from Lahore, Pakistan, where musculoskeletal disorders from patient lifting were highly prevalent. [12] This ergonomic burden is a global concern, as confirmed by a systematic review from Taiwan that identified patient transfer as a primary risk factor for injuries among HCWs. [13]

The chemical and biological hazard profile is equally concerning. Exposure to disinfectants (47.4%) and laboratory chemicals (33.2%) indicates routine contact with harmful substances. Most critically, the widespread biological exposure to blood and body fluids (55.7%) and infectious patients (54.5%) represents a direct threat of pathogen transmission. This prevalence is not unique to our setting. Studies from Nigeria have documented similarly high rates of biological risks, particularly sharps injuries. [14] Furthermore, a broader scoping review across Low- and Middle-Income Countries (LMICs) confirms that these dangers are widespread, and the measures in place to reduce them are frequently insufficient. [15] The sharps injury rate in our study was 14.6%, while lower than some reports, but remains a significant and preventable risk, echoing concerns raised in studies from Pakistan and Nigeria. [12,14]

4.2. The awareness-practice gap

Perhaps the most critical finding is the stark gap between recognized risk and consistent protective behavior, epitomized by the low rate of consistent PPE use (45.8%). This reveals a failure not of individual knowledge but of systemic support. Our data on inadequate training programs provide a clear explanatory factor, a finding consistent with a previous local assessment in a Benghazi pediatric hospital. [16]

Table 8: Association between occupational exposures and health outcomes

Health Outcome	Occupational Exposure	p-value
Musculoskeletal disorders (MSDs)	Patient handling	0.001
	Lack of safety training	0.001
	Repetitive movements	0.001
Work absenteeism	Lack of safety training	0.001
	Psychological distress	0.001
Accidental exposure to biological materials	Inconsistent glove use	0.001
	Lack of safety training	0.001

Table 9: Multivariate analysis of factors associated with health outcomes in healthcare workers

Outcome & Predictors	(aOR)	95% CI	P value
Musculoskeletal disorders			
Patient handling	4.12	2.38 -7.14	0.001
Repetitive movements	3.25	1.89 -5.58	0.001
Lack of training	1.85	1.08 -3.16	0.025
Work absenteeism			
Psychological distress	3.05	1.82 -5.10	0.001
Lack of training	2.18	1.30 -3.65	0.003
Accidental exposure to biological materials			
Inconsistent glove use	4.25	2.31 -7.81	0.001
Lack of training	2.85	1.52 -5.34	0.001

This knowledge practice gap is a well-documented phenomenon, as demonstrated in the Egyptian context, where high awareness did not ensure safe practice. [10]

A study from a Nigerian tertiary facility explicitly found that while HCWs possessed high knowledge of hazards, their safety practices were inconsistent, primarily due to a lack of equipment and training. [17] Research from Uganda further identified the lack of PPE as a key predictor of hazard exposure. [18]

The stark difference from the 80.6% compliance rate reported in Saudi Arabia. [11] is telling. It suggests that our setting faces a significant gap in the institutional support that enables safe practices. This likely points to a lack of prioritized funding, inconsistent availability of equipment, and weak enforcement of safety rules. When the right equipment is guaranteed and safety is deeply woven into the daily culture, using protection becomes a natural reflex for healthcare workers. Our environment, however, like many Low- and Middle-Income Countries [15], seems

to lack this foundational support. Consequently, poor PPE use is not a matter of personal failure, but a clear sign of a system that is failing its workers.

4.3. Work absenteeism

The significant association found between psychological distress and work absenteeism highlights a cascading consequence of the hazardous work environment. Burnout and stress among healthcare staff aren't personal weaknesses; they are warning signs of an overburdened system. This emotional strain doesn't just hurt individuals; it wears down the team's ability to function safely and effectively. Our finding aligns with international evidence. Research in Australia established a strong link between psychological distress, work overload, and increased absenteeism. [19] Similarly, a Romanian study demonstrated how chronic work stress transforms into burnout, directly resulting in higher sick leave rates. [20] The contributing factors are evident in our context and others: the constant risk of exposure, understaffing, and high workload. Studies from Uganda and the Philippines explicitly link job pressures and overtime to psychosocial distress. [18,21] When HCWs are absent due to stress-related illness, the burden on remaining staff intensifies, creating a vicious cycle that exacerbates both psychosocial and physical risks.

4.4. Intervention for safety improvement

The data presented, contextualized within the global body of literature, point toward specific, interdependent domains for intervention to mitigate the documented risks. A shift from isolated measures to an integrated, system-wide strategy is imperative. Evidence consistently underscores the critical role of comprehensive and continuous training. As demonstrated in a study from Ghana, targeted educational programs can directly bridge the gap between hazard awareness and safe practice. [22] This result is parallel with existing evidence from Egypt and Nigeria, underscoring the urgent need to bridge identified training deficiencies. [10,17] The persistent reporting of inadequate PPE access as a fundamental barrier, from Pakistan to Nigeria, establishes its provision as an essential foundation for safety. This mandates that healthcare administrations prioritize and guarantee a consistent, reliable supply chain. [12,14] A systematic review from Taiwan conceptualizes this effectively within the hierarchy of controls, advocating for a layered defense combining engineering, administrative, and PPE-based strategies. [13] Keeping healthcare workers safe means changing how the system works. It starts with making sure they always have protective equipment, get hands-on training, and work under clear safety policies. But the real key to lasting safety is tackling the root causes of exhaustion and stress. The evidence shows there's no way around it: we must invest in hiring more staff and ensuring their workloads are actually manageable. This is the essential foundation for a strong, healthy team. [20-22]

4.5Limitations

The interpretation of these findings must consider several limitations. First, the cross-sectional design establishes associations but cannot infer causality between exposures and outcomes. Second, the use of purposive sampling within selected Benghazi facilities may limit the generalizability of prevalence estimates to all healthcare workers in Libya. Third, data were based on self-reports, which are susceptible to recall bias and social desirability bias. Despite these limitations, this study provides timely, evidence-based insights into a severe occupational health crisis and identifies clear, actionable targets for intervention.

5. Conclusion

Healthcare workers in Benghazi deal with significant occupational hazards, including physical, chemical, mechanical, psychological, and biological risks. key modifiable risk factors for adverse health outcomes among healthcare workers: A pervasive lack of safety training emerged as a major independent risk factor for multiple adverse health outcomes, significantly associated with musculoskeletal disorders, work absenteeism, and accidental biological exposure. Furthermore, specific exposures were strongly linked to specific harms: patient handling and repetitive movement to musculoskeletal disorders, psychological distress to absenteeism, and inconsistent glove use to accidental biological

exposure.

This study's key strengths lie in generating new evidence from the context of Benghazi, derived from five local healthcare facilities, and in its analytical application of multivariate regression to pinpoint specific and modifiable risk factors. These combined methodological and analytical contributions establish a robust, evidence-based foundation for designing targeted occupational health interventions.

Recommendation

1. Ensure Immediate Access to personal protective equipment & Training: Guarantee a reliable supply of personal protective equipment, especially gloves, and implement mandatory, practical safety training for all staff to close the critical knowledge-practice gap.
2. Conduct a Workload & Staffing Assessment: Systematically review and adjust staffing levels and shift patterns to create sustainable workloads and directly reduce the primary driver of work overload and burnout.
3. Implement Physical and Mental Health Programs: Create a prevention program for musculoskeletal injuries and provide confidential psychological support services to combat stress and burnout.
4. Develop a leadership-driven safety culture: Make safety a fundamental part of work by supporting leaders, holding everyone accountable, and rewarding safe behaviors, so that safety becomes a daily habit for all.

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Conflict of Interest

The authors declare that there are no conflicts of interest.

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Research Article

Assessment of Knowledge and Practice Regarding Hemodialysis Procedure among Nurses at Benghazi Hospital: Cross-Sectional Study

Masiugah Al-Hadaad*, Rania M. A. Madi, Bushra A. Al_Bayou**,** Hanin F. Al_Maqsabi ,and Mariam A. Al_Qabsi

Department of Health services administration, University of Benghazi, Libya

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ABSTRACT

Kidney Services Center-Benghazi in Libya is facing a significant healthcare challenge due to the rising number of kidney failure cases. Nurses play a pivotal role in providing excellent care for these patients. The aim of the study is to evaluate nurses' knowledge and practice of patient management of chronic kidney disease (CKD) at the Kidney Services Center-Benghazi. A cross-sectional descriptive study was carried out among nurses at the Kidney Services Center in Benghazi. A purposive sampling method was employed, involving 85 nurses who worked specifically in the hemodialysis unit, and a response rate of 87.1%. The study was conducted between 5 January and 23 February 2025, utilizing questionnaires to gather data. The reliability analysis utilized Cronbach's $\alpha = 0.647$. Data analysis involved descriptive and inferential statistics. The majority of nurses were consistently assessed for fluid retention, blood pressure, lab values, and complications. 74% educated patients about CKD progression, 66% emphasized medication adherence, and 60% provided information on dietary restrictions and fluid balance. 51% of nurses collaborated with other professionals, and 64% regularly assessed psychological issues. Treatment coordination and psychosocial support were also high, with 75.7% documenting patient care correctly. Dialysis monitoring was also a priority. The study concluded that nurses have good knowledge and clinical practice in managing CKD, including patient education, medication administration, and clinical documentation. However, gaps in interdisciplinary collaboration and psychosocial assessment affect holistic care.

* Corresponding author.
E-mail address: masiugha.alhaddad@uob.edu.ly

1. Introduction

Chronic kidney disease (CKD) is a major health concern worldwide, affecting both developing and developed countries [1]. In 2017, CKD ranked as the 12th leading cause of mortality globally [2]. Patients with impaired kidney function require dialysis, and nurses play a crucial role in ensuring these patients receive proper treatment [3]. The Centers for Disease Control and Prevention (CDC) has developed training programs to promote safe dialysis practices, covering hygiene, access care, injection safety, personal protective equipment (PPE), and station disinfection [4][5].

Libya faces significant healthcare challenges due to a rising incidence of kidney failure, with an estimated 5,500 people affected and approximately 600 new cases annually [6]. Nurses are essential in the safe management of hemodialysis (HD) patients, particularly in infection prevention and control (IPC) procedures. However, non-compliance with these practices by some nurses highlights the need for ongoing training. Nurse practitioners also serve as the first line of defense in primary care, where their expertise in CKD can help slow or prevent disease progression to kidney failure [7][8].

Hemodialysis services in Libya encounter considerable systemic and clinical challenges that negatively impact patient outcomes and healthcare quality. A prospective multicenter study involving 38 dialysis centers in Libya reported a concerning one-year mortality rate of 21.2%, with cardiovascular disease and infections accounting for 31% and 16% of deaths, respectively, indicating issues with clinical monitoring and staffing levels [9]. National reviews also reveal a significant staffing deficit, with an average nurse-to-patient ratio of 1:3.7, alongside non-compliance with established dialysis adequacy standards [10]. Infection control remains a critical issue, as approximately 34.9% of dialysis patients test positive for hepatitis B or C, suggesting inadequate infection control measures and the occurrence of nosocomial transmission within dialysis units [11]. Furthermore, routine management of dialysis patients in Libya reveals major deficiencies such as anemia, electrolyte imbalances, and poor mineral control. Studies in Benghazi identified these challenges, while a five-year cohort study in Tripoli reported a high 51.4% mortality rate among chronic hemodialysis patients, with diabetes and hypertension as leading comorbidities. These findings underscore the urgent need for systemic reforms including enhanced nurse training, stricter infection control, and increased government investment in dialysis infrastructure [12].

This study aims to evaluate the knowledge and practices of nurses at Benghazi Hospital regarding hemodialysis patient management. The objective is to identify strengths, weaknesses, and influencing factors to recommend targeted training programs that will improve patient care quality. The problem statement highlights that insufficient knowledge among nurses about chronic kidney disease management is associated with poor practices, resulting in adverse health outcomes for patients.

2. Methodology

2.1 Study design, setting, population and period

This was a cross-sectional analytical study to evaluate the knowledge and practices of nurses concerning chronic kidney disease (CKD) patient management between 5 January and 23 February 2025. This design was chosen to facilitate an analysis of the associations among nurses' demographic characteristics, their comprehension of CKD management, and their application of these practices. The study focused on registered nurses working in the haemodialysis units at Benghazi Kidney Hospital, recognizing their direct role in the care of dialysis patients. A prerequisite for participation is a minimum of six months' experience within a dialysis unit, intended to ensure a foundational understanding of

established procedures. Exclusions newly employed or recently hired staff and administrative personnel who do not engage in direct patient care. The study encompasses both male and female nurses across various work shifts to achieve a representative cross-section of the nursing workforce. The research will be carried out in designated referral hospital within Benghazi, Libya, which serve as treatment centre for patients diagnosed with chronic kidney disease. This institution may encompass specialized renal dialysis units as well as general medical wards where the management of CKD is a standard component of care. The intended participants for this research are registered nurses currently providing care within rental units, dialysis centre, or relevant internal medicine departments situated in the selected hospital in Benghazi.

2.2 Study sample

The study utilized a purposive sampling method to select participants from the nursing staff at Benghazi Kidney Hospital, specifically targeting the 85 nurses working in the haemodialysis unit due to their direct involvement in the procedures. The final sample size was influenced by nurse availability and willingness to participate during the data collection period. A total of 74 questionnaires were collected, with 11 nurses being on leave this time. Response rate was 87.1% All participants provided informed consent after being informed of the study's objectives. The recruited nurses represented a variety of ages, educational backgrounds, and experience levels, allowing for a broad analysis of knowledge and practice differences and aiding in the identification of strengths and areas for improvement in haemodialysis care nursing practices.

2.3 Inclusion and exclusion criteria

The inclusion criteria for participants were registered nurses working in haemodialysis

units who had spent at least six months of experience working in the dialysis unit departments and were willing to provide informed consent. Conversely, exclusion criteria for the study include nurses who are on leave during the data collection period, interns or student nurses, and nurses employed in departments not associated with CKD management.

Eligible nurses assessed for eligibility
(n = 85)
↓
Nurses who completed the questionnaire
(n = 74)
↓
Non-respondents / excluded
(n = 11)

Figure 1: Flow diagram of nurse participation in the study

Of the 85 eligible nurses, 74 completed the questionnaire, yielding a response rate of 87.1%.

2.4 Data collection instrument

Data were collected by using a structured, self-administered questionnaire. This questionnaire is organized into three distinct sections: Section A will collect demographic data such as age, gender, education level, and years of experience; Section B will assess knowledge related to CKD management through multiple-choice or true/false questions; and Section C will evaluate practice using Likert scale items to gauge routine patient management activities. The questionnaire will be adapted from previously validated tools identified in the literature and will undergo expert review to confirm its face and content validity [13]14][15]. A reliability test for the questionnaire was made, and the reliability of the questionnaire was [0.647], indicating a moderate but acceptable level of internal consistency for exploratory research, the questionnaire questions were designed from previous studies [16] [17]. To suit the environment and place of study.

2.5 Data Analysis

The study data were analysed by statistical

program for the Social Sciences (SPSS) version 23. Descriptive statistics (means, standard deviations, frequencies) will be used to summarize data. Inferential statistics

3 Results and discussion

3.1 Demographic characteristics

Table 1 shows the demographic variables that the study participants had (59%) of the participants were female, and (45%) of the participants had a bachelor's degree. Such a high level of qualification is likely contributing to the overall strong practice scores observed, where 93.2% of nurses demonstrated good practice.

Table 1: Demographic Characteristics of the Study Participants (n = 74)

Variable	Category	Frequency (n)	Percentage (%)
Sex	Male	30	41
	Female	44	59
Age (years)	Less than 25	12	16
	25–35	33	45
	36–45	26	35
	More than 45	3	4
Educational qualification	Diploma	12	16
	Bachelor	33	45
	Graduate studies	3	4
	Other	26	35
Years of experience	Less than 1 year	4	5
	1–5 years	30	41
	6–10 years	23	31
	More than 10 years	17	23
Special training course about hemodialysis	Yes	59	80
	No	15	20

This supports the argument by Thomas & Aggarwal that advanced education and clinical training are critical predictors of quality care in nephrology settings [18]. Most of the subjects (45%) were between 25–35 years old; this younger workforce may correlate with higher adaptability and openness to continuous professional development, as supported by Iacono et al. [19], who found that younger nurses tend to engage more actively in ongoing training. (41%) of the participants had experience ranging from (1-5 years), and (87%) of the participants had attended a special training course about hemodialysis procedure.

3.2 Knowledge regarding haemodialysis among study participants

Most participants adhered to essential dialysis monitoring protocols, with over 60% regularly evaluating laboratory results and monitoring blood pressure and fluid retention. These findings align with international studies, such as Alashek et al. (2019), which highlighted nurses in Libya effectively following standard procedures. Berenguer et al. (2019) found that healthcare professionals with specialized training in chronic kidney disease demonstrated better monitoring practices, emphasizing the importance of continuous training for improved dialysis care quality [20] [21] [22]. Most nurses regularly educated patients about CKD progression (74.3%) and medication adherence (66.2%). This emphasis reflects global standards for CKD management, which prioritize patient empowerment and knowledge as part of self-management strategies [23][24]. However, the variability seen in some practices, such as interdisciplinary collaboration (only 51.4% always), reveals gaps that could impact holistic patient care. while a small minority never or seldom perform these duties. With high "always" replies for guaranteeing appropriate medication usage (76.7%) and accurate recording (75.7%), the somewhat lower rates for nutritional and fluid education, however, point to the need for more regular practice in these areas as well as strong participant expertise in treatment coordination.

While the study shows a commendable level of clinical engagement, the presence of moderate scores (6.8%) and "sometimes" responses across multiple domains suggests the need for more standardized protocols and reinforced training in areas such as collaboration and psychosocial care. Investing in continuous professional education and team-

based care approaches could address these discrepancies and enhance consistency [25]. These findings underscore the multifaceted role of nurses in CKD care, beyond physical management, aligning with findings from Berenguer et al. [20], who advocate for integrated psychosocial support in chronic illness care.

Female nurses (n = 44) demonstrated a higher mean total score (M = 66.52, SD = 5.55) compared with male nurses (n = 30; M = 64.00, SD = 6.68). The standard error of the mean was lower among female nurses, indicating less variability in their scores. Table 2 presents descriptive statistics only.

An independent samples *t*-test was conducted to examine differences in mean total scores between female and male nurses. The mean difference was 2.52 points (95% CI: −0.40 to 5.44). This difference was **not statistically significant**, t (72) = 1.77, p = 0.081. The effect size indicated a moderate effect (Cohen's d = 0.42). however, the current study identified no statistically significant difference in total scores between female and male nurses, despite a moderate effect size. This finding aligns with the research conducted by Elhaddad et al., which indicated no notable gender differences in nurses' knowledge and practices concerning CKD management within a Libyan healthcare context [16]. A cross-sectional study in Saudi Arabia by Alshahrani et al. indicated that nurses' clinical performance was not significantly affected by gender, implying that professional training and experience may be more critical than gender in influencing performance outcomes [26]

Table 4 summarizes the continuous variables, where age was coded into four categories with a mean of 2.28 (SD = 0.79), suggesting that participants were mainly in the mid-age groups. The mean total score was 65.5 (SD = 6.12), with scores ranging from 46 to 75, reflecting generally high knowledge levels among participants.

A one-way analysis of variance (ANOVA) was conducted to examine differences in total scores across educational levels. The results indicated no statistically significant difference between the groups, F (3, 70) = 0.197, p = 0.898. This suggests that educational level did not have a significant effect on total score among the study participants.
Figure 2 indicates that 95% of participants have good knowledge and practice, while 5% have a medium level. This indicates a high overall level of knowledge among the participants.

The study's findings in Benghazi contrast substantially with previous reports regarding Libya's overall healthcare system, which frequently highlighted higher infection rates and inadequate staffing [17]. The high performance of nurses in this study may suggest current improvements or targeted efforts in nurse education and practice; however, a national assessment is necessary. Unlike some global studies, this research found no instances of "poor practice," which could be due to strong institutional support, ongoing training, or potential self-assessment biases.

Table 2: Comparison of Mean Total Scores by Sex (n = 74)

Sex	N	Mean	Std. Deviation	Std. Error Mean
Male	30	64.0	6.68	1.22
Female	44	66.52	5.55	0.84

Table 3. Independent Samples Test

t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Cohen's d
-1.77	72	0.081	-2.52	1.43	-0.42

Table 4: Summary of Continuous Variables (n = 74)

Variable	N	Minimum	Maximum	Mean ± SD
Age (coded categories)	74	1	4	2.28 ± 0.79
Total Score	74	46	75	65.50 ± 6.12

Table 5: One-Way ANOVA Results for Total Score by Educational Level

Source	Sum of Squares	df	Mean Square	F (p-value)
Between Groups	22.819	3	7.606	0.197 (p = 0.898)
Within Groups	2707.681	70	38.681	
Total	2730.500	73		

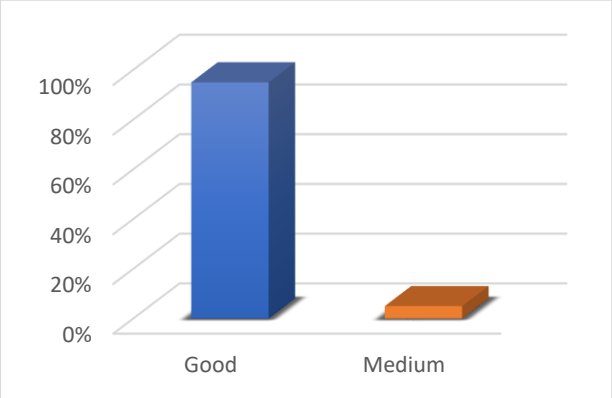


Figure 2: The percentage of knowledge and practice among the study participants (n = 74).

Table 6. Multiple Linear Regression Analysis of Factors Affecting Nursing Practice

Variable	B	SE	t	p-value
Constant	69.32	3.40	20.41	<0.001
Age (years)	3.52	1.54	2.29	0.025
Female (ref = Male)	-0.89	1.56	-0.57	0.570
Years of experience	-1.97	1.36	-1.45	0.151
Training (Yes)	-0.01	3.42	-0.00	0.997

Model statistics: $R^2 = 0.109$, Adjusted $R^2 = 0.057$, $F = 2.11$, $p = 0.089$, $n = 74$.

Multiple linear regression analysis showed that age was a statistically significant predictor of nursing practice scores ($p = 0.025$). Gender, years of haemodialysis experience, and prior haemodialysis training were not significantly associated with practice scores.

4. Conclusions

This study assessed the knowledge and practice of nurses in haemodialysis care in Benghazi, revealing that over 95% of participants demonstrated good adherence to monitoring procedures, patient education, and medication management. No nurses were found to have poor practice, indicating a strong commitment to care standards. While female nurses scored slightly higher than males, this difference was not statistically significant, nor was educational level linked to practice scores. Age emerged as the only significant predictor of nursing performance, suggesting that experience enhances skills in dialysis care. However, areas such as interdisciplinary collaboration and psychosocial support presented gaps which could negatively affect the delivery of holistic patient care, highlighting the need for ongoing standardization and improvement in non-technical aspects of practice.

While these findings are encouraging, especially when compared to previous studies in other countries like Iraq, Saudi Arabia, Nepal, and Egypt, there's still room for improvement. Specifically, collaboration among healthcare teams and providing psychological support to patients needs more focus. Building on these positive results, the aim should be to further enhance performance and spread these good practices throughout the system.

Recommendation

Based on the study findings, several recommendations are made:

Eenhance interdisciplinary collaboration among healthcare professionals to improve patient care.

Prioritize ongoing professional development that includes nutritional counselling and psychosocial support; standardize clinical and educational protocols to ensure consistent care.

Emphasize comprehensive management of chronic kidney disease (CKD) through patient-centred education and self-management; and conduct larger, multi-centre studies for validation and to reduce self-reporting bias.

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Conflicts of Interest

No conflicts of interest.

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Research Article

Evaluated Daily Intake and Health Risk Assessment of Some Toxic Heavy Metals in Baby Powder for Various Brands Marketed in Benghazi, Libya

Maysson M. Yaghi [1*], Zainab A. Alhursh [2] and Afia A. EL Shawish [1]

[1] Department of Chemistry, Faculty of Science, University of Benghazi, Al-Abyar, Libya.
[2] Department of Cytotechnology, Faculty of Biomedical Science, University of Benghazi, Libya.

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ABSTRACT

Baby powder is a popular baby care product that is used to keep the baby's skin dry and prevent the development of dermatological conditions. Recently, there has been growing scientific interest about the presence of toxic heavy metals in baby powder that has led to concerns regarding its potential effects on human health and the environment. In this study, sixteen baby powder brands that are widely in demand at various pharmacies located in Benghazi were collected in November 2024. First, metals, including aluminium, cadmium, chromium, copper, lead, and nickel, were analyzed in the selected samples using atomic absorption spectrophotometry after a suitable digestion process, followed by the evaluation of health risks across the age groups for infants by the calculation of the chronic daily intake (CDI) that is measured in mg/kg/day from dermal absorption, target hazard quotient (THQ), hazard index (HI), and carcinogenic risk (CR). In regard to heavy metal toxicity, Al, Pb, Ni, Cu, Cr and Cd in all examined baby powders were above the permissible threshold established by the United States Food and Drug Administration (FDA). The findings indicate that periodic monitoring and quality control of baby powders is necessary to meet safety standards and protect infant health. Further, the result of non-carcinogenic and carcinogenic risk estimates was lower than the limits of safe risk (HQ and HI > 1 and cancer risk CR < 1×10^{-4}), suggesting no potential lifetime cancer risk.

* Corresponding author.
E-mail address: maysoon.yaghi@uob.edu.ly

1. Introduction

The widespread daily use of personal care products and cosmetics that may contain heavy metals as impurities in its ingredients such as lead, chromium, and cadmium represent a growing public health concern [1]. Cosmetic products are part of everyday personal care practices and encompass a broad spectrum of formulations, including skincare formulations, personal hygiene products, fragrances, and talcum powders. These products are routinely applied directly to the skin and face with the aim of enhancing or altering physical appearance, in consequence increasing the chance of repeated and prolonged human exposure to potentially toxic constituents. The presence of metals in cosmetics can be attributed to three possible sources: the primary ingredients themselves, color additives, or metal-coated equipment utilized during manufacturing [2].

According to the United States Food and Drug Administration (FDA), cosmetics are defined as products intended for external application to the human body for cleansing, beautifying, promoting attractiveness, or altering appearance, without affecting the structure or physiological functions of the body [3]. This broad definition requires the safety of all ingredients used in cosmetic products. The United States researchers identified approximately 10,500 industrial chemicals, that used to prepare cosmetic products, including pesticides, carcinogens, reproductive toxins, endocrine disruptors, surfactants, degreasers, and plasticizers [4]. Among these substances, toxic heavy metals such as lead, nickel, arsenic, chromium, cadmium, and mercury were detected in various cosmetic products, showing toxic effect on human health, even at low concentrations [5,6,7].

Exposure to heavy metals in cosmetics can vary depending on the product type and usage patterns. While some products, such as shampoos and toothpaste, are rinsed shortly after application, others including lipsticks, body lotion, and talcum powders are often applied over large surface areas and remain in contact with the skin for particular amount of time [8], which increase the potential for dermal absorption and may also facilitate inhalation or incidental ingestion. The primary route of exposure for heavy metals in cosmetic products is through dermal absorption, with ingestion and inhalation being the secondary routes. Consequently, long-term or intensive use of contaminated cosmetics may lead to cumulative exposure and pose significant risks to human health and the environment. [9]. The baby talcum powder is a cosmetic product that, commonly used for infants and children to prevent diaper rash and maintain skin dryness due to its moisture absorbing properties and its ability to reduce friction [9] where talc is the primary ingredient of baby powder and it is produced by finely grinding talc, an extremely soft mineral derived from magnesium rich rocks through multiple processing stages. Heavy metals are naturally occurring elements on the earth, which are constituents of groundwater or soil. Due to industrialization and an increase in living standards, several anthropogenic sources have made water and soil polluted, thus containing heavy metals. Through mining and processing of talc, the powder may become contaminated with heavy metals.

Infants represent a highly vulnerable population owing to the incomplete development of their immune and detoxification systems, making them more susceptible to toxic effects. Furthermore, talc products contaminated with heavy metals are believed to be associated with increased carcinogenic risks, as these metals can act as carcinogenic agents [10].

Most of the studies have investigated heavy metal contamination in cosmetic products, most have focused primarily on determining heavy metals concentrations rather than assessing associated health risks. For instance, Omenka and Adeyi (2016) analyzed levels of heavy metals in a variety of cosmetic and personal care products, the result showed that the content of cadmium, lead, and nickel were above the permissible limits in cosmetic products [11]. Similarly, studies in Libya, focused on examine heavy metals in cosmetic products. For example, Rahil et al. (2016) examined heavy metals concentration including Fe, Cu, Cr, Zn, Pb and Cd in 25 cosmetic samples marketed in Benghazi, based on their

study, the results demonstrated that the concentrations of Pb in one sample and Cd in twenty samples were above permissible limits in cosmetic products by certain companies [12]. Another, study in Tripoli (2023) analyzed selected cosmetics (including only three brands of baby talcum powder) was marketed in Tripoli, Libya, detected varying levels of heavy metals such as lead (Pb), arsenic (As), cadmium (Cd), and nickel (Ni). Base on their study that all samples possessed high amount of Pb prohibited by European regulation [13]. On the other hand, a few studies were focused primarily on determining heavy metals concentrations in baby powder, where in 2010 and 2016, the U.S.A. court found asbestos and heavy metals such as lead and cobalt in Johnson and Johnson baby powder and talc-based body powder, and ordered Johnson and Johnson to compensate for the danger of their products. [6]. In 2019, the U.S.A. Food and Drug Administration (FDA) found that Blyif-Kor powder and a line of Johnson's Baby Powder, manufactured in 2018, were contaminated with heavy metals such as arsenic, cadmium, chromium, and lead. However, the ingredient declaration label of the product only states "Talc", so the fenestration testing technology for monitoring the talcum mineral and heavy metal powder of cosmetics urgently needed to be established [7]. Atomic Absorption Spectroscopy (AAS) is used to analyze the heavy metals in baby powder products. The method is capable of measuring total recoverable amounts of heavy metals down to the parts per billion level. Quality and accuracy can be maintained by using standard method performance requirements for each heavy metal analysis. The limit of detection is calculated using low-level calibration standards and the instrument blank measurement, giving a value that can be associated with the specified lower calibration level of the method. [10,11,12].

Despite the plenty of studies about detection of heavy metals in cosmetic products in the Libyan, here is an absence of research addressing heavy metal contamination in baby powders or talcum powders within the Libyan scientific literature. Furthermore, there have been no efforts made investigate the health risks associated with toxic elements in baby powder across different infant age groups. Therefore, the present study aims to determine the heavy metals concentration (including aluminum, cadmium, chromium, copper, lead, and nickel) in baby powder using Atomic Absorption Spectroscopy (AAS). Also assess age-specific health risks among infants by estimating daily metal intake, evaluating non-carcinogenic risks associated with heavy metals, and assessing carcinogenic risks through the calculation of chronic daily intake (CDI, mg/kg/day) via dermal absorption, target hazard quotient (THQ), hazard index (HI), and cancer risk (CR) for commonly used baby powders in Benghazi. The findings obtained from the health risk assessment are subsequently assessed in relation to the standard reference thresholds prescribed by the United States Environmental Protection Agency (USEPA) [14]. Measured heavy metal concentrations are evaluated against permissible limits defined by the FDA.

2. Material and Methods

2.1 Reagent and Instrumentation:

BDH Chemicals Ltd, UK supplied chemicals and reagents (Alchohol) of analytical grade, from which all other ingredients were obtained. Concentrated Aqua Regia (composition of concentrate of conc.) HNO_3, along with conc. H_2O_2. The digestion of the samples was performed using conc. 97% HNO_3 with 35% H_2O_2 with the metal salts [$Pb(NO_3)_2$, $NiCl_2.6H_2O$ and $Cr(NO_3)_3$] being utilized as standards.

The prepared digests were analyzed using a GBC Scientific Equipment Ltd. - 932 Plus - Atomic Absorption Spectrometer. This advanced instrument offered accurate and reproducible results, effectively determining the metal ion concentrations in the samples.

2.2 Sample collection

In this study, a total of sixteen commonly used baby talc powders were collected from various pharmacies located in Benghazi Libya. The sampling was conducted using a systematic random approach, with samples chosen from the same month of production but from different locations. Table 1 summarizes

the characteristics of the baby powder samples examined in this study, including their corresponding identification codes.

Table 1. Samples of Baby Powder retrieved from markets located in Benghazi.

No.	Code of Sample	Brand of baby talcum powder	Country of Origin
1	P1	Johnson's (baby powder)	Thailand
2	P2	Johnson's (sleep time)	Thailand
3	P3	Johnson's (baby powder)	Indonesia
4	P4	Johnson's (milk + rice)	Indonesia
5	P5	Johnson's (blossoms)	Indonesia
6	P6	Johnson's (bedtime)	Indonesia
7	P7	Nunu (baby powder)	Saudi Arabia
8	P8	Nunu	Saudi Arabia
9	P9	Chicco	Italy
10	P10	Chicco	Italy
11	P11	Baby Roz	Turkey
12	P12	Baby rose	Tunisia
13	P13	Petrova	United Arab Emirates
14	P14	Felce Azzurra (Talco Classico)	Italy
15	P15	Felce Azzurra (Talco Fresco)	Italy
16	P16	Dalin	Turkey

The systematic methodology for sample collection aims to provide reliable data for subsequent analysis of heavy metal content in these products.

2.3 Quality Control

Chemical analysis necessitated internal validation guidelines, which were aligned with the quality control procedures implemented in chemical analysis, resulting in an improved controlled quality. All reagents were used to test the chemical properties of glass, so that glass was not contaminated with metals. The reagents were packed tightly in glass sample containers to prevent any contamination with reagents. Prior to analysis, the performance of instruments was tested for daily calibration using standard solutions of the investigated elements and multi-level calibration standards to verify their linearity, with the results published in Analytical Techniques – The Performance of Instruments being verified before the analysis. To ensure the accuracy of the results, all samples were analyzed in triplicate (n = 3) and method precision was measured using the relatiometry method precision was evaluated using the relative standard deviation (%RSD), which was required to be less than 20% as an acceptable criterion for repeatability.

The linear range was considered a useful indicator of the analytical method's efficiency, as demonstrated by calibration curves that displayed a correlation coefficient ($R^2 > 0.99$) across the instrument's linear response, highlighting high sensitivity and good linear response of the instrument. The objective sample was analyzed for interference-free selective screening to ensure the absorbance of the target elements was pure and free of any absorbance bias. Similarly, to achieve a precise and consistent result, every glass of utensil was cleaned thoroughly with a cocktail of 10% nitric acid solution for 24 hours, followed by a thorough cleaning with deionized water for the full cleaning. Prior to analysis, laboratory contamination was eliminated and all subsequent analyses were analyzed using standard and blank measurements to ensure the integrity of the analysis and prevent laboratory contamination.

2.4 Experiment:

Collected of Baby Powder Samples were analyzed in the Food Chemistry Laboratory, Department of Nutrition, Faculty of Public Health, University of Benghazi. Where this experiment employed a systematic approach to the wet digestion of baby powder samples, ensuring precise analysis of their elemental composition [15]. A researchers weighted (2 g) of each type of baby powder into cleaned digestion flasks, 10 ml of concentrated nitric acid (97%HNO_3) has been added. This strong oxidizing agent facilitated the breakdown of organic matter while releasing metal ions for analysis. The flasks content is heated on a hot plate at a controlled temperature range of 70–80 °C for 30 minutes. This step enabled the effective dissolution of the sample matrix. After heating, the flasks were left to cool to room temperature.

Following the initial digestion, 5 ml of hydrogen peroxide (35%H_2O_2) has been added to each flask. Hydrogen peroxide promoted the oxidation of residual organic material. The mixture was vigorously heated until white fumes appeared, signifying the release of nitrogen oxides and the complete oxidation process. After completing the digestion and allowing the solution to cool, deionized water was then used to top up this volume to a predetermined final volume. All the previous steps of sample preparation are repeated with blanks After digestion, the samples were allowed to sediment overnight and then filtered using No. 42 Whatman filter paper to prepare for Atomic Absorption Spectroscopy.

2.5 Statistical Analysis

Statistical analyses were conducted using the Statistical Package for the Social Sciences (SPSS), version 20.0 (IBM Corp., New York, USA). Experimental data were reported as mean values accompanied by their corresponding standard deviations, and inferential comparisons were performed using the t-test with a 95% confidence interval to evaluate differences between groups.

2.6 preparation of standard curve

After setting the atomic absorption spectrophotometer to optimal conditions, measure the absorbance of a variety of standard metal solutions. To perform flame analysis, the standard solution has been diluted with 0.1 M HNO_3 to create a series of standards that involve the concentration of the elements to be measured. Each sample was analyzed in triplicates. Absorption is plotted against mg of metal/L solution. All data will be coded before being entered into a computer.

2.7 Health Risk Assessment of Toxic Elements Baby Powder

Human health risk assessment evaluates potential adverse health effects resulting from exposure to chemical substances, including both carcinogenic and non-carcinogenic agents, following methodologies outlined by the United States Environmental Protection Agency.. The risk of carcinogenic and non-carcinogenic carcinogenicities in Libya remains unregulated, as there is no consensus on an acceptable maximum risk level currently in place. In this study health risk assess was determined based on of the chronic daily intake (CDI) that is measured in mg/kg/day from dermal absorption, target hazard quotient (THQ), and hazard index (HI), and carcinogenic risk (CR).

Infants and children are more vulnerable to environmental contaminants due to the physiological differences between infants and children, making them more susceptible to higher doses of exposure. Infants have less developed protection mechanisms in their system, including an incompletely developed blood–brain barrier, limited plasma protein binding capacity, reduced hepatic and renal metabolic clearance, and an underdeveloped immune response, which are often underestimated [14,16]. Infants are especially sensitive to dermal contact contaminants due to their higher specific surface area [17].

This study conducted in partnership with the EPA utilized the agency's own health risk assessment (EPA-TCME) approach to evaluate the potential health effects of exposure to metals, which is associated with different types of health risks, such as cancer-causing and non-cancerous contaminants. CR is used to assess carcinogenic potential risks, while non-CR can cover both carcinogenic and non-carcinogenic contaminants. Firstly, the concentration of each contaminant was measured, and then

qualitative and quantitative estimations of the health risks associated were made to achieve this. In this study, the possibility of toxic heavy metal hazards was investigated for Al, Cd, Cr, Cu, Pb, and Ni, which could cause health issues. The human health risks are measured through exposure pathways that include dermal contact of polluted media. In each sex babies (0.5–3 years), health risks from these routes were evaluated based on their age and health in this study.

2.7.1 Estimated Chronic Daily Intake of Heavy Metals (CDI)

When contaminants are absorbed through the skin, they are referred to as dermal exposures. People who come into direct contact with baby powder are particularly at risk for exposure to this pathway. Estimated daily intake levels were calculated by combining the quantified metal concentrations with average body weight (Bw) parameters for male and female infants. The WHO [18] assessed the P95th percentile of the weight for girls and boys at for 0.5,1, 2 and 3 years, taking into account the child-growth standard table. The mean Bw was determined based on the standardized method of measuring child growth and development.

Equation (1) from the Environmental Protection Agency (USEPA) was used to calculate the chronic daily intake (CDI) that is measured in mg/kg/day from dermal absorption [35,36,39].

$$\text{Chronic daily intake } (CDI) = \frac{Cs \times SA \times AF \times ABS \times EF \times ED \times 10^{-6}}{BW \times AT} \quad (1)$$

Where, Cs: measured concentration of heavy metals in samples (mg/kg); while the default value for each parameter in the health risk calculation is described as the following, SA: Surface area of skin exposed (cm²); AF: Adherence factor (0.07 mg/cm²); ABS: Dermal absorption factor (0.001, unitless); EF: Exposure frequency (350 days/year); ED: Exposure duration (0.5, 1, 2 or 3 years); BW: Body weight (kg); AT: Averaging time (days). Table 2 indicated BW, SA, and AT parameters that used separately of girls and boys for these calculations and listed them here.

Heavy metal Concentration in the sample was determined in this study, while other factors were set to the default value [19].

The effect of the daily intake of heavy metal on the toxicity of heavy metal to humans varies according to the estimated daily intake saw a significant increase in funding for research and development initiatives [16].

2.7.2 Non-Carcinogenic Risk of Heavy Metals for Babies

The hazard quotient of each metal in the analyzed baby powder samples was used to calculate the non-carcinogenic hazard quotient (HQ) of the metals in the samples due to the presence or absence of carcinogenic carcinogenic infant formulas. The RfD values for children are seen in Table 3, which were used to calculate noncarcinogenic risks based on their respective RfD values and CDI values, respectively. The chronic reference dose (RfD) of a toxicant and chronic daily intake (CDI) of the toxicant (mg/kg/day) are related in relation as shown in Equation (2):

$$\text{HQ} = \frac{\text{CDI dermal}}{RFD\ dermal} \quad (2)$$

Where RfD is the estimated maximum permissible dose for human through daily exposure [20], as shown in Table 3.

Table 2: The parameters BW, SA, and AT for boy and girl their ages 0.5,1,2 and 3 years.

Age (years)	**0.5**		**One**		**Two**		**Three**	
Gender	**Boy**	**Girl**	**Boy**	**Girl**	**Boy**	**Girl**	**Boy**	**Girl**
BW (kg)	7.93	7.30	9.65	8.95	12.15	11.48	14.34	13.85
SA (cm²)	4500	4150	5750	5500	8000	7500	10000	9250
AT=EF×ED	350×0.5=		350×1=		350×2 =		350×3=	
(days)	175		350		700		1050	

Table 3: Reference doses (RfD) of six heavy metals [21-24].

Age (years)	0.5		1		2		3	
Gender	**Boy**	**Girl**	**Boy**	**Girl**	**Boy**	**Girl**	**Boy**	**Girl**
***RFD* (Al)**	0.012	0.009	0.018	0.015	0.031	0.025	0.053	0.045
***RFD* (Cd)**	0.0008	0.0007	0.0011	0.001	0.0014	0.0012	0.0017	0.0015
***RFD* (Cr)**	0.002	0.0018	0.003	0.0027	0.0045	0.004	0.006	0.0055
***RFD* (Cu)**	0.031	0.028	0.046	0.042	0.062	0.056	0/083	0.075
***RFD* (Pb)**	0.0004	0.0003	0.0005	0.0004	0.0006	0.0055	0.0008	0.0007
***RFD* (Ni)**	0.012	0.011	0.018	0.016	0.031	0.028	0.053	0.047

Most baby powder samples with different metals contained a hazard quotient, HQ carcinogenic risk and non-carcinogenic quotients, which was calculated. If the HQ values is more than one, the exposed babies are likely to experience adverse health effect. [16].
The potential health risks associated with exposure to toxic elements in infants aged 0.5 to 3 years were evaluated through the calculation of the estimated chronic daily intake (CDI), target hazard quotient (THQ), and hazard index (HI).The HI values were obtained by using the total THQ corresponding to each body weight at different ages, as demonstrated in equation (3) [25].

$$HI = \Sigma HQ = HQ\ Al + HQ\ Cd + HQ\ Cr + HQ\ Cu + HQ\ Pb + HQ\ Ni \quad (3)$$

2.7.3 Carcinogenic risk

Carcinogenic risk refers to the incremental likelihood that an individual may develop cancer over a lifetime as a consequence of exposure to chemical agents under defined exposure conditions. [24,25].
The carcinogenic risk value of mix trace metals was calculated to estimate whether the consumers are likely to suffer from cancer, and this can be evaluated from equation:
Carcinogenic risk=CDI ×SF [26,27,28].
Where CDI is the chronic daily intake of carcinogens ($mgkg^{-1}d^{-1}$) and SF is the slope factor of hazardous substances. The reported slope factor for Al, Cd, Cr, Cu, Pb and Ni are 0.0014, 6.300, 0.500, 0.017, 0.0085 and 0.91 $(mg/kg/d)^{-1}$, respectively [16,19].

3- Results and discussion

3.1 Levels of toxic heavy metals in baby powder samples

The results obtained, shown in Table 4, indicated the initial measurements in ppm, while Table 5 shows the calculated concentrations in mg/kg, along with the average concentrations and standard deviations for each element.
The assessment of heavy metal concentrations in consumer products, such as baby powder, has become essential due to the associated health risks posed to the population, particularly infants. These toxic elements, measured in parts per million (ppm) using atomic absorption spectroscopy (AAS).

3.1.1 Aluminum Content

The range concentrations of aluminum in all investigated baby powder samples were found to be from 12.32 mg/kg in Johnson's "Sleep Time" powder from Thailand to 275.475 mg/kg in "Baby Roz" powder from Turkey, as presented in Table 5.
Figure 1, illustrates these with the mean average of 113.183 mg/kg across samples. It has to be noted that the U.S. Food and Drug Administration (FDA) established a maximum safe limit for aluminum in baby powder at 0.400 mg/kg [16]. In the current study all samples are above the U.S. Food and Drug Administration (FDA), suggesting potential health risks.

Table 4. The measured concentration of heavy metals (ppm) in baby powder, values Mean ± SD.

Code of Sample	Metals contente (ppm)					
	Aluminum (Al±SD)	**Cadmium (Cd±SD)**	**Chromium (Cr±SD)**	**Copper (Cu±SD)**	**Lead (pb±SD)**	**Nickel (Ni±SD)**
P1	3.061±0.004	0.091±0.130	LDL	1.164±1.012	LDL	0.280±0.009
P2	0.493±0.007	LDL	LDL	1.091±0.005	0.358±0.0004	0.229±0.008
P3	5.254±2.200	LDL	LDL	0.317±0.007	0.511±0.0004	2.005±0.032
P4	9.997±1.040	0.118±0.007	1.079±0.001	0.755±0.006	0.259±0.0014	LDL
P5	4.652±0.009	0.133±0.008	1.062±0.002	0.561±0.001	LDL	0.546±0.004
P6	1.999±0.007	0.202±0.018	0.200±0.0005	1.238±0.016	0.180±0.0008	LDL
P7	2.926±0.007	0.297±0.003	0.555±0.009	0.319±0.008	LDL	0.631±0.081
P8	1.018±0.007	0.252±0.008	0.062±0.0001	2.205±0.250	LDL	0.155±0.006
P9	3.409±0.009	0.379±0.008	1.999±0.008	0.768±0.005	0.026±0.0017	0.219±0.006
P10	8.506±0.035	0.775±0.019	1.106±0.008	0.301±0.005	0.042±0.0006	LDL
P11	11.019±0.03	LDL	0.233±0.0004	3.099±1.008	0.312±0.0013	2.188±0.022
P12	2.608±0.006	LDL	1.606±0.007	1.084±0.008	0.418±0.0006	0.599±0.016
P13	0.881±0.004	LDL	0.770±0.008	0.922±0.015	LDL	0.027±0.007
P14	7.590±0.046	0.904±1.031	LDL	0.441±0.006	LDL	LDL
P15	1.568±0.004	0.113±0.0002	1.868±0.006	1.930±0.006	0.209±0.0020	LDL
P16	7.456±0.024	0.457±0.005	0.989±0.006	1.402±0.009	0.623±0.0008	0.346±0.006
Mean	4.530	0.491	1.429	1.099	0.294	0.417

Table 5. The concentration of heavy metals (mg\Kg) in baby powder, values mean.

Code of Sample	Metals contente (mg\Kg)						
	Aluminum (Al)	Cadmium (Cd)	Chromium (Cr)	Copper (Cu)	Lead (Pb)	Nickel (Ni)	Total Metals
P1	76.525	2.275	LDL	29.1	LDL	7.000	114.900
P2	12.325	LDL	LDL	27.275	8.95	5.725	39.600
P3	131.350	LDL	LDL	7.925	12.775	50.125	202.175
P4	249.925	2.950	26.975	18.875	6.475	LDL	298.725
P5	116.300	3.325	26.550	14.025	LDL	LDL	160.200
P6	49.975	5.050	5.000	30.95	4.5	LDL	90.975
P7	73.150	7.425	13.875	7.975	LDL	15.775	118.200
P8	25.450	6.300	1.550	55.125	LDL	3.875	88.425
P9	85.225	9.475	49.975	19.2	0.65	5.475	170.00
P10	212.65	19.375	27.650	7.525	1.05	LDL	337.150
P11	275.475	LDL	5.825	77.475	7.8	54.700	351.325
P12	65.200	LDL	40.150	27.1	10.45	14.975	132.450
P13	22.025	LDL	19.250	23.05	LDL	0.675	65.000
P14	189.750	22.600	LDL	11.025	LDL	LDL	223.375
P15	39.200	2.825	46.700	48.25	5.225	LDL	142.200
P16	186.400	11.425	24.725	35.05	15.575	8.650	257.600
Min.	12.325	LDL	LDL	7.525	LDL	LDL	39.600
Max.	275.475	22.600	49.975	77.475	15.575	54.700	351.325
Mean	113.183	5.814	18.014	27.495	4.591	10.436	179.533
FDA	0.400	3.000	5.000	13.000	0.100	0.600	

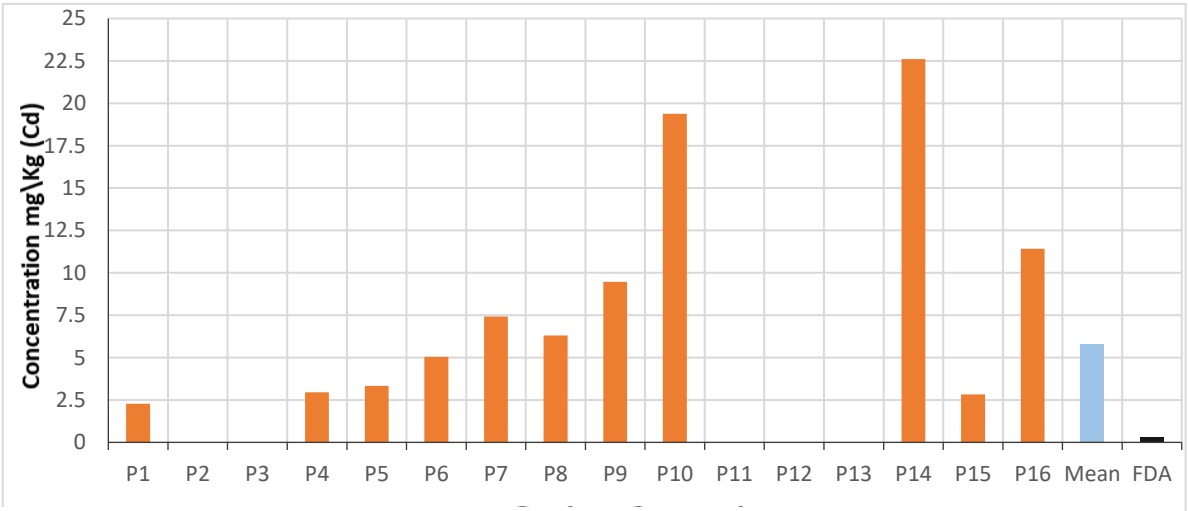


Figure 1. Aluminum concentrations (mg/Kg) in Baby Powder samples.

Infants with underdeveloped renal systems are particularly vulnerable to aluminum exposure [16,17]. That, might be led to weakened bone structures and increased health risks in individuals with renal insufficiency [18]. Also, this are linked to Alzheimer's disease and can negatively affect the nervous system [19,20,21].

3.1.2 Cadmium Content

Figure 2, shows the Cd concentration, where five out of sixteen baby powder samples tested was undetectable, with the mean average of 5.814 mg/kg. The lowest concentration was identified in Johnson's baby powder from Thailand, containing 2.275 mg/kg, while the highest concentration was found in Felce Azzurra (Talco Classico) from Italy, which contained 22.900 mg/kg.

Looking at all baby powder samples in Table 5, shows concentration more than 3.00 mg/kg, which above the permissible limits of FDA [26].

This result contrasts with previous studies that reported lower concentrations of cadmium in baby powder. Where K.S. G. Rehman *et al*., observed Cd levels ranging from 0.001 to 0.080 mg/kg in 30 different baby powder brands in Pakistan [22], also a study in Malaysia [23] documented Cd levels between 3.4 and 4.7 ppb (0.0034–0.0047 mg/kg).

Once Cd enters the human system, it accumulates predominantly in the liver and kidneys and is subsequently excreted very slowly through urinary and fecal pathways, leading to potential long-term retention and

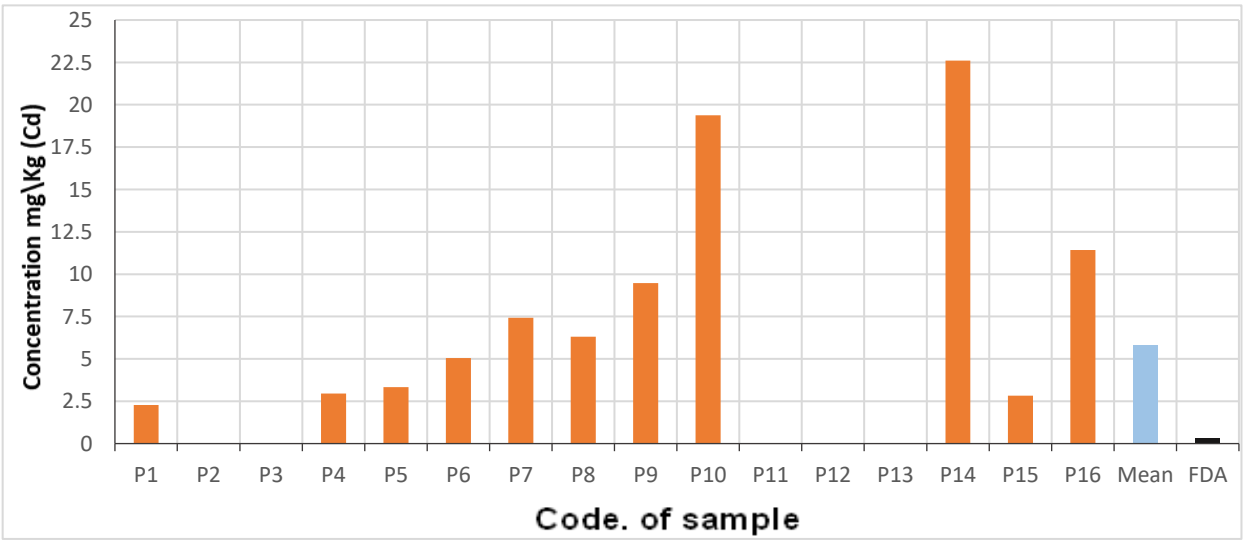


Figure 2. Cadmium concentrations (mg/Kg) in Baby Powder samples.

bioaccumulation [24].

The International Agency for Research on Cancer (IARC) has classified Cd as a Group 1 carcinogen due to its confirmed carcinogenic effects, particularly following inhalation, which can induce lung cancer [24]. Moreover, cadmium exposure has been associated with tumorigenesis in other organs, notably the prostate and kidneys [25]. However, the health risks associated with Cd, particularly in consumer products such as baby powder, are significant [26].

3.1.3 Chromium Content

Table 5, demonstrates that the Cr content within the baby powder samples with an average of 18.014 mg/kg, Since the FDA has outlined the safe limit of 5 mg/kg for Cr as an impurity in baby powder, [26] it can be concluded that all baby powder samples under the present study are above the safe limit recommended by FDA. While, Chromium was undetectable in four samples, as shown in Figure 3. However, the lowest detected concentration was 1.550 mg/kg in the Nunu sample from Saudi Arabia. In contrast, the highest detected amount was 49.975 mg/kg in the Chicco sample from Italy.

levels in Pakistani talcum powders ranging from 0.08 to 0.35 mg/kg, which are lower than those observed in this study [22]. S. Jamali *et al*. were reported a Cr concentration of of 0.3 to 0.3883 mg/kg in talc product [27], while K. S. Almugren et al. documented significantly higher concentrations in Malaysian samples, ranging from 4.883 to 5.846 mg/kg (4883.0 to 5846.0 ppb), [23] which exceed both this study's.

Both forms of (Cr III) and (Cr VI), can trigger immune responses associated with contact allergies, especially in infants [28]. This is particularly concerning as infants may be exposed to chromium through talcum powder application or inhalation, which poses additional risks due to their developing systems [29]. Many European Union countries and Canada have restricted chromium use in cosmetics due to these risks. Chromium's highly corrosive nature can exacerbate allergic reactions in the skin and respiratory tract, and chronic inhalation exposure may increase the risk of lung, nasal, and sinus cancers [41].

3.1.4 Copper Content

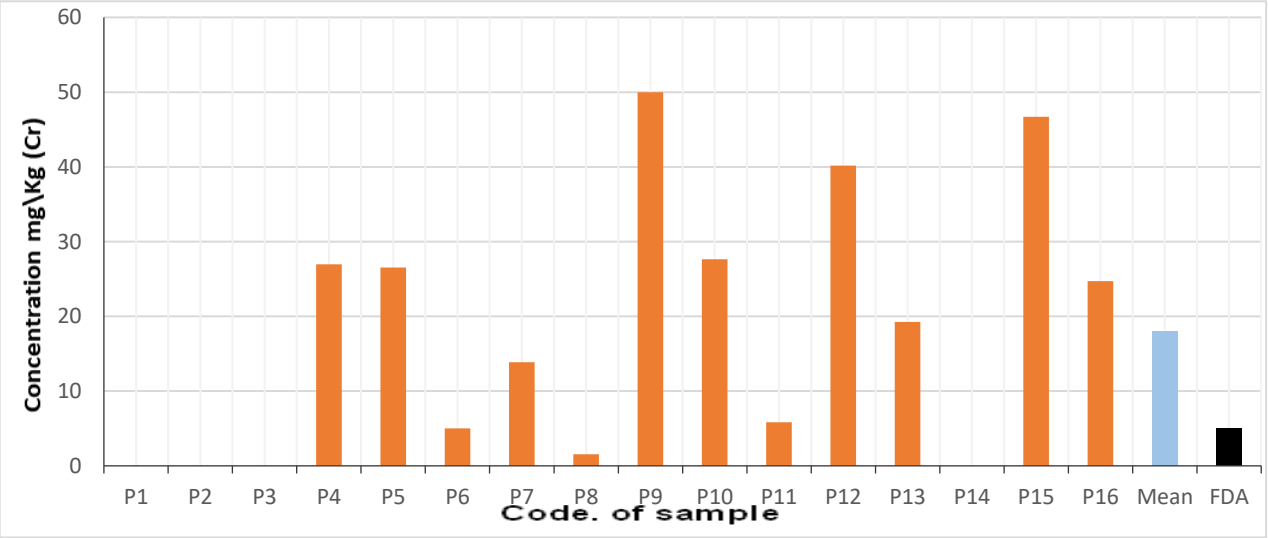


Figure 3. Chromium concentrations (mg/Kg) in Baby Powder samples.

Figure 4, demonstrates that the Cu content within the baby powder samples is ranging from, 7.525 mg/kg in Chicco powder manufactured in Italy, to 77.475 mg/kg in Baby Roz powder produced in Turkey. As shown in Table 5 the average Cu concentration across all tested baby powder samples was 27.495 mg/kg. The FDA has set a safe limit of 13 mg/kg for Cu as an impurity in baby powder products [26], it

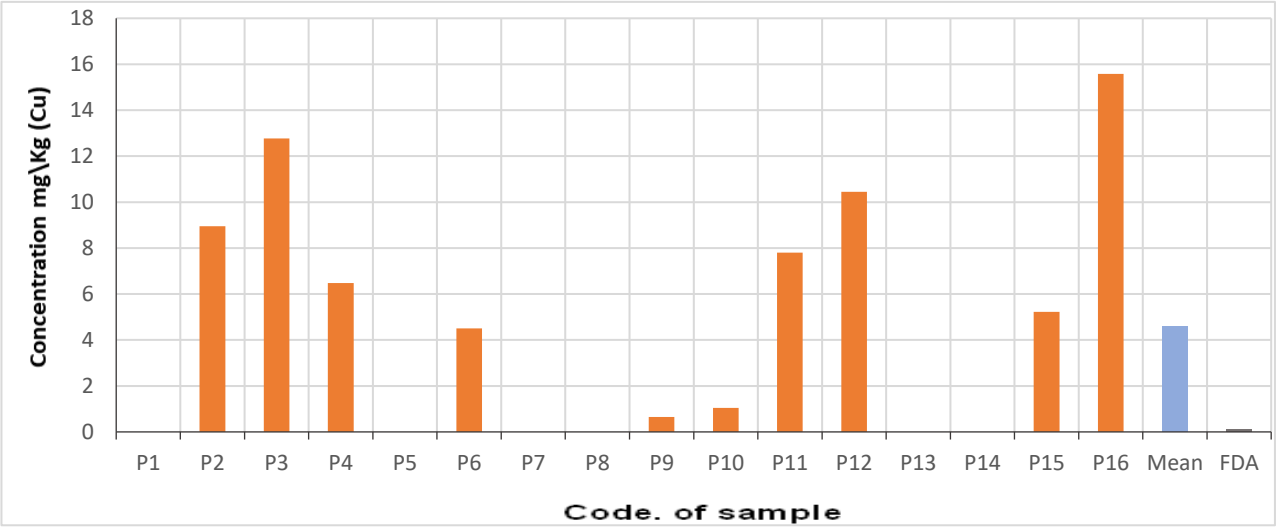


Figure 4. Copper concentrations (mg/Kg) in Baby Powder samples.

can be concluded that all baby powder samples under the present study are above the allowable safe limit thus pose significant risk to human health due to Cu toxicity.

In contrast to earlier findings by Ghana Rehman et al. [22] and by K.S. Almugren et al. [23], which are both lower than present study.

Copper is a vital trace element in the human body, essential for red blood cell production and iron metabolism. Its effects are dose dependent, with minimal amounts needed for optimal physiological functions [43].

3.1.5 Lead Content

Figure 5 also revealed that the cadmium content within all the baby powder samples appeared to be in the range of 4.500 to 15.575 mg/kg. When the results were compared with the 0.1 mg/kg permissible limits in baby powder recommended by Food and Drugs Administrative (FDA) [35]. The investigated baby powders in this study exceeded the permissible limits, which could potentially pose health risks to consumers from dermal exposure.

In contrast, lead content was undetectable in approximately half of the samples, with two samples presenting lower concentrations of 0.65 and 1.05 mg/kg. The average lead concentration across all baby powder samples 4.591 mg/kg, as indicated in Table 5. Other researches show variable lead content in baby products, such as 0.0006 to 1.05 mg/kg found by [36] and a range of 2585.0 to 1944.0 ppb (2.585 to 1.944 mg/kg) reported by [37]. Interestingly, the lead levels in baby powder samples analyzed in this study were unexpectedly higher than safety limit set by the FDA, warranting further investigation.

Lead exposure is linked to severe health risks,

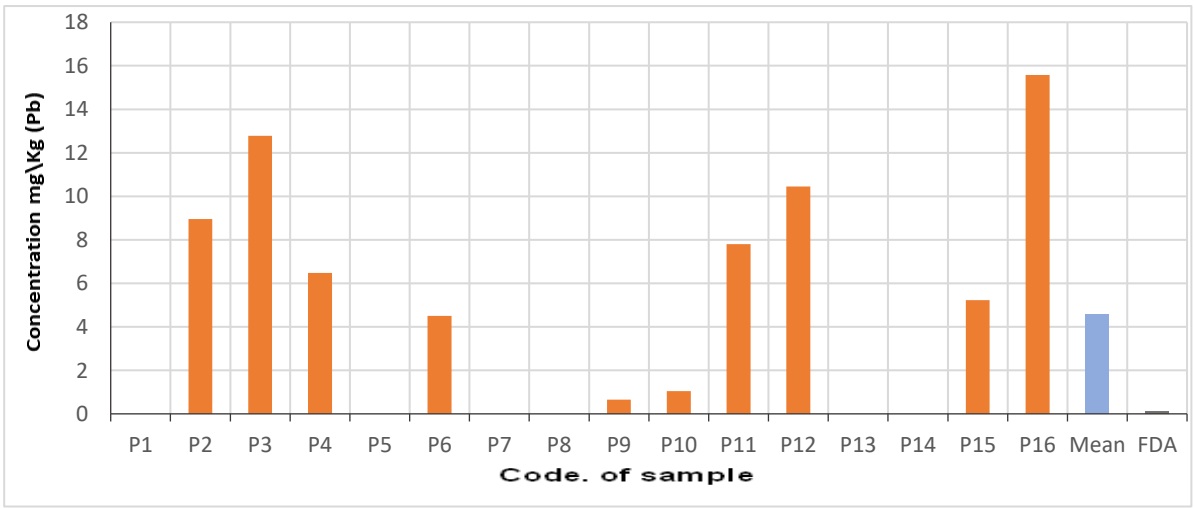


Figure 5. Lead concentrations (mg/Kg) in Baby Powder samples.

including disruptions in hemoglobin synthesis, elevated blood pressure, renal damage, miscarriage, and neurological impairments [31]. The U.S. Food and Drug Administration recommend not containing lead in consumer products like baby powder due to its toxicity and severe health impacts [3]. Lead is one of the top four heavy metals threatening human health, and studies on animal models suggest that lead compounds, such as lead acetate and lead phosphate, may have carcinogenic properties, as highlighted in a recent Department of Health and Human Services (DHHS) report. U.S. [45].

3.1.6 Nickel Content

The FDA has established a maximum permissible limit of 0.6 mg/kg for nickel concentration in products [26]. Analysis of baby powder samples revealed that most products were above this threshold, with nickel levels undetectable in seven samples. However, two samples exceeded the permissible limit. These included Johnson's Baby Powder from Indonesia, with a nickel concentration of 50.125 mg/kg, and Baby Roz from Turkey, with a concentration of 54.700 mg/kg. The lowest concentrations ranged between 0.675 and the highest concentration 50.125 mg/kg, as detailed in Table 5 and as shown in Figure 6. The average nickel concentration across all samples was 10.436 mg/kg .Interestingly, findings from Ghana Rehman *et al*. indicated that nickel concentrations in baby powder ranged from 3.102 to 2.207 mg/kg [36], which is significantly lower than the results obtained in the current study. Nickel (Ni) plays a dual role in biological systems. While it is an essential element for the growth and enzymatic functions of specific microorganisms and plants, excessive exposure to nickel poses health risks [46]. Notably, concentrations as low as 0.5 mg/kg (500 ppb) have been implicated in triggering contact dermatitis [47].

The elevated concentrations of Al, Pb, Ni, Cu, Cr, and Cd observed in all baby powder samples above FDA permissible limits strongly indicate contamination originating primarily from raw talc materials, which are known to naturally contain heavy metals depending on their geological source. Insufficient purification and refining during raw material processing likely contributed to the persistence of these metals. In addition, manufacturing-related factors, including inadequate quality control, contaminated processing equipment, and environmental exposure during production, may have further increased metal concentrations. These findings underscore the necessity for stricter regulatory control, improved manufacturing practices, and systematic monitoring of raw materials to prevent heavy metal contamination in baby powder products.

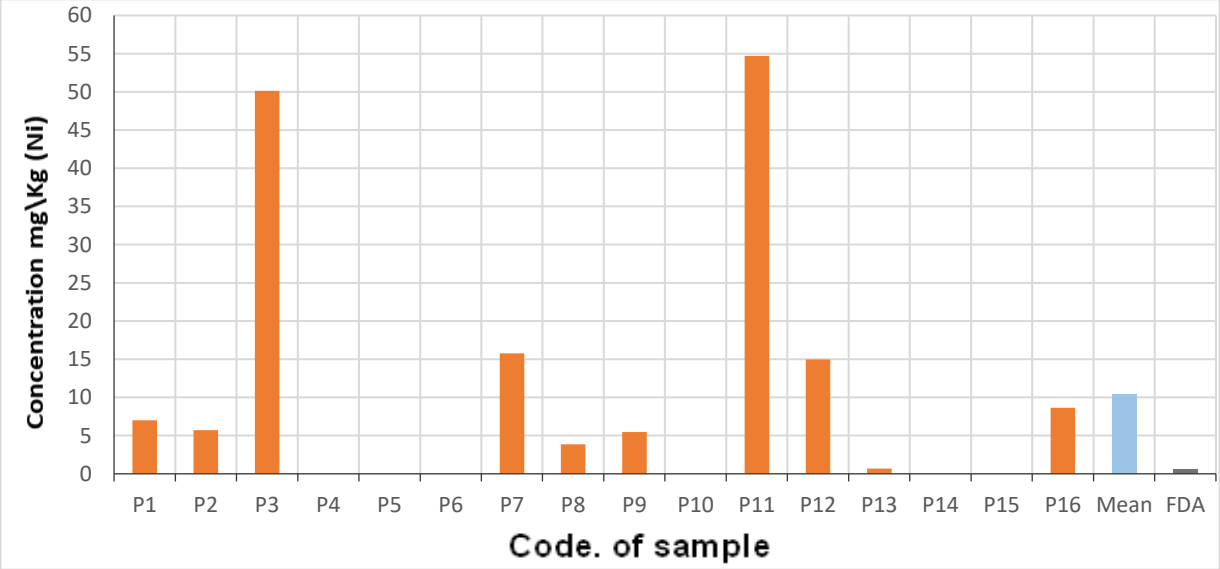


Figure 6. Nickel concentrations (mg/Kg) in Baby Powder samples.

2.2 Health Risk Assessment of use Baby Powder

The average concentration (mg\Kg) of the six metals, namely aluminum, cadmium, chromium, copper, lead, and nickel were used to calculate the chronic daily intake (CDI).

The four age groups for babies were comparable the daily exposure to baby powder. Figures 7 and 8 shows the distribution of data for the CDI. The baby powder samples exhibit decreasing mean CDI values in the order Al>Cd>Cr>Cu>Ni>Pb.

In spite of inconclusive findings from prior studies, previous studies not finding any correlation between sex differences. This study revealed that exposure daily per body weight

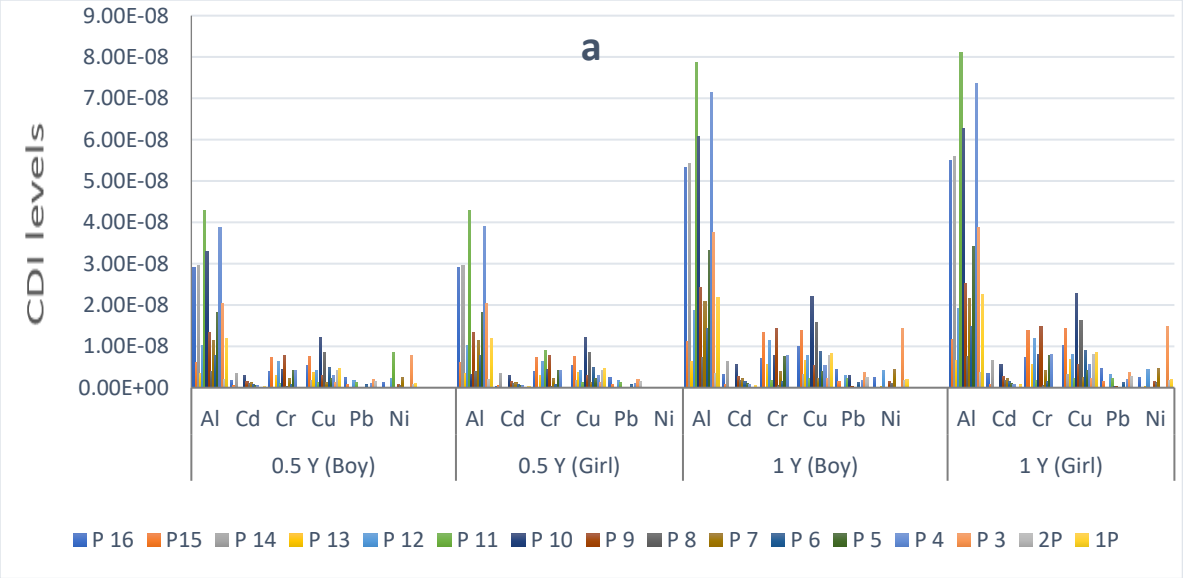


Figure 7: The chronic daily intake (CDI) values of heavy metals (mg/day) for 0.5 and 1 Years old.

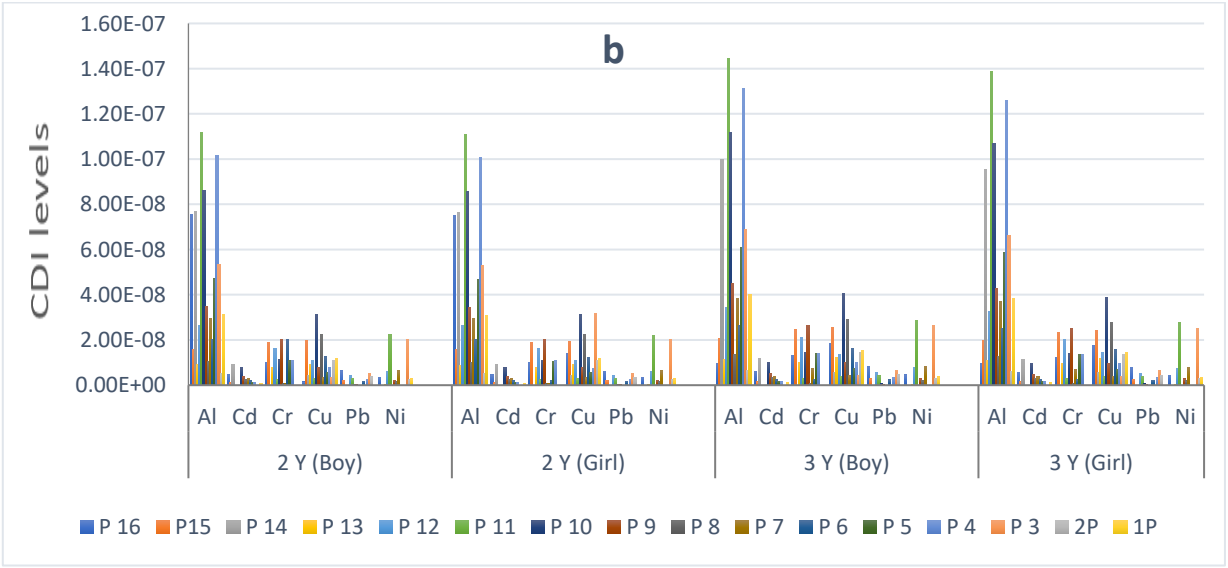


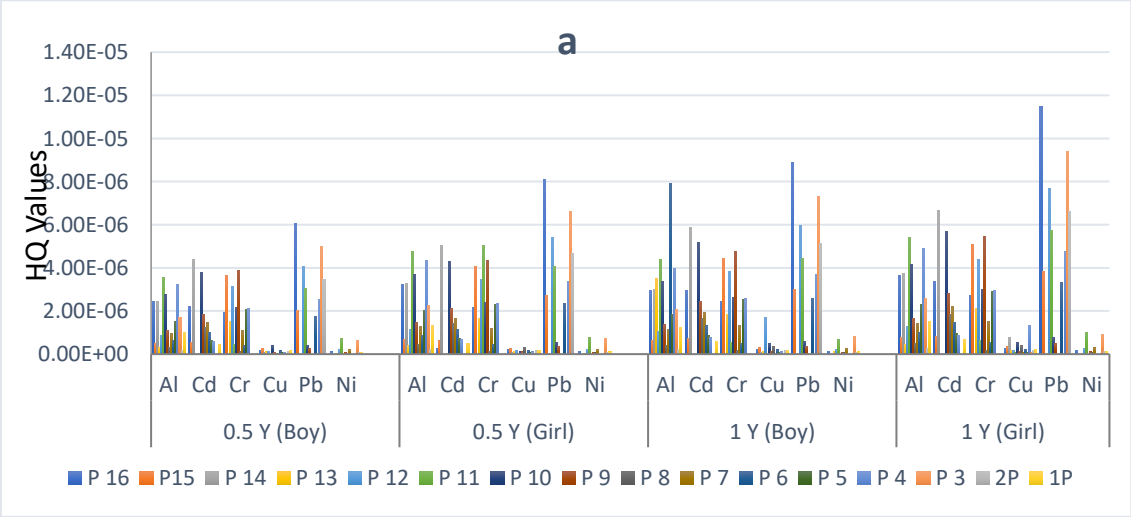
Figure 8: The chronic daily intake (CDI) values of heavy metals (mg/day) for 2 and 3 Years old

unit for girls aged 0.5 and 1 year was slightly higher than that compared to exposure to boy babies of the same ages, and vice versa for ages 2 and 3 years, where the chronic daily intake for boys is higher than for girls. For each heavy metal, the daily exposure per each body weight unit increases with an increase in the baby's age. The results obtained in figures 9 and 10

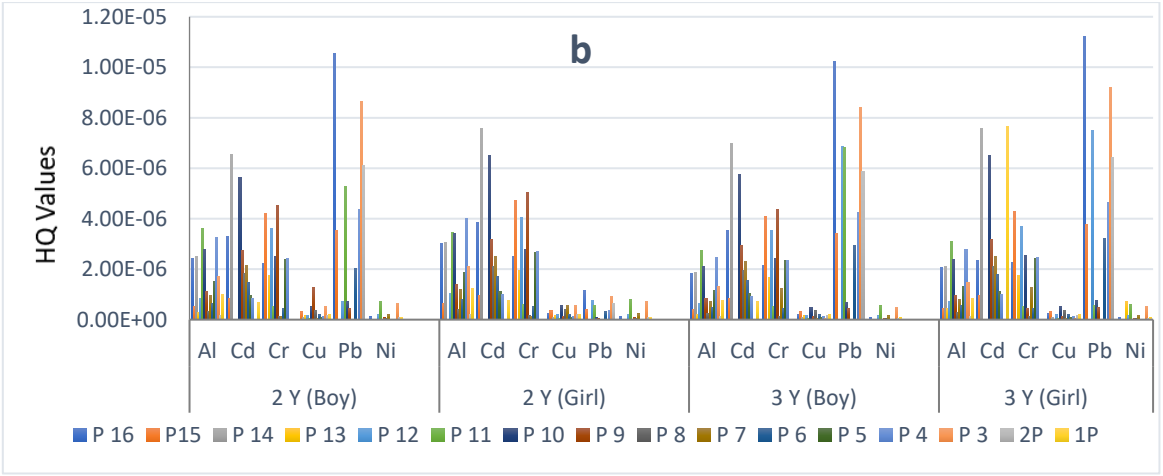
showed the range HQ values for boys had 0.5, 1, 2 and 3 y of age, were: 1.672×10^{-6}-1.292×10^{-5}, 2.097×10^{-6}-1.761×10^{-5}, 1.944×10^{-6}-1.866×10^{-5}, 1.715×10^{-6}-1.807×10^{-5}, and girls had the range of HQ values were: 2.091×10^{-6}-1.403×10^{-5}, 2.506×10^{-6}-2.160×10^{-5}, 2.306×10^{-6} - 1.084×10^{-5} and 1.889×10^{-6}- 1.820×10^{-5}.

The target hazard quotient (HQ) for the six metals studied for each sample was calculated and then has been plotted graphically as shown in the figures 9 (0.5y & 1y) and figures 10 (2y & 3y). These figures revealed that the HQ for all the metals was lower than 1 obtained for all the baby powder samples, indicating that dermal adsorption of the studied baby powder by infants' babies (0.5 to 3 y of age) of Libya would not pose babies to a high risk of health issue.

The mean HI values were 6.041×10^{-6}, 8.187×10^{-6}, 7.743×10^{-6}, 7.874×10^{-6} for 0.5, 1, 2 and 3y of boys, and for girls were 7.192×10^{-6}, 9.869×10^{-6}, 9.429×10^{-6}, and 8.347×10^{-6}, respectively. This study revealed that girls' HI value was higher than that of boys, with a lower HI value compared to boys, as a result of their lighter body mass. The HI values were less than the established criteria 1, and the inverse relationship with age was observable as the HI values were inversely related to those of the assumed age. HI value expresses the combined non-carcinogenic effects of multiple elements. For the utilization of selected baby powder, HI was <1 as shown in Table (6) indicating that consumers are found to be safer.



Figurer 9. The hazard quotient (HQ) values of heavy metals (mg/Kg/day) for 0.5 and 1 Years old.



Figurer 10. The hazard quotient (HQ) values of heavy metals (mg/Kg/day) for 2 and 3 Years old.

Table (6): The hazard index (HI) values of heavy metals (mg/day) for 0.5, 1, 2 and 3 Years old.

Code No. samples	Age of Boy				Age of Girl			
	0.5	**1**	**2**	**3**	**0.5**	**1**	**2**	**3**
P1	1.672 $\times10^{-6}$	2.097 $\times10^{-6}$	1.944 $\times10^{-6}$	1.715 $\times10^{-6}$	2.091 $\times10^{-6}$	2.506 $\times10^{-6}$	2.306 $\times10^{-6}$	1.889 $\times10^{-6}$
P2	3.851 $\times10^{-6}$	5.570 $\times10^{-6}$	6.503 $\times10^{-6}$	6.229 $\times10^{-6}$	5.093 $\times10^{-6}$	7.132 $\times10^{-6}$	1.132 $\times10^{-6}$	6.816 $\times10^{-6}$
P3	7.359 $\times10^{-6}$	1.023 $\times10^{-5}$	1.107 $\times10^{-5}$	1.024 $\times10^{-5}$	3.690 $\times10^{-6}$	1.296 $\times10^{-5}$	4.341 $\times10^{-6}$	1.469 $\times10^{-5}$
P4	8.522 $\times10^{-6}$	1.112 $\times10^{-5}$	1.106 $\times10^{-5}$	1.012 $\times10^{-5}$	1.079 $\times10^{-5}$	1.297 $\times10^{-5}$	8.241 $\times10^{-6}$	1.122 $\times10^{-5}$
P5	4.289 $\times10^{-6}$	5.325 $\times10^{-6}$	4.975 $\times10^{-6}$	4.565 $\times10^{-6}$	5.129 $\times10^{-6}$	6.259 $\times10^{-6}$	5.764 $\times10^{-5}$	4.938 $\times10^{-6}$
P6	3.923 $\times10^{-6}$	5.346 $\times10^{-6}$	4.802 $\times10^{-6}$	5.645 $\times10^{-6}$	3.986 $\times10^{-6}$	6.470 $\times10^{-6}$	3.555 $\times10^{-6}$	6.227 $\times10^{-6}$
P7	3.715 $\times10^{-6}$	4.710 $\times10^{-6}$	3.495 $\times10^{-6}$	4.442 $\times10^{-6}$	4.388 $\times10^{-6}$	5.486 $\times10^{-6}$	4.609 $\times10^{-6}$	4.800 $\times10^{-6}$
P8	1.753 $\times10^{-6}$	2.591 $\times10^{-6}$	2.711 $\times10^{-6}$	2.722 $\times10^{-6}$	2.338 $\times10^{-6}$	2.982 $\times10^{-6}$	3.1323 $\times10^{-6}$	2.951 $\times10^{-6}$
P9	7.251 $\times10^{-6}$	9.151 $\times10^{-6}$	1.014 $\times10^{-5}$	8.753 $\times10^{-6}$	8.433 $\times10^{-6}$	1.064 $\times10^{-5}$	9.847 $\times10^{-6}$	5.244 $\times10^{-6}$
P10	9.469 $\times10^{-6}$	1.228 $\times10^{-5}$	1.211 $\times10^{-5}$	1.145 $\times10^{-5}$	1.105 $\times10^{-5}$	1.421 $\times10^{-5}$	1.334 $\times10^{-5}$	1.268 $\times10^{-5}$
P11	7.801 $\times10^{-6}$	1.010 $\times10^{-5}$	1.017 $\times10^{-5}$	1.066 $\times10^{-5}$	1.468 $\times10^{-5}$	1.285 $\times10^{-5}$	5.435 $\times10^{-6}$	9.856 $\times10^{-6}$
P12	8.360 $\times10^{-6}$	1.124 $\times10^{-5}$	5.556 $\times10^{-6}$	1.134 $\times10^{-5}$	1.040 $\times10^{-5}$	1.380 $\times10^{-5}$	6.253 $\times10^{-6}$	1.226 $\times10^{-5}$
P13	1.907 $\times10^{-6}$	5.583 $\times10^{-6}$	2.184 $\times10^{-6}$	2.056 $\times10^{-6}$	2.271 $\times10^{-6}$	6.001 $\times10^{-6}$	2.468 $\times10^{-6}$	2.230 $\times10^{-6}$
P14	6.907 $\times10^{-6}$	8.950 $\times10^{-6}$	9.109 $\times10^{-6}$	8.931 $\times10^{-6}$	8.375 $\times10^{-6}$	1.115 $\times10^{-5}$	1.072 $\times10^{-5}$	9.776 $\times10^{-6}$
P15	6.962 $\times10^{-6}$	9.089 $\times10^{-6}$	9.394 $\times10^{-6}$	9.052 $\times10^{-6}$	8.332 $\times10^{-6}$	1.088 $\times10^{-5}$	7.012 $\times10^{-6}$	9.739 $\times10^{-6}$
P16	1.292 $\times10^{-5}$	1.761 $\times10^{-5}$	1.866 $\times10^{-5}$	1.807 $\times10^{-5}$	1.403 $\times10^{-5}$	2.160 $\times10^{-5}$	1.084 $\times10^{-5}$	1.823 $\times10^{-5}$
Mean of HI	6.041 $\times10^{-6}$	8.187 $\times10^{-6}$	7.743 $\times10^{-6}$	7.874 $\times10^{-6}$	7.192 $\times10^{-6}$	9.869 $\times10^{-6}$	9.429 $\times10^{-6}$	8.347 $\times10^{-6}$

The carcinogenic risk (CR) was calculated for each metal and then plotted graphically as shown in the figures 11 (0.5y & 1y) and 12 (2y & 3y). Carcinogenic risk between 1×10^{-6} to 1×10^{-4} is regarded as acceptable [38]. From the result, that the cancer risk of each metal was found to be lower than the acceptable range, is indicating no CR from consumption from dermal exposure of baby bower by infants.

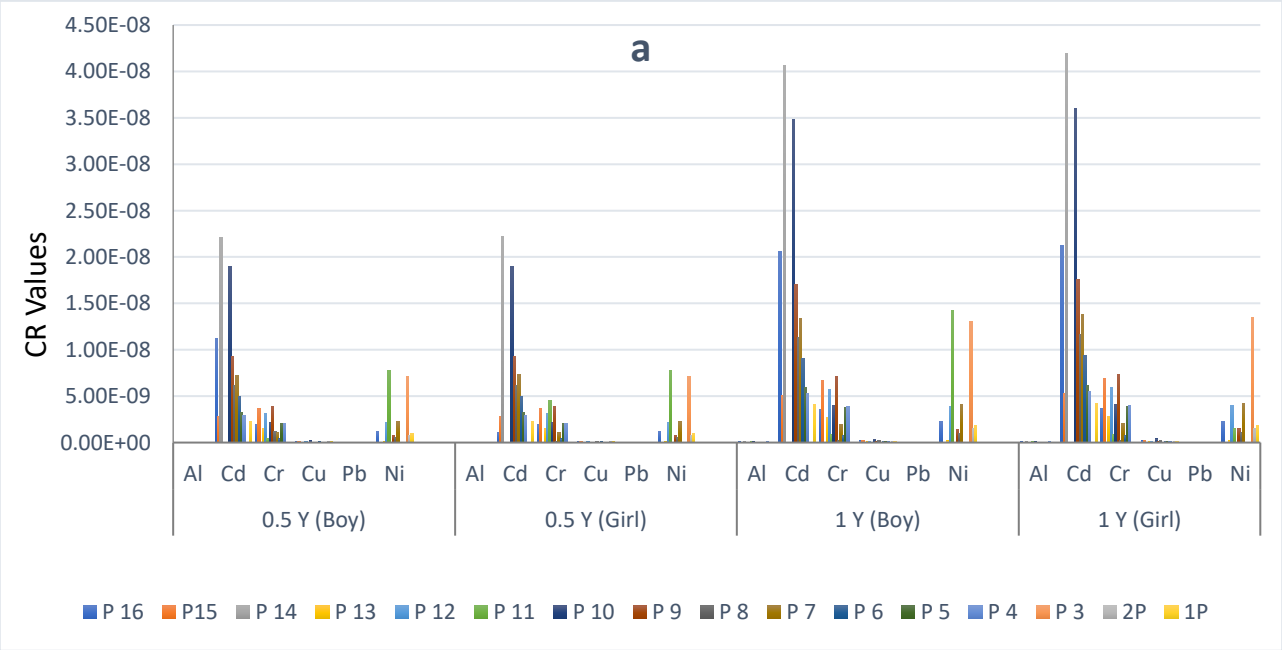


Figure 11. The carcinogenic risk (CR) of heavy metals (mg/day) for 0.5 and 1 Years old.

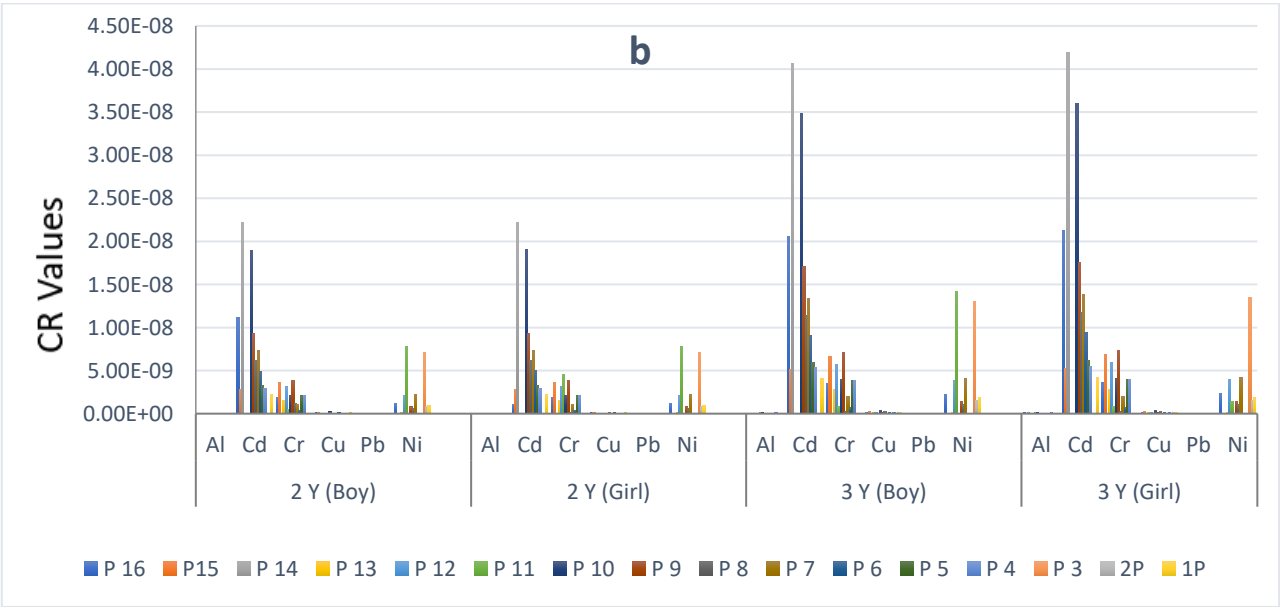


Figure 12. The carcinogenic risk (CR) of heavy metals (mg/day) for 2 and 3 Years old.

4. Conclusion

The results of this study indicate that Cr, Cd, Ni, Pb, Al and Cu concentration levels in most of baby powders sold in Benghazi are not compliance with FDA safety standards for heavy metal content.
The results indicate that the levels of heavy metals in the baby powder samples do not pose a significant health risk to infants according to established safety standards. The carcinogenic risk (CR) values for all metals were below the acceptable threshold, demonstrating a low probability of cancer development through indirect ingestion or dermal exposure. Furthermore, the non-carcinogenic risk indices (HQ and HI) were less than 1 in all samples, suggesting that dermal absorption of heavy metals by infants aged 0.5–3 years is unlikely to result in adverse health effects.

5. Limitations of the Study

Several limitations should be acknowledged in this study. Notably, the sample size was limited to sixteen baby powder products obtained from selected pharmacies within Benghazi City. Expanding the number of samples and including a broader geographic distribution would enable a more robust and representative evaluation of heavy metal contamination in baby powders across the region. The study exclusively evaluated four heavy metals (aluminum, cadmium, chromium, copper, and lead). While the other potentially harmful metals, such as mercury (Hg) and arsenic (As), were not included in the assessment.

Recommendations

Regulations on heavy metals in baby powders should be tightened, and strict quality control should be implemented during production. It is necessary to conduct regular monitoring of heavy metal levels and educate parents about the associated health risks. Research on the effects of heavy metal exposure should be supported, and the use of safe, non-toxic alternatives should be encouraged. In addition, transparency among manufacturers should be improved, cooperation with them should be strengthened, and awareness campaigns should be launched to raise awareness of the risks of heavy metals in products intended for children.

Acknowledgments

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Conflicts of interest

The authors of this study have declared no conflicts of interest and received no external funding..

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Research Article

Evaluation of The Association Between Depression and Diabetes Among The Diabetic Patients Treated in Benghazi Diabetic Clinic

Heithum S. Baiu[1*], Sarah A. Al-Maghriby[1], Malak A. Al-Houty[1], Sarah M. Al-Farjany [1], Duaa M. Bala [1], Maryam Y. Al-Sultany [1]

[1] Department of Health Education, Faculty of Public Health, University of Benghazi, Libya

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ABSTRACT

Diabetes and depression have a bidirectional relationship and are prevalent among Libyans. Thus, in this concurrent case-control study, the relationship between depression and diabetes was investigated. The data were collected simultaneously from a total of 112 participants (56 diabetics and 56 controls). The data were collected through a written questionnaire. The binary logistic regression was used to evaluate the relationship between socio-demographic variables, lifestyle variables, depression and diabetes. Marriage was statistically significantly related to diabetes compared to single individuals (P= 0.014; odd ratio= 49.742, 95% CI (2.193 1128.483)). The confidence interval range is very wide. It is an imprecision due to the small sample size. BMI was statistically significantly related to diabetes (P = 0.013; odd ratio = 1.136, 95% CI (1.027 to 1.257)). Eye diseases were statistically significantly related to diabetes compared to "the 'no complications' group". (P= 0.001; odd ratio= 18.196, 95% CI (3.312 to 99.972)). However, the confidence interval is very wide. It is an imprecision due to the small sample size. However, the other variables were not statistically significantly related to diabetes. The research hypothesis was not supported since there is no sufficient evidence for the relationship between depression and diabetes. It is recommended for health educators to encourage diabetic patients, patients with depression, and people without diabetes and depression to follow a healthy lifestyle and to adhere to the depression screening test (diabetic patients and the public).

* Corresponding author.
E-mail address: Heithum.baiu@uob.edu.ly

1. Introduction

Diabetes is a chronic disorder characterized by high blood glucose levels because of low insulin production or peripheral resistance to insulin, according to the World Health Organization [1].Depression is a low mood status with a loss of happiness or interest in doing activates for at least two weeks which impedes daily activities, according to the World Health Organization [2].

Diabetes is prevalent among Libyans in accordance to the World Bank in 2021, which showed the prevalence of diabetes in Libya was 8.7% for the age of people ranging from 20 to 79 years old [3]. Additionally, depression is also prevalent among Libyans, with a previous study published in 2023 that indicated the prevalence of depression was approximately 24% [4].

Furthermore, the prevalence of depression in Libyan diabetic patients is high and inconsistent based on the different studies conducted in Libya [3,5,6]. According to the study published in 2021, the prevalence of depression in diabetics was 66.5%, while other studies conducted in 2020 and 2024 showed that the prevalence of depression in diabetic patients was 30.5% and 24.7% respectively.[3,5,6]

It is evidenced that the relationship between diabetes and depression is reciprocal.[7] depression patients are at risk of diabetes, since the patients with depression follow an unhealthy lifestyle [7]. Additionally, diabetic patients are at risk of depression, since diabetic patients might be subjected to psychological shock (diabetes diagnosis), complications of diabetes or fear from the complications of the diabetes [8].

Despite the studies published in Lebanon, Iran, and United Kingdom indicating that there is insufficient evidence for a relationship between depression and diabetes,[9-11] other studies were published in the United states of America, Saudi Arabia, Bangladesh, China, and South Korea stating that there is a relationship between depression and diabetes [12-18].

Although many studies around the world have been conducted to evaluate the relationship between depression and diabetes, there are very few published studies conducted in Libya to evaluate the relationship between depression and diabetes. Thus, the study was conducted to evaluate the relationship between depression and diabetes in Libya.

2. Methodology

2.1 Study Design

A concurrent case control study was conducted to evaluate the association only between Depression (risk) and diabetes (outcome). It is a cross-sectional case - control association. The Case control study design was preferred over the cohort study design since it is cheap, not takes much time, and requires a smaller sample size than cohort study within the same statistical power [19].

2.2 Sampling procedure, sample size and power calculation

A Sample size formula to calculate the sample size for a case control study was used. Since the prevalence of depression among Libyans for the time period from 2011 to 2023 was 23.68%,[4] the proportion of the risk (depression) among the controls was 24%. Since the prevalence of depression among Libyan diabetic patients was inconsistent according to the different studies,[3,5,6] the proportion of the risk (depression) among the cases was hypothesized to 50%. The ratio of the cases to controls was assigned as 1:1. Confidence interval was 95%. The 2 sided Alpha was 0.05. The study power was assigned as 0.80. Thus, the sample size was 112 (56 cases and 56 controls). Additionally, the sample size was verified by using the EPI TOOLS [20].

Since randomization in Libya is almost impossible [21], the sampling method in the study was convenient sampling for both cases and controls.

2.3 Study population

56 cases and 56 controls were enrolled in the study. Inclusion criteria for cases include the patients who were diagnosed with diabetes and treated in the Benghazi Diabetic Clinic from February to June 2025 of either gender of any age. Exclusion criteria for cases include patients with normal bereavement, diagnosed with bipolar manic depression, on

antidepressant, diagnosed with delusional disorder, diagnosed with Alzheimer's disease, diagnosed with schizophrenia, diagnosed with end stage renal disease, suffering from chronic pain, diagnosed with cancer, diagnosed with hypothyroidism, taking oral contraceptive, taking steroids, taking antiepileptic medications, and taking beta blockers.

Inclusion criteria for controls include the participants from the University of Benghazi. (Security personnel, staff, and teaching staff) during the time period from February to June 2025 who do not have diabetes. Exclusion criteria for controls include the people with normal bereavement, diagnosed with bipolar manic depression, on antidepressant, diagnosed with delusional disorder, diagnosed with Alzheimer's disease, diagnosed with schizophrenia, diagnosed with end stage renal disease, suffering from chronic pain, diagnosed with cancer, diagnosed with hypothyroidism, taking oral contraceptive, taking steroids, taking antiepileptic medications, and taking beta blockers.

2.4 Data collection and management

A written questionnaire was used to collect the data from the participants in the study. The data were collected from the cases (diabetics) and controls (non-diabetics) for the time period from February to June of 2025. The cases were recruited from Benghazi Diabetic Clinics while controls were recruited from the community (University of Benghazi) to avoid control selection bias. In order to preserve temporality, patients with clinically significant depression (moderate depression or moderately severe depression or severe depression) [22], were asked whether the first episode of depression symptoms before or after the diagnosis of diabetes.

The data collected include:

Sociodemographic data: age, gender, level of education, marital status, employment status, income status, family history of diabetes, and family history of depression.

Lifestyle factors data: physical activity, smoking status, sleep pattern, BMI, and controlled diet status.

Other data diseases status other than diabetes (complications of diabetes), and depression status.

In order to avoid the self-report bias, the height and weight were measured for each participant in the study and the BMI was computed by SPSS before starting data analysis. Then, the BMI was categorized into underweight (BMI is less than 18.5), normal weight (BMI from 18.5 TO 24.99), overweight (BMI from 25 to 29.99), and obesity (BMI is 30 or higher) [23]. Since the subjective measurement of physical activity might lead to recall bias and self-report bias, the physical activity was measured objectively. The Metabolic Equivalent Task was calculated according to the duration, the frequency, and the type of exercise to measure the intensity of physical activity[24]. The participants with zero MET were categorized with the sedentary lifestyle, while participants with 0.1 to 14.99 MET were categorized with light or moderate intensity exercise, and the participants with 15 or higher MET were categorized with the high intensity exercise [25]. The depression symptoms status was measured by the (PHQ9). The depression symptoms status was categorized into five groups (No or minimal depression, mild depression, moderate depression, moderately severe depression, and severe depression) [26]. The range of the scoring of the depression symptoms is from 0 to 27 with 10 or higher as the cutoff of the clinically significant depression (major depressive disorders) [6,14]. Since age, gender, family history of diabetes, and family history of depression are confounders in the study according to a previous study [14], and the biological believable facts, these variables were to be adjusted during data analysis by the binary logistic regression test. Since the restriction technique of adjusting confounders (family history of diabetes and family history of depression) during data collection will interfere with the generalizability, the adjustment of confounders during data analysis was preferred.

2.5 Data analysis

The SPSS software version 25 was used to analyze the data. First, the data were entered in

the Excel sheet. Secondly, the data were uploaded to the SPSS. Then, the data cleaning was performed on the SPSS to ensure the accuracy of the results in the study. After that, the descriptive analysis was performed by cross tabulation between the diabetes status variable (outcome) and the independent variables (socioeconomic variables, lifestyle variables, diseases status other than diabetes variable, and depression status variable) to calculate the counts and the percentages. The cross tabulation was performed since all the independent variables and dependent variable were categorical variables. In order to be included in the cross tabulation test, the BMI was recoded into the categorical variable by the SPSS. Additionally, the prevalence of clinically significant depression (major depression disorder) was calculated for both cases and controls. Furthermore, the onset of clinically significant depression (major depression disorder) for the diabetic patients (cases) was calculated according to the cutoff of the depression symptoms, which is 10 or higher. Since the dependent variable (diabetes status) is a dichotomous variable and the independent variables are multiple, the binary logistic regression was used to perform the inferential analysis in the study. The binary logistic regression was preferred over the chi square test since the binary logistic regression can control confounders in the study (age, gender, and the family history of diabetes), and it can calculate the odd ratio of the polychotomous variables. The assumptions for the binary logistic regression (normalcy) were tested before proceeding with the inferential analysis. The data of the study met the assumptions. All the categorical variables were recoded as dummy variables (dummy coding). As a part of the binary logistic regression, the odd ratio was calculated to evaluate whether there is a relationship between each independent variable and a dependent variable. The statistically significant results were to be for P values of less than 0.05 and with the confidence interval ranges do not pass through 1. Finally, the cross tabulation between depression status and the .socioeconomic variables, lifestyle factors, disease status other than diabetes were performed for controls to access the prevalence of depression in controls according to these factors

2.6 Ethical considerations, methods to obtaining informed consent

An approval was obtained from the Benghazi Diabetic Clinic to collect data from the diabetic patients treated in the clinic.

The ethical considerations to engage participants in the study were followed, which include voluntary participation of participants, informed consent from the Participants to participate in the study, Anonymity, and confidentiality.

Additionally, all information taken from the references has been paraphrased to avoid plagiarism.

2.7 Pretest or pilot study

In order to verify that the (PHQ9) questionnaire was valid and reliable according to the culture of the community, a pilot study was conducted in January of 2025. The Patient Health Questionnaire 9 was valid and reliable. The Cronbach Alpha Correlation coefficient was 0.658. Since the Cronbach correlation coefficient is greater than 0.60 [27], the (PHQ9) is reliable. The other parts of the questionnaire in the study were valid since they were taken from the validated questionnaire of a previous study [6].

3. Results and Discussion

According to the socio-demographic characteristics, most controls (50%) were categorized within 35 to less than 55 years old group while most cases (50%) were categorized within 55 years or older group. It is logical since people with 45 years old and older are at high risk of type 2 diabetes [28]. However, the inferential analysis indicated that there is insufficient evidence for a relationship between age 35 years old to less than 55 years old group, and 55 years old or older group and diabetes compared to age group less than 35 year old (p values= 0.997, 0.530 respectively) which is in disagreement with a study in Bangladesh [14], which showed the statistical significant association between age groups and diabetes.

Additionally, most of the controls (71.4%) and most cases (67.9%) were female. Also, inferential analysis showed that there is insufficient evidence for the relationship between gender and diabetes (p value= 0.150), which is in agreement with a study in Bangladesh [14].

Furthermore, most of the controls (62.5%) were categorized with undergraduate degrees, while most cases (30.4%) were categorized with primary or middle school as their highest level of education. It is logical since a high level of education decreases the risk of disease according to the general knowledge about the topic[29]. However, the inferential analysis indicated that there is insufficient evidence for a relationship between educational levels and diabetes compared to illiterate (p values= 1, 0.999, 0.999, 0.998), which is not in agreement with a study in Bangladesh [14].

Moreover, most of the controls (57.1%) were singles while most cases (67.9%) were married. At the same time, the inferential analysis stated that there is a relationship between marriage and diabetes compared to single individuals group (p value= 0.014, odd ratio= 49.742, 95% CI 2.193 to 1128.483), which is consistent with another study [14]. However, the confidence interval range is very wide. It is an imprecision due to the small sample size.

In addition to that, 58.9% of controls and 33.9% of cases were governmental employee. Also, the inferential analysis showed that there is insufficient evidence for a relationship between the employment status with different categories and diabetes compared to unemployed group (p values= 0.806, 0.397, 0.999, 0.236), This is inconsistent with the Bangladeshi study [14]. Also, most controls (53.6%) earned income between 1000 to less than 3000 Libyan Dinar, while most cases (30.4%) earned income between 500 to less than 1000 Libyan Dinar. Further, the inferential analysis proved that the income levels were not related to diabetes compared to income less than 500 Libyan Dinar (p value= 0.168, 0.736, 0.373), which agrees with another study [14].Finally, the percentage of controls (35.7%) to have a family history of diabetes was higher than the percentage of cases (26.8%) to have a family history of diabetes, which is not in agreement with the general knowledge about the topic [30]. Besides, the inferential analysis indicated that the family history of diabetes was not related to diabetes (p value=0.453). Since the sampling procedure in the study was convenient sampling, it might be the characteristics of the sample in the study were different from the general population. Thus, the study could be subjected to the selection bias.

Based on the lifestyle factors, most controls (75%) and cases (92.9%) were nonsmoker. On the other hand, 5.4% of cases and 17.9% of controls were active smokers. Further, the inferential analysis revealed that smoking status with different categories was not related to diabetes compared to non-smokers (p values=1, 0.999, 1, 0.097). It is rational since diabetic patients are usually recommended by their doctors to stop smoking in order to increase their insulin sensitivity.[1]. However, the results are not in agreement with a previous study published in Bangladesh [14].

Additionally, most controls (60.7%) and cases (49.1%) were categorized as a controlled diet sometimes. On the other hand, 14.5% of cases and 8.9% of controls adhered to a controlled diet. At the same time, the inferential analysis stated that the controlled diet status with different categories was not related to diabetes compared to “not controlled diet” group (p values= 0.336, 0.728).It is justifiable, since doctors usually recommend diabetic patients to adhere to a controlled diet to control blood glucose level to decrease the risk of complications of diabetes [1].

Furthermore, most controls (53.6%) and cases (39.3%) suffered from sleeping disturbance sometimes. On the other side, the high percentage of the cases (33.9%) and controls (25%) suffered from sleeping disturbance. Besides, the inferential analysis indicated that the sleeping disturbance status with different categories was not related to diabetes compared to “no sleeping disturbance” group (p values=0.392, 0.734). It is sensible since the prevalence of sleep issues among Libyans is very high, whether for diabetic or non-diabetics, according to a previous study published in Libya [31].

Moreover, most of the controls (39.3%) were overweight while most cases (53.6%) were obese. In addition to that, the inferential analysis indicated that the BMI was related to diabetes (p value=0.013, odd ratio= 1.136, 95% CI= 1.027 to 1.257). It is logical for the highest percentage of diabetic patients to be obese, since there is a bidirectional relationship between obesity and diabetes [32]. Also, it is logical for the high percentage of non-diabetic Libyans to be overweight, since most Libyans follow an unhealthy lifestyle [33]. The results are in agreement with a previous study published in Bangladesh [14].

Finally, most of the controls (41.1%) and cases (58.9%) adhered to light or moderate intensity exercise. In addition to that, the percentages of cases and controls which adhered to the high intensity exercise were 1.8% and 17.9% respectively. Further, the inferential analysis stated that the physical activity with the different categories was not related to diabetes compared to the sedentary lifestyle (p values= 0.736, 0.111, 0.495). It is rational for diabetic patients to adhere to moderate intensity exercise as it is a part of the lifestyle modification that is recommended by doctors for diabetic patients.[1] Also, it is justifiable that the lowest percentage of cases adhere to high intensity exercise, since it is recommended for diabetic patients by doctors to avoid the high intensity exercise especially if the blood glucose level is not controlled [34].

As stated by the disease status other than diabetes, most controls (87.5%) and cases (44.6%) were categorized with “no diseases”. group Further, most cases were diagnosed with eye diseases (21.4%) while a very low percentage of controls (3.6%) were diagnosed with eye diseases. At the same time, the inferential analysis indicated that eye diseases were related to diabetes (p value= 0.001, odd ratio = 18.196, 95% = 3.312 to 99.972), which is in agreement with a previous study published in Bangladesh [14]. Odd ratio indicated that diabetes is related to eye diseases. It is sensible since diabetes causes retinopathy according to the general knowledge about the topic.[1] However, the confidence interval range is wide. It is an imprecision due to the small sample size

As indicated by depression status, most cases (50%) and controls (38.2%) were mild depressant. At the same time, 23.6% of controls and 22% of cases were suffered from moderate depression. Additionally, 5.5% of controls and 4% of cases were suffered from moderately severe depression. Furthermore, 7.3% of controls and 4% of cases were suffered from severe depression. See table 1. Notably, the differences in the percentages between the cases and controls according to the depression status were very small. Thus, the inferential analysis indicated that the depression status with the different categories was not related to diabetes compared to no or minimal depression (p values=0.121, 0.752, 0.883, 0.915), which is in agreement with other studies published in Lebanon, Iran, and United Kingdom [9-11]. However, the findings are in disagreement with the general knowledge about the topic and the previous studies published in the United States of America, Saudi Arabia, Bangladesh, China, and South Korea [12-18]. See table 2 for further information. Since the sample used for analyzing the relationship between depression and diabetes was 100, thus there were missing data as the total sample size was 112. As the depression variable was string when it is uploaded from excel to spss, the missing data were handled through treating blanks as user missing values when the variable is automatically recoded to numeric variable.

As stated by the major depression disorder (clinically significant depression), the prevalence was a little bit higher for controls (36.4%) than for cases (30%). See figure 1.

According to the onset of major depression disorder (clinically significant depression), most diabetic patients (86.7%) were exposed to the first episode of depression symptoms after the diagnosis of diabetes. See figure 2. It is logical since people might be shocked from the diagnosis of diabetes or it might be due to the psychological stress from the possibility of the occurrence of diabetic complications which might lead to depression for diabetic patients [8].

Since the analysis indicated that there is no relationship between depression and diabetes, the reasons about that were evaluated by performing cross tabulation between independent variables and depression for controls (non-diabetics). The analysis indicated that a high percentage of controls were categorized as a very low income level, to be with a Low level of education, to be married (marital conflicts), to be a governmental employee (workplace conflicts), and to follow an unhealthy life style (passive smoking, sleeping disturbance, uncontrolled diet, overweight, and obesity) therefore, depression is also prevalent among non-diabetics (controls).

For diabetic patients, almost half (44.6%) of them did not have any diabetic complications. Thus, this is considered other reason why there is insufficient evidence for the relationship between depression and diabetes.

Table1. Depression categories distribution for cases and controls

Variable		Cases		Controls	
		N	%	N	%
Depression status	No or Minimal depression	10	20%	14	25.5%
	Mild depression	25	50%	21	38.2%
	Moderate depression	11	22%	13	23.6%
	Moderately severe depression	2	4%	3	5.5%
	Severe depression	2	4%	4	7.3%

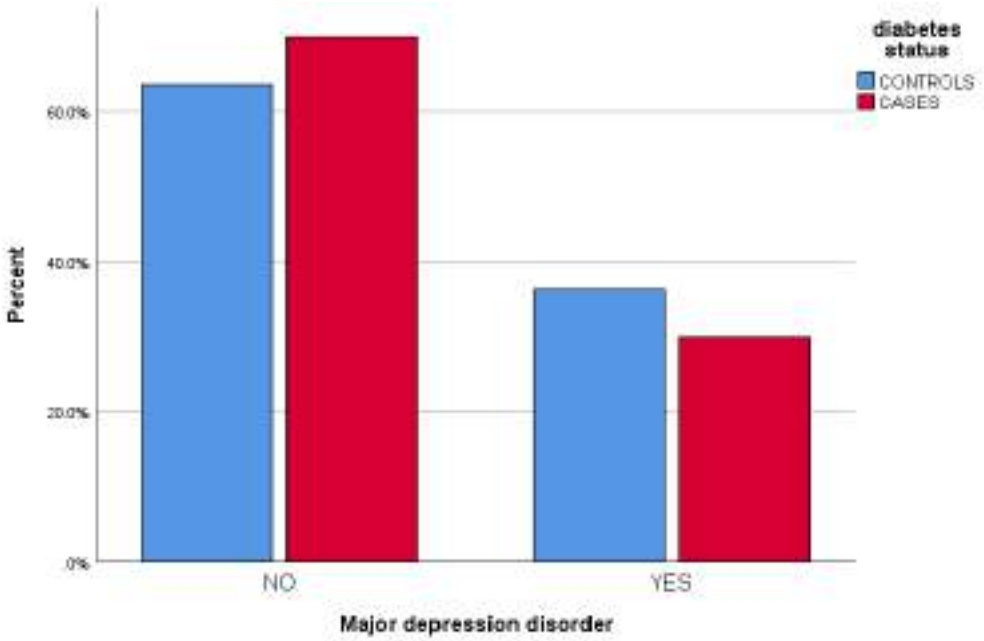


Figure1. Bar chart shows the percentages of Major Depression disorder among cases and controls

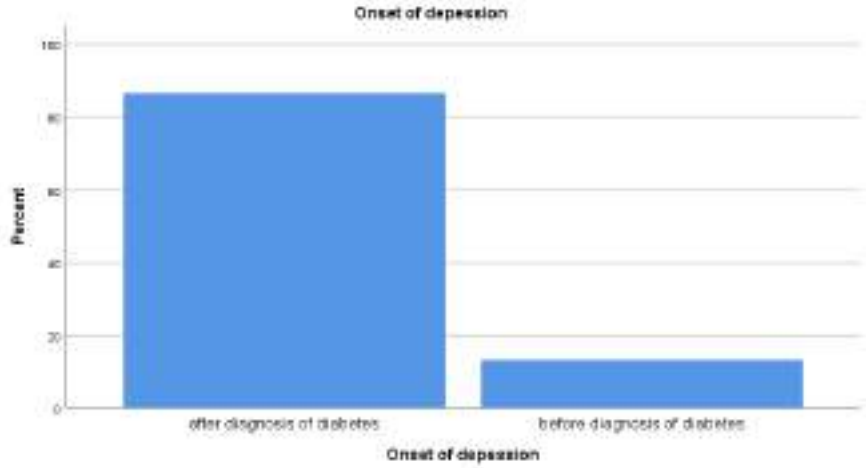


Figure2. Bar chart shows the onset of depression among the diabetic patients (cases)

Table2. The key inferential analysis tools to access the relationship between depression and the diabetes status by using binary logistic regression.

Statistical tools	*P value*	Odd ratio	95% CI	
			Lower	Upper
No or minimal depression (reference)	0.304			
Mild depression	0.121	2.567	0.779	8.461
Moderate depression	0.752	0.786	0.177	3.501
Moderately severe depression	0.883	0.824	0.063	10.700
Severe depression	0.915	0.876	0.077	9.977

4. Conclusion and Recommendations

The study indicated that there is insufficient evidence for the relationship between independent variables (socioeconomic variables, lifestyle variables, complications of diabetes, and depression) and diabetes except for the relationship between independents variables (marriage, BMI, and eye diseases) and diabetes which were statistically significant.

It is recommended to conduct further studies on the same topic, since the study is one of a very few studies that have already been

conducted in Libya to evaluate the relationship between depression and diabetes.
It is recommended for conducting sensitivity or matching analyses in a future study.
Additionally, it is recommended for health educators to encourage the Libyan people to adhere to a healthy lifestyle which includes smoking cessation, to sleep well, to adhere to a healthy diet, and to decrease weight. Moreover, health educators should recommend Libyan people starting from the age of thirties to adhere to the screening test for depression.
Furthermore, it is recommended for health educators to encourage diabetic patients to follow a healthy lifestyle which includes sleeping well, to adhering to a controlled diet, and to decrease weight in order to control the blood glucose level and to prevent depression.
In addition to that, it is recommended for health educators to encourage diabetic patients to adhere to the depression screening test.
Finally, it is recommended for health educators to encourage patients with the depression but not diabetic yet to follow a healthy lifestyle in order to relief the depression symptoms and to decrease the risk of diabetes.

5. Limitations of the study

Since randomization is almost impossible in Libya due to many factors, including lack of a strong database in Libya, the sampling procedure was convenient sampling (participants not randomly selected), which might lead to the study being subjected to selection bias. The selection bias is clear in the study for the percentage of the family history of diabetes, which is higher for controls than cases. Additionally, the selections bias is clear in the study, since the percentage of major depression disorder is higher in controls than in diabetics
For controls, it might be possible for some of them to have diabetes, but they were not to be diagnosed with diabetes (subclinical cases).
The Patient Health Questionnaire 9 is used for the screening of depression and to measure the severity of depression symptoms, but it is not used for diagnosis of clinical depression.
Finally, the diabetic complications were to be self-reported by the participants, which might lead to the study being subjected to the self-report bias.

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Conflict of Interest

No conflict of interest was declared by Authors.

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Research Article

Cross-Sectional Analysis of Carcinogenic Chemical Exposure in Healthcare Facilities: A Case Study from Benghazi

Fawzeia H. Elmhalli* and Asma B. Elshebani

Department of Infectious Disease, Public Health Faculty, University of Benghazi, Libya

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ABSTRACT

Chemical substances used in hospital environments, including potential carcinogens, pose significant risks to both patients and healthcare workers. This study aimed to evaluate carcinogenic substances present in the formulations of selected chemicals used in hospitals and healthcare centres, including pesticides, air fresheners, detergents, and sterilisation agents. A cross-sectional study was conducted using two tools: a structured questionnaire and observational checklist to collect data from four healthcare centres in Benghazi (HGH, BMC, SAC, and SHC). A total of 94 participants were included, with the sample size calculated for an unknown population using a Z-score corresponding to an 80% confidence level. The identified products were categorised into four groups according to their function, and the presence of carcinogenic substances was analysed. Among the 54 chemical products assessed, 14 were found to contain highly hazardous compounds classified as prohibited by the World Health Organization. The results highlight the need for continuous monitoring and systematic documentation of chemical agents used in healthcare locations to reduce occupational and patient exposure to carcinogenic substances. It is recommended that Infection Control Offices maintain comprehensive records of all chemical agents in use and exercise direct oversight over their application.

*Corresponding author
Email address: fawzeia.almhalli@uob.edu.ly

1. Introduction

Health workers are exposed to many chemicals daily that may harm their health and cause health problems [1,2]. Therefore, the handling of these chemicals is considered a source of concern [3], and relevant staff must pay attention and monitor regular amounts used [4]. They are encountered in the context of diagnostic and therapeutic procedures, in laboratory work, in preparation and cleaning activities [1,5]. Health care is consistently one of the most labour-intensive industries, yet this issue has received little attention from those involved in occupational health and safety research and regulation [6]. Most chemicals commonly used in hospitals and other healthcare settings are not covered by national and international occupational exposure standards [7]. To date, little effort has been made in tracking the chemicals most used, let alone study the mechanisms and severity of exposure and the epidemiology of the effects on the healthcare workers involved **[**8]**.** Healthcare workers are regularly exposed to accidental chemical hazards through incidental contamination or prolonged exposure. APP (Accidental Poisoning and Pollution)[9]. Numerous chemicals used in healthcare are considered volatile organic compounds. [10]. Proper use of chemicals and pesticides is important for preventing contamination of the environment. Exposure to the chemical varies depending on whether it is a hospital or clinic and according to which department in the hospital. Chemicals can be categorized into several types, such as disinfectants, sterilizers, detergents, air fresheners, and pesticides [11, 4]. Carcinogenic chemicals cause malignant tumors, increase their incidence, and reduce the latency period required for tumor formation. [12].Through their use as air fresheners, pesticides, or detergents, these carcinogens are intentionally released. Excessive spraying and gas emissions may cause cancer and malignant tumours associated with pesticides, especially in children, who are the most highly sensitive group to the carcinogenic effects of pesticides.
Many pesticides are used in hospitals to eliminate pests [9], which are considered dangerous, more toxic, and cause chronic effects. More than 150,000 people die each year from pesticide poisoning. Most deaths result from self-poisoning through ingestion, not from occupational or accidental exposure, which is usually topical or through inhalation. [13]. There is evidence on the association between long exposure to pesticides in occupational locations and a higher incidence of chronic diseases [14], including different types of cancer [15]. However, data on non-occupational exposures are too scarce to allow for any conclusions to be drawn [16].

The aim of the study is to identify the chemical substances used in hospitals and health clinics, compare their components with the recently issued list of carcinogens from the World Health Organization, and determine the methods of selecting, using, and storing them, as well as their compliance with safety and security procedures..

2. Methodology

2.1 Study Area

The study was conducted in the city of Benghazi, the second most populous city in Libya, which had an estimated population of 1,207,250 in 2020. [17]. Located on the north-eastern Mediterranean coast, Benghazi is administratively divided into 30 zones and includes major healthcare facilities. The study was conducted at Al-Hawari General Hospital and Benghazi Medical Center, as well as at polyclinics including Al-Sabri Clinic and Shabna Clinic

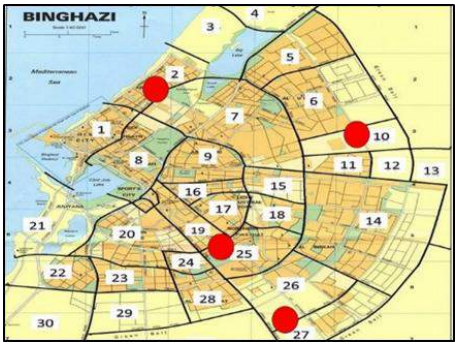


Figure 1.Locations of the selected healthcare facilities in Benghazi

2.2 Study Design

A cross-sectional quantitative design was employed to evaluate the presence of carcinogenic substances in chemical products, including pesticides, air fresheners, detergents, and sterilizing agents, used in selected healthcare facilities in Benghazi. A random sample of two hospitals and two polyclinics was evaluated. Data were collected using two tools: a structured questionnaire administered through interviews with infection control personnel and managers, and an observational checklist adapted from the

Integrated Pest Management Toolkit developed by the Statewide IPM Program and the California Department of Pesticide Regulation was used for on-site monitoring and inspection [18].

2.3 Study Participants

The sample size was 94 health workers from four health centres, determined using sample size formula unknown population: $N = Z^2 \times P (1 - P) / e^2$ (19). Where are: Z-score at 80 % Confidence Interval, Z= 1.28, Standard deviation, P = 0.5, Margin of error, e = 6.6 %, $N = 1.6384 \times 0.5 (1 – 0.5) / 0.004356$, N = 94.

Table1 : Hospital Names, Sample Size of Study ParticipantsAnd Time Of Data Collection

Hospitals	Sample	Date
HGH	40	February 13 to March 3
BMC	25	February 4 to February 27
SHC	15	February 4 to February 11
SAC	15	February 4 to February 20
Total	94	February 4 to March 3

Participants were selected using systematic sampling from four health care centres and hospitals showed in (Table 1). The study participants were from the infection control office, a cleaning company or were nurses. Collected data started in 4th of February until 3rd of March 2024.

2.4 Statistical Analysis

The questionnaire and the checklist collected the data, were analysed using the Statistical Package for the Social Sciences (SPSS) software (version 22) to generate descriptive statistics, including frequency tables and bar charts.

3. Results and discussion

31 A structured questionnaire

The results from the questionnaire indicate who is responsible for selecting the chemicals used in the four health centres (Figure 2). In BMC, the responsible party is the pest control company, with a small percentage of decisions influenced by the hospital's Infection Control Office. Al Hawari hospital shows similar results. In Al-Sabri, however, chemical selection is mainly the responsibility of the administration, followed by the pest control office. At Shabna Clinic, the responsible party is the Infection Control Office.

The questionnaire also showed that approximately 56.4% of the materials used were of unknown origin, and in 72% of cases, the containers did not include labels describing their internal contents (Figure 3).

Regarding storage methods, the study found that in 45% of the health centres, storage practices are determined by administrative decisions (Figure 4). Meanwhile, 55% do not follow international standards for the storage of these chemicals. The Infection Control Office is primarily responsible for setting prevention standards in all centres (57%), followed by hospital administration (23%). However, the actual rate of implementation of these protective standards among workers was only 51%.

Furthermore, 66% of workers reported cases of cancer occurring in these centres during their period of employment.

3.2 Observational Checklist

The results obtained from the observational checklist, based on interviews with managers and infection control personnel, the collected data were categorised into four groups: pesticides,(Table 2), sterilization (Table 3), air fresheners (Table 4) and detergents (Table 5), the four tables showed the carcinogenic substances that were present in the formulations of some chemicals used in hospitals and other health care centres. The substances were divided into two categories: approved or banned according to list of classifications of cancer substances to humans,

from the international agency for research on cancer (IARC) at WHO (IARC Monographs Volumes 1–135). Figure 5 indicated that 25% of the chemicals used at the four-study areas were carcinogenic. However, this percentage differed according to each of these materials that we listed and the percentage of their presence in each hospital

Figure 6 shows the frequency in the presence

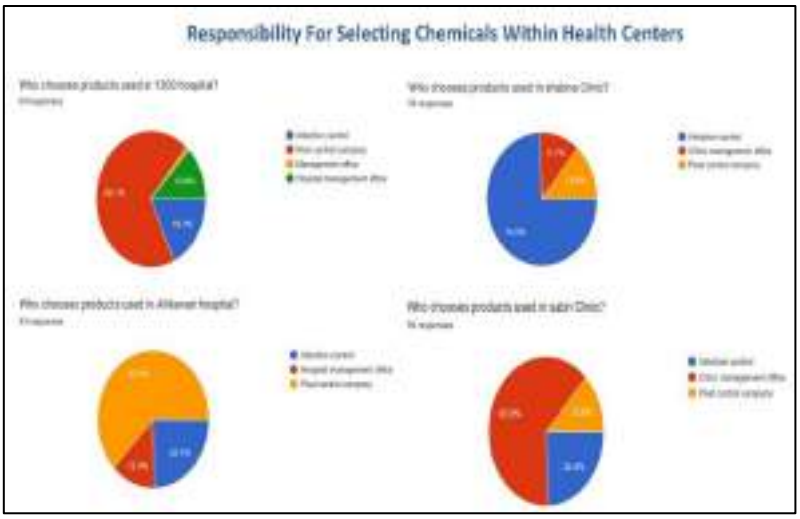


Figure 1. Responsibility For Selecting Chemicals Within Health Centers

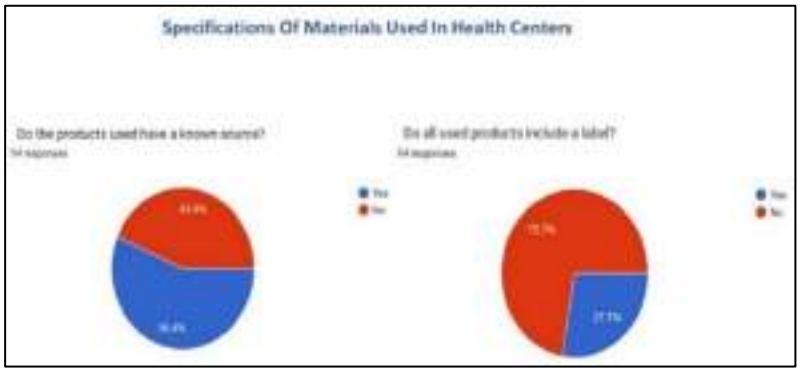


Figure 2. Charts show the percent of known sourcesthose without a labe

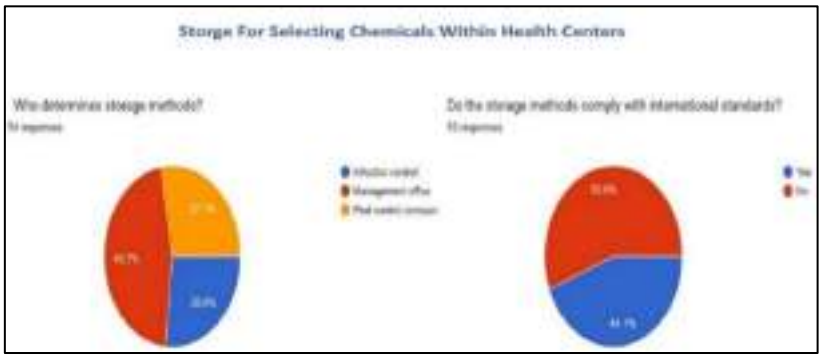


Figure 3 Storage For Selecting Chemicals Within Health Centers

of this substance and the percentage of its presence in each hospital. This leads us to the second part of this study with the results from the checklist. Out of the 54 products investigated throughout the four-health care facilities, around 14 of them had a highly

hazardous substances that is banned in other countries based on the database of pesticides action network [20] International and/or WHO [21] as class 1b. According to these database there are 8 pesticides each under the category of medium-risk (class II) and low risk (class III) pesticides, respectively. Twenty-seven pesticides are registered for use in Libya under Category U (unlikely to cause any hazard). The most used is the Helak pesticide, which contains Cypermethrin , Tetrametrine, and Germ off disinfectant. Quantitatively. In this study about 75% of the total pesticides found to be used, were classified as extremely or highly hazardous pesticides, which aligns closely with results from a recent study conducted in India [14]. Ethylene oxide which is the most widely used disinfectant currently, is considered a toxic substance of the first degree because it causes breast cancer and leukaemia [1]. Ethylene Oxide gas is widely used today as disinfectant in many health care settings, it has been linked to allergic contact dermatitis and serious health conditions, including breast cancer or leukaemia. Despite limited evidence for human cancers, it is also classified as Group 1 carcinogen [20,22]. Contamination can still occur in hospitals, even when trained staff carefully follow safety guidelines and monitoring procedures. This underscores the need for healthcare facilities to carry out regular monitoring and to continuously strengthen risk-management strategies and protective measures. Efforts should focus on developing monitoring systems that are practical, efficient and less expensive.

In this study, nearly 66% of healthcare workers knew someone who had been diagnosed with cancer during their years of work, so these finding suggest that long lasting monitoring and systematic records keeping could help identify the risks related to toxic chemicals exposure[4].

Table 2. Approval status of pesticides: 8 of 18 in use were approved

Pesticide	**Chemical integrated**	**R.U**	**P.S**	**Hospital**
1. Helak	cypermetrine, which has a deadly effect, tetrametrine, and piperonyl butexide	Yes	Banned	HGH, BMC
2. Raid	Sumithrin0.136%, prallethin 0.109%, DI water 52.432%, propellan, solvent & other ingredient 47.323%	Yes	Approved	BMC, HGH SHC, SAC
3. Cychloros 55% EC	Chlorpyrifos50%, Cypermethrin 5%	Yes	Banned	HGH
4. AbaMectin	Abamectin1.8%	Yes	Approved	HGH
5. Murin facuom past	Brodifaxoum, Denathonium Benzoatw, palatable substances &Co-formulates	Yes	Approved	HGH
6. AMP 2CL	Acetamiprid puro	Yes	Banned	HGH
7. Cyhpeno max	Cyphenothrin 10%	Yes	Approved	HGH
8. lambda cyhalothrin	Pyrethroids	Yes	Approved	HGH
9. bromadiolone	Broprodifacoum; Bromatrol	Yes	Approved	HGH
10. raviox	Difenacom	Yes	Approved	HGH, BMC
11. General Disinfectan	Chloroxylenol 0.36%	Yes	Approved	BMC
12. Cyperx	Cypermethrin 10%, Tetramethrin 2%PBO 10%	Yes	Banned	BMC
13. Delta_Vam 5 Sc	Deltamethrin 5%	Yes	Banned	BMC
14. DK10.2, Microcapsule	Cypermethrin (CASN.52315_07_8)10g	Yes	Banned	BMC
15. Tetra	Tetramethrin (CASN.7696-12-0) 2g	Yes	Banned	BMC
16. Piperonilbutossido, 17. Coformulanti	Piperonilbutossido,(CASN.51.03.6) 10g, Coformulanti q.b.a 100g	Yes	Banned Banned	BMC
18. Tornado CS	Lambda_cyhalothrin 10%	Yes	Banned	BMC

Equation 1. R.S> Ready to Use, P.S> product states

Table3 . Approval status of sterilizers: 4 of 17 in use were banned.

Sterilizers	**Chemical integrated**	**R. U**	**P. S**	**Hospital**
1. SaniBact.TRU	Unknown	Yes	Approved	All
2. Zhermack	Unknown	Yes	Approved	SHC
3. Cidex	Citrinex 15%	Yes	Banned	SAC, HGH
4. Novadex-DA	Glutaraldehyde 2% nasal toxicity	Yes	Approved	SHC
5. Kohersolin FF	Glutaraldehyde 50 mg/g, benzyl-C12-18-alkyldimethyl-ammonium chlorides 30 mg/g, chloride 30 mg/g	Yes	Approved	HGH
6. Prodex	5,75formencetale400g glutaraldehyde perthantal) Surfactants, conosion whetors, preservatetary.	Yes	Approved	BMC
7. DR. DEEP	Mineral Water, Shea Butter, Ceramide, BSASM, Jojoba Seed Oil, green tea, chamomile, Centella Asiatica, rosemary, licorice and more.	Yes	Approved	BMC
8. Povoiderm	Iodine	Yes	Banned	BMC
9. korsolex	Glutaral and 15,2 g, (ethylenedioxy) dimethanol: 19,7 g	Yes	Approved	SHC
10. Bactinyl 5M	Peroxides, quaternary ammoniums, and ethanol.	Yes	Approved	SHC
11. Germ _off	Alcohol 77% &Aloe vera	Yes	Banned	SHC, HGH
12. Seni hand	Alcohol> 70%	Yes	Banned	SHC
13. MYCARE	Alcohol75%	Yes	Banned	SHC
14. Alcohol	Methanol 96%	Yes	Approved	SHC
15. Quiclear	Active ingredient: benzalkonium chloride, Inactive: Aqua, benzalkonium chloride. Glycerin, perfume	Yes	Approved	SHC
16. Hand soap	Sulfate, Cocamidopropyl Betaine, Cocamide DEA, Cocamidopropylamine Oxyde, Citric Acid, Sodium Chloride, Glycerin, DMDMHydantoin	Yes	Approved	SHC, HGH
17. Dettol	Chloroxylenol, palm oil, titanium, mugo pine	Yes	Approved	HGH, BMC, SAC

Table4 . Approval status of air fresheners: 3 of those in use were approved

A.Freshener	**Chemecal integrated**	**R.U**	**P.S**	**Hospital**
1. Lamis	Stabilizers, perfumes, preservatives, purified water	Yes	Approved	HGH, BMC, SAC
2. Touri	Stabilizers, perfumes, preservatives, purified water	yes	Approved	HGH, BMC
3. Frida	Perfume, water, preservatives, and emulsifiers	Yes	Approved	HGH
4. Frisia	Unknown	Yes	Unknown	SAC
5. Fresh	Lilac and lavender perfume, preservatives	Yes	Unknown	SAC

Table5 . Approval status of Detergents: 6 of 12 in use were approved

Detergent	Chemical integrated	R.U	P.S	Hospital
1. Fema	Calcium carbonate 30%, industrial detergent and odor 50%	Yes	Approved	HGH, BMC, SAC
2. Vixal	Chlorine	Yes	Approved	HGH, BMC, SHC
3. Clorox	Sodium hypochlorite 5%	Yes	Approved	HGH, BMC, SAC
4. Vanish	Hydrogen peroxide, anionic surfactants,	Yes	Approved	HGH
5. Yeri _ sol	Unknow	Yes	Unknow	HGH
6. Happy	Unknown	Yes	Unknow	HGH, BMC, SAC
7. Fax	Unknow	Yes	Unknow	BMC
8. Cesris	Unknow	Yes	Unknow	BMC
9. Maxellmagic	Unknow	Yes	Unknow	BMC
10. Caled	Unknown	Yes	Unknow	BMC
11. Loryal	Non-ionic surfactants <0%, fragrance, methylchloroisothiazolinone,, methylisothiazolinone	Yes	Approved	HGH
12. Stainl steel	Unknown	Yes	Approved	HGH

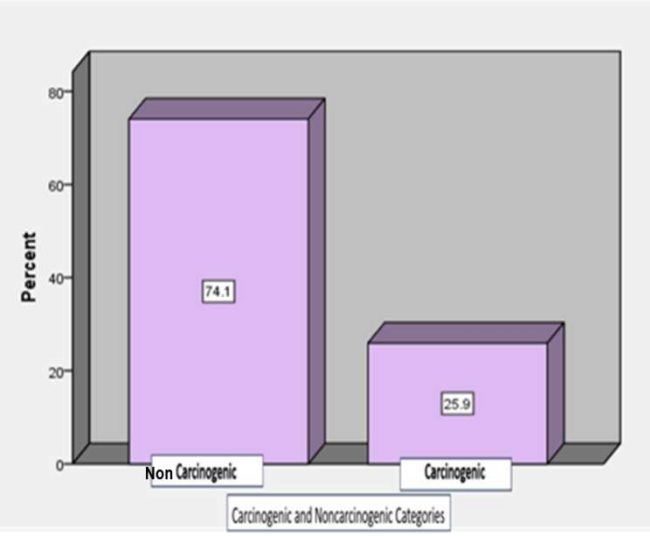


Figure 4. Carcinoginc and Non.Cacinogrnic Categories

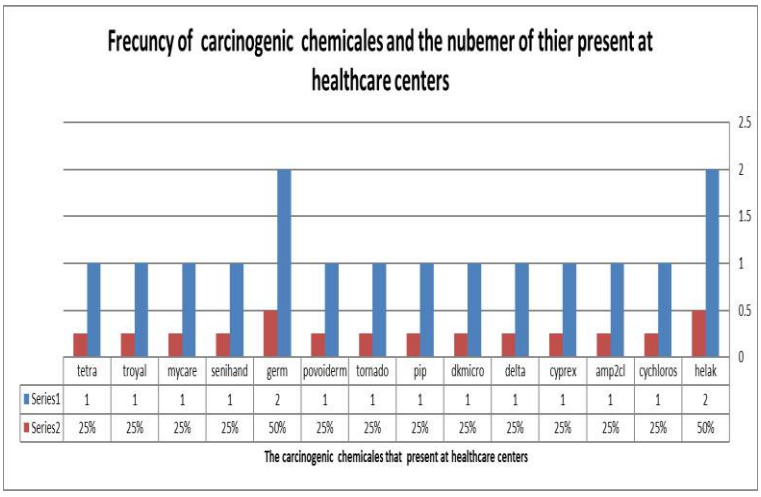


Figure 6. Frequency and percentage of the substance detected in each hospital

4. Conclusions

The study concludes that many materials used in health centres contain dangerous materials, and long-term exposure to these chemicals may lead to many diseases, including tumours and cancers. The questionnaire has proven that many workers in health centres are affected by tumours, as well as general absence of consideration in prevention procedures and prevention programs. The study therefore recommended that healthcare facilities be routinely monitored continuously to improve risk management plans. Protective equipment must also be used which makes monitoring simpler, faster, and less expensive. Ensuring the quality of chemicals while knowing their sources is very important. The place and methods of storage must comply with international health standards. The Office of Infection Control should also inspect the materials used, use them under their supervision, and train workers to protect themselves is necessary and imperative.

6. Ethical Consideration

The study protocol, being questionnaires, interviews, and the checklist were all authorized by the Administration at the Department of Public Health in the Public Health faculty. The study was authorized by the hospitals administration and the head of the Environmental Health Office in each of the four hospitals.

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Conflict of Interest

The authors declare no conflicts of interest.

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Research Article

Actemra Therapy and Survival Outcomes in Critically Ill COVID-19 Patients: A Retrospective Analysis

Monier. Mohammed[1], Aimen M. Khalifa[2], Ghada Ali S. Abbas[1] and Guma M.K. Abdeldaim[1]

[1]Department of Medical Microbiology, Faculty of Medicine, University of Benghazi,
[2]Department of Medicine, Faculty of Medicine, Elmarj, University of Benghazi, Libya

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ABSTRACT

Tocilizumab (Actemra), an interleukin-6 receptor antagonist, has demonstrated potential as a therapeutic option for severe COVID-19 by mitigating the hyperinflammatory response associated with disease progression. This study aimed to assess the impact of Actemra therapy on survival outcomes among hospitalized patients with severe or critical COVID-19 in a real-world setting. A retrospective observational cohort study was conducted at a COVID-19 isolation center in Al-Marj City, Libya. Adult patients with severe or critical COVID-19 admitted between August 2020 and December 2021 were included. Data on demographics, clinical status, and laboratory results were extracted from medical records. The primary outcome was survival status, with secondary outcomes being hospital stay length and hospitalization-free survival time. A total of 195 patients were included (median age 58 years; 71.3% male), of whom 26.2% received Actemra. The Actemra group had higher ICU admission rates, gastrointestinal symptoms, and CPAP use, but reduced the prevalence of diabetes and hypertension. Actemra recipients experienced longer hospital stays and higher levels of inflammatory markers. Kaplan–Meier analysis revealed significantly longer survival in the Actemra group (mean 29.9 vs. 10.1 days, $p < 0.001$). Cox regression indicated a 77% reduction in hospitalization risk with Actemra (HR 0.230, $p < 0.001$). Logistic regression showed over fourfold increased survival odds (OR 4.552, $p = 0.001$). The study concluded that Actemra therapy significantly improved survival and reduced hospitalization risk in severe and critical COVID-19 patients. These findings support its targeted use in hyper inflammatory patients, with further randomized trials needed to confirm benefits and safety.

*Corresponding author
Email address: monier.mohammed@uob.edu.ly

1. Introduction

The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is responsible for the coronavirus disease 2019 (COVID-19), which has emerged as one of the most pressing global health issues of the 21st century. Because it was the first time it was identified
The pandemic has placed a significant burden on healthcare systems around the world, resulting in widespread sickness and mortality in late 2019. Severe COVID-19 infections are frequently linked to high death rates, multi-organ failure, and acute respiratory distress syndrome, particularly in those who are hospitalized or critically ill patients [1, 2].
A characteristic feature of severe COVID-19 is the emergence of a hyperinflammatory condition, commonly referred to as a cytokine storm. This condition is characterized by marked increase levels of pro-inflammatory cytokines, such as interleukin-6 (IL-6), and is associated with rapid clinical deterioration [3, 4]. Elevated IL-6 levels are strongly correlated with disease severity, increased oxygen requirements, prolonged hospital stays, and higher mortality rates [5]. Consequently, targeting IL-6 inhibition has emerged as a promising therapeutic strategy to reduce the inflammation and improve clinical outcomes in patients with severe COVID-19 [6].
Tocilizumab (Actemra), a humanised recombinant monoclonal antibody that inhibits both soluble and membrane-bound IL-6 receptors, blocks IL-6–mediated signalling and has been widely used in treating autoimmune and inflammatory diseases [6]. The potential benefits of Tocilizumab in COVID-19 include reducing inflammation, preventing progression to respiratory failure, and enhancing survival. Numerous randomized controlled trials (RCTs) and meta-analyses have investigated this potential benefit, yielding mixed results. The RECOVERY trial found that adding Tocilizumab when added to standard care significantly reduced mortality in hospitalized, hypoxic COVID-19 patients with elevated inflammatory markers [7]. Similarly, the REMAP-CAP trial reported improved survival and reduced progression to organ support in critically ill patients [8]. However, other studies, such as the COVACTA trial, did not find significant differences in mortality or clinical status at day 28 [9], while smaller RCTs and observational studies reported varied outcomes [10, 11]. This variability is reflected in systematic reviews; some meta-analyses report a significant reduction in mortality and increased hospital discharge rates [12, 13], while others note that analyses limited to peer-reviewed RCTs sometimes fail to find a significant association [13]. Additionally, the drug's safety profile, particularly concerning the increased risk of secondary infections, remains a topic of discussion [12]. A significant gap persists in real-world evidence from low- and middle-income countries (LMICs), as the current body of research on this intervention is predominantly derived from high-resource settings where healthcare infrastructure and patient populations may not be comparable. The present study was undertaken to assess the impact of Actemra therapy on survival outcomes within a real-world hospital context. Even in a low-resource environment, we predicted that Actemra treatment would be linked to better survival among severely sick COVID-19 patients.

2. Methodology

2.1.Study Design and Location

A retrospective observational study was carried out at the COVID-19 Isolation Center in Al-Marj City, Libya.

2.2.Study Population

The study included adult patients aged 18 years and older who were admitted to the isolation center between August 2020 and December 2021 with a clinical classification of severe or critical COVID-19. Confirmation of SARS-CoV-2 infection was confirmed by positive real-time reverse transcription polymerase chain reaction (RT-PCR) test performed on nasopharyngeal swab samples, or by a validated rapid antigen test.

The inclusion criteria required that patients be admitted to the isolation center during the

study period, have laboratory confirmed SARS-CoV-2 infection, and meet the definition of severe or critical COVID-19 based on clinical and radiological assessments.

The exclusion criteria included patients with incomplete medical records and those who were moved to another hospital before their clinical outcomes were assessed.

2.3.Data Collection

The data were collected from the hospital's electronic and paper medical records using a standardized data collection form. The variables collected included demographic information such as age, sex, and vaccination status; comorbidities such as diabetes, hypertension, cardiovascular disease, chronic kidney disease, respiratory disease, and cerebrovascular accident; clinical characteristics including ICU admission, CPAP use, and respiratory or gastrointestinal symptoms; and laboratory findings such as complete blood count, renal and liver function tests, inflammatory markers (CRP, ferritin, D-dimer, lactate dehydrogenase, and procalcitonin), cardiac markers (troponin and CK-MB), and blood gas parameters. Treatment-related data included the receipt of Actemra and other supportive or pharmacological therapies. Outcomes assessed were survival status (alive or deceased), length of hospital stay, and hospitalization-free survival time. Due to the fact that the study was retrospective and used anonymized data, the need for patient consent was waived. All data were handled in accordance with the Declaration of Helsinki and the national data protection regulations.

2.4. Statistical analyses

IBM SPSS Statistics (version 22; IBM Corp., Armonk, NY, USA) was used to analysed the data. Differences between categorical variables were assessed using the chi-square or Fisher's exact test, depending on the data distribution. (Actemra vs. non-Actemra). Continuous variables which were reported as medians and interquartile ranges (IQRs) were compared using the Mann–Whitney U test. For survival analysis, time-zero was defined as the date of hospital admission. The primary outcome was time to death, with patients discharged alive censored on their date of discharge. The Kaplan-Meier method was used to estimate survival distributions, which were then compared using the log-rank test. A Cox proportional hazards regression model was used to estimate adjusted hazard ratios (HRs) for mortality. Covariates for adjustment (e.g., age, key comorbidities, and disease severity) were pre-selected based on their clinical significance and proven association with COVID-19 outcomes in the literature. Multivariable logistic regression was used to identify independent predictors of survival. Acknowledging the inherent limitations of an observational study, confounding by indication is a major consideration, as the decision to administer Actemra was made by treating clinicians based on disease severity and clinical judgment, rather than randomization. All statistical tests were two-tailed, and a p-value was considered statistically significant if it was less than 0.05.

3. Results

Among the 195 patients included in the study, the majority were male (71.3%) and unvaccinated (92.3%). A high proportion required ICU admission (69.7%). The most prevalent comorbidities were diabetes (56.4%) and hypertension (53.3%). Clinically, dyspnea (99.5%), cough (89.7%), and fever (87.2%) were the most frequent symptoms. Actemra was administered to 51 patients (26.2%).

3.1 Actemra vs. Non-Actemra

Chi-square tests showed that Actemra recipients had higher ICU admission rates (92.2% vs. 61.8%, $p < 0.001$), gastrointestinal symptoms (60.8% vs. 40.3%, $p = 0.012$), and CPAP use (92.2% vs. 61.8%, $p < 0.001$) than non-recipients. They had lower rates of diabetes (43.1% vs. 61.1%, $p = 0.026$) and hypertension (41.2% vs. 57.6%, $p = 0.043$), and all were PCR-positive for COVID-19 ($p = 0.001$).

Mann–Whitney U tests indicated the Actemra group was younger (mean rank 75.0 vs. 106.2, p = 0.001) but had longer hospital stays (133.5 vs. 84.7, p < 0.001). They had higher platelet counts (p < 0.001), bilirubin (p = 0.04), LDH (p < 0.001), D-dimer (p = 0.02), ferritin (p = 0.01), and random blood sugar (p = 0.002), but lower urea (p = 0.03), creatinine (p = 0.03), and procalcitonin (p < 0.001). These differences highlight the presence of confounding by indication, where the treatment was allocated based on perceived severity.

3.2.Survival Analysis

Among the 195 patients included in this study, 111 (56.9%) died and 84 (43.1%) survived. The association between Actemra therapy and survival status was examined using the chi-square test (Table 1). The results showed a statistically significant relationship between Actemra use and survival outcomes *(p < 0.001)*, indicating that patients who received Actemra had a higher survival rate than those who did not.

Table1: Association between Actemra Therapy and Survival Outcomes

Survival Status	Actemra Group (51)	Non-Actemra Group (144) _	Total (195)
Survived, n (%)	35 (68.6%)	49 (34.0%)	84 (43.1%)
Died, n (%)	16 (31.4%)	95 (66.0%)	111 (56.9%)

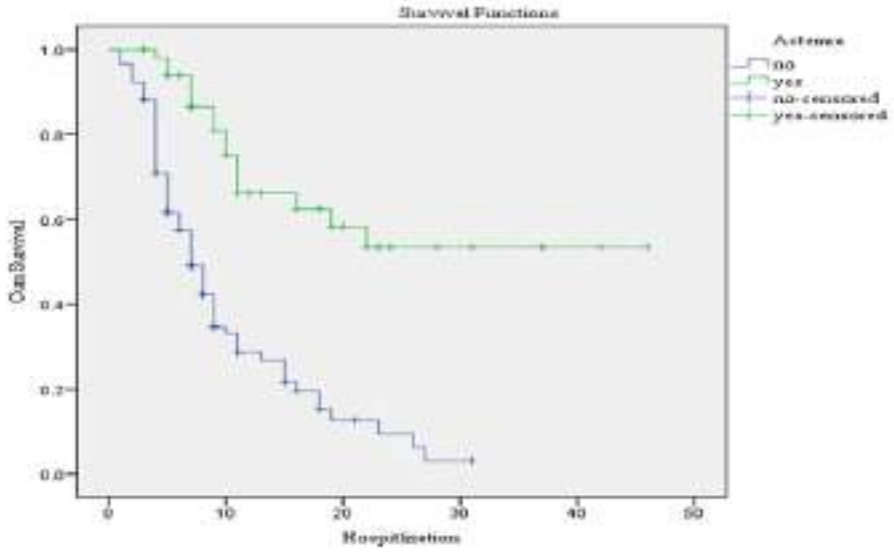


Figure 1: Kaplan–Meier Survival Curves for Actemra and Non-Actemra Groups.

Table 2: Mean Survival Time by Actemra Treatment Group

Actemra Treatment	Mean Survival Time (days)	95% CI Lower	95% CI Upper
No	10.1	8.48	11.73
Yes	29.9	23.86	35.92

3.2.1.Kaplan–Meier Survival Analysis

Kaplan–Meier survival curves demonstrated a significantly longer survival time in patients who received Actemra than in those who did not (Figure 1) The survival probability remained higher in the Actemra group across the study period, with the log-rank test confirming a statistically significant difference ($p < 0.001$). The mean survival time for the Actemra group was 29.9 days (95% CI: 23.86–35.92), whereas it was 10.1 days (95% CI: 8.48–11.73) for the non-Actemra group (Table 2). The log-rank test indicated a highly significant difference between the two groups (χ^2 (1) = 33.08, $p < 0.001$) (Table 3). These results indicated a significant survival rate benefit associated with Actemra treatment during the study period.

3.2.2.Cox Proportional Hazards Regression

Predictors of hospitalization risk were identified using a multivariable Cox proportional hazards regression model after adjusting for potential confounders. (Table 3). Actemra treatment demonstrated a strong independent association with reduced hospitalization risk, exhibiting a hazard ratio (HR) of 0.230 (95% CI: 0.128–0.412, $p < 0.001$), This corresponds to a 77% decrease in the hazard of hospitalization among recipients compared to non-recipients. Increasing age was also a significant predictor, with each additional year associated with a 2.2% rise in hospitalization risk (HR: 1.022, 95% CI: 1.007–1.036, $p = 0.003$). Diabetes mellitus showed a trend toward increased risk (HR = 1.471, 95% CI: 0.962–2.248), though this association was not statistically significant ($p = 0.075$). Other variables, including hypertension, white blood cell count, and troponin levels, did not reach significance in the adjusted model (all $p > 0.05$). These findings indicate that, after adjustment for confounders, Actemra use and older age are key determinants of hospitalization risk, while the other clinical variables examined did not contribute substantially to the model.

Table 3: Multivariable Cox Regression Analysis of Predictors for Hospitalization

Variable	B (SE)	Hazard Ratio (HR)	95% CI for HR	*p*-value
Actemra (yes vs. no)	−1.470 (0.298)	0.230	0.128–0.412	<0.001
Age (per year)	0.022 (0.007)	1.022	1.007–1.036	0.003
Diabetes (yes vs. no)	0.386 (0.216)	1.471	0.962–2.248	0.075
Hypertension (yes vs. no)	−0.125 (0.209)	0.882	0.586–1.329	0.548
WBC count	−0.002 (0.009)	0.998	0.980–1.016	0.837
Troponin	0.421 (0.268)	1.524	0.901–2.576	0.116

3.2.3.Logistic Regression Analysis

Predictors of survival (alive vs. deceased) were assessed by using a multivariable logistic regression model after adjusting for potential confounders, including age, diabetes mellitus (DM), CKMB, troponin, D-dimer, procalcitonin, C-reactive protein (CRP), erythrocyte sedimentation rate (ESR), and ferritin (Table 4). Actemra therapy was a strong independent predictor of survival, with an odds ratio (OR) of 4.552 (95% CI not shown, $p = 0.001$), demonstrating that, after adjusting for other factors, patients treated with Actemra had a survival rate that was more than four times higher than those who did not

receive the medication. Increasing age was significantly linked to lower odds of survival (OR = 0.968, p = 0.007), indicating that the odds of survival decreased by around 3.2% for each additional year of age. Higher D-dimer levels were also significantly associated with increased mortality (OR = 1.000, p = 0.031), suggesting that elevated coagulation activity may be associated with poorer outcomes. Other variables, including diabetes mellitus and inflammatory markers (CRP, ESR, and ferritin), showed no statistically significant associations ($p > 0.05$) with survival in the adjusted model.

Table 4. Multivariable Logistic Regression Analysis of Predictors for Survival

Variable	B	S.E.	Wald	df	Sig.	Exp(B)
Actemra	1.516	0.453	11.208	1	0.001	4.552
Age	-0.033	0.012	7.161	1	0.007	0.968
DM	-0.276	0.349	0.626	1	0.429	0.759
CK-MB	-0.006	0.005	1.133	1	0.287	0.994
Troponin	-0.645	0.512	1.586	1	0.208	0.525
D-dimer	0.000	0.000	4.633	1	0.031	1.000
Procalcitonin	-0.415	0.214	3.761	1	0.052	0.660
CRP	-0.001	0.002	0.461	1	0.497	0.999
ESR	-0.005	0.006	0.634	1	0.426	0.995
Ferritin	0.000	0.000	0.481	1	0.488	1.000
Constant	3.561	1.014	12.330	1	0.000	35.187

4. Discussion

Actemra treatment was substantially linked to better survival in this cohort analysis of 195 hospitalized patients, results in contrast to standard care. It is important to note that the substantial effect size observed may be influenced by the observational design and confounding factors and does not prove causation. Our findings of a significant association with reduced mortality align with results from large-scale trials, such as the RECOVERY trial [7], and meta-analyses that have confirmed the efficacy of IL-6 receptor antagonists in reducing short-term mortality (summary OR ~0.86) and the progression to mechanical ventilation [17]. A meta-analysis of individual patient data revealed that IL-6 suppression also improved discharge rates and reduced the probability of death (HR ~0.75–0.85) [17]. However, our study's level of relationship (OR = 4.552) was significantly more than the summary estimates from meta-analyses of randomized trials (e.g., RR ~0.89) [18], this discrepancy likely reflects key differences in study design, patient selection, and unmeasured confounding inherent to our real-world analysis, rather than a superior treatment effect. The observed benefit is consistent with some retrospective cohort studies [19].

However, the COVACTA trial yielded neutral results, showing no significant benefit in mortality or clinical status at day 28 [9], and other randomized trials have reported mixed outcomes [10, 11]. This inconsistency in the literature is a recognized challenge, often attributed to high heterogeneity (I^2 up to 88% in some meta-analyses [20]) arising from variations in patient selection, timing of treatment, and concomitant therapies [14, 8]. Observational studies have suggested that earlier initiation, particularly in patients with elevated IL-6 or CRP levels, yields greater benefits [20]. This is supported by evidence indicating that Actemra is most effective in critically ill patients with severe inflammatory responses, potentially explaining the positive results in our cohort, which exhibited high

baseline inflammatory markers [21, 16]. In our study, the higher baseline LDH and ferritin levels in the Actemra group may reflect a more severe inflammatory phenotype, supporting targeted IL-6 blockade in such cases. Lower procalcitonin levels suggest fewer bacterial co-infections, potentially contributing to better outcomes and aligning with findings that lower procalcitonin levels are predictors of a positive response [22].

The findings support the early and targeted administration of Actemra in patients exhibiting severe disease and signs of hyperinflammation, aligning with its proposed mechanism of action in mitigating cytokine release syndrome [20]. The integration of biomarker-based selection, such as LDH, ferritin, and procalcitonin, may enhance treatment efficacy. As demonstrated in the RECOVERY and REMAP-CAP trials, the concurrent use of corticosteroid therapy may augment efficacy [7, 8], underscoring the value of combination therapeutic approaches. Typical dosing regimens of 8 mg/kg (maximum 800 mg) intravenously, occasionally repeated, were effectively employed in this and other studies [21, 23]. However, the potential for an increased risk of secondary infections associated with Actemra use warrants consideration [16]. Although our study did not primarily focus on adverse events, existing literature presents mixed findings regarding this risk [18, 24]. Consequently, vigilant monitoring for bacterial or fungal infections remains a critical precaution for patients receiving IL-6 blockade, particularly those with pre-existing immunocompromised conditions.

The strengths of our study lie in the robust sample size (n = 195), which enhances its statistical power. We employed a variety of statistical methods, including survival analysis and multivariable regression. Furthermore, the use of real-world data increases the generalizability of our findings to clinical practice.

The retrospective and observational nature of the study restricts the ability to establish causal relationships. The presence of baseline differences between groups raises the possibility of residual confounding, and the lack of randomization, along with unmeasured covariates, may have influenced the results. Laboratory data only reflect baseline values, without accounting for post-treatment trends. As with many real-world studies, the timing of treatment administration was not standardized, which is a critical factor that could have influenced outcomes. Additionally, data on secondary infections, a key safety endpoint highlighted in the literature, were not systematically captured.

5. Conclusions

The study concluded that Actemra therapy was associated with a significantly higher chance of survival and reduced hospitalization risk in this cohort of patients. These results align with the growing evidence supporting IL-6 blockade in severe inflammatory diseases, particularly COVID-19; however, further prospective randomized controlled trials should be conducted to confirm survival benefits, along with subgroup analyses to refine patient selection and research on the optimal timing of Actemra administration. Long-term follow-up studies, as well as research on secondary infections and adverse events in specific patient populations, are also necessary.

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Conflicts of Interest

The authors declare that they have no conflicts of interest

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Research Article

Evaluating the Use of Internet of Things Technologies in Chronic Diseases From the Perspective of Healthcare Providers

Hana Slaeh*, Anfal wanes, Astberq Salem, Hussein Alghmari and Thekra Abdullah

Department of Health Informatics, University of Benghazi, Libya

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ABSTRACT

The healthcare sector has experienced notable advancement through the adoption of Internet of Things (IoT) technologies, particularly in chronic disease management. This study aimed to evaluate healthcare providers' perceptions of the benefits and challenges associated with IoT implementation. A cross-sectional study was conducted among 150 healthcare providers using a structured questionnaire to assess perceived benefits and barriers to IoT adoption. The findings indicated a consensus regarding the significant potential of IoT technologies, with 70 participants acknowledging the role of these technologies in improving patient monitoring. However, major barriers to implementation were identified, including a lack of skilled personnel and weak technical capacity (79.3%), inadequate policies (76.7%), and high costs (60.6%). Despite positive awareness of IoT benefits, effective integration into healthcare systems requires addressing human and structural challenges by ensuring adequate infrastructure, qualified personnel, and clear regulatory frameworks.

* Corresponding author.
E-mail address: Hana.slaeh@uob.edu.ly

1. Introduction

Modern smart applications have become increasingly prevalent following the COVID-19 pandemic and are now extensively utilized across various sectors, including healthcare. Among the most influential technological advancements of the modern era is the Internet,

which has laid the foundation for more advanced digital innovations such as the IoT.

IoT refers to an ecosystem of interconnected smart devices including sensors, smartphones, and radio-frequency identification (RFID) tags that enable continuous communication between objects and individuals across time and space. This interconnectedness allows for the delivery of a wide range of services tailored to users' specific needs. In healthcare, IoT technologies significantly enhance efficiency and effectiveness by transforming traditional systems into integrated, data-driven care models.

IoT plays a crucial role in supporting personalized healthcare interventions, facilitating the sharing of healthcare plans across regions, enabling continuous care delivery, improving prognostic accuracy, and enhancing patient adherence to treatment regimens. By promoting improved clinical outcomes and higher-quality care, this comprehensive and dynamic approach is particularly beneficial for individuals with chronic diseases [6]. Given the rising prevalence of chronic conditions—especially in low- and middle-income countries—there is an urgent need for technology-based solutions that support active disease management [7,8]. In this context, IoT technologies have emerged as one of the most promising tools for improving healthcare quality while simultaneously reducing associated costs [6,9].

Despite the substantial potential of IoT, significant gaps remain in the literature regarding healthcare professionals' perceptions, awareness, and adoption of these technologies. Limited attention has been paid to understanding providers' knowledge of IoT, their current usage patterns, the perceived benefits, and the challenges encountered during implementation [10]. Addressing these gaps is essential to ensure the effective integration of IoT into clinical practice.

Accordingly, this study aims to explore healthcare professionals' perspectives on the use of IoT technologies in the management of chronic diseases. Specifically, it examines their level of knowledge and awareness, the extent of IoT adoption within healthcare organizations, and the types of IoT devices and systems currently in use. Furthermore, the study investigates perceived impacts such as reductions in hospital admissions, earlier detection of health deterioration, and improved patient compliance, thereby providing insight into the clinical value and practical applicability of IoT systems [11,12].

In addition, this research seeks to identify key barriers to effective IoT implementation, including inadequate infrastructure, workforce shortages, high implementation costs, data security and privacy concerns, and the absence of clear regulatory frameworks. Beyond offering evidence-based practical recommendations, the study aims to contribute to a broader strategic framework that supports informed decision-making and fosters sustainable digital innovation in the healthcare sector. Ultimately, this work aspires to bridge existing knowledge gaps by providing a comprehensive understanding of how healthcare professionals perceive and utilize IoT technologies in the management of chronic diseases.

The integration of Internet of Things IoT technologies has significantly advanced healthcare systems, particularly in chronic disease management. Prior studies have examined the capabilities of IoT in improving patient monitoring, data security, and clinical outcomes.Secure and scalable IoT architectures have been proposed to support healthcare data management. Notably, the LoRaChainCare framework combined LoRaWAN, blockchain, and IPFS technologies, demonstrating low reductions in HbA1c levels, improved cardiovascular risk detection, and decreased hospital admissions among high-risk patients using AI-powered IoT solutions [13]. Additionally, IoT-based user tracking systems have achieved high accuracy in applications such as movement analysis and fall detection [20].

Recent research has focused on privacy-preserving IoT frameworks, including federated learning approaches, which achieved high predictive performance while ensuring data security [15]. Studies on user acceptance

further indicate that trust and perceived usefulness are key factors influencing the adoption of IoT-based healthcare services [16]. techniques for real-time monitoring and individualized risk prediction in chronic diseases such as cardiovascular disorders, diabetes, and cancer [12]. However, ethical concerns, data privacy issues, and algorithmic bias remain critical challenges. Large-scale literature analyses using hybrid methods, including LDA and Fuzzy AHP, identified cardiovascular diseases and diabetes as the primary domains for IoT intervention, particularly in developing countries [15]. Systematic reviews have emphasized the benefits of integrating IoT with artificial intelligence (AI) and machine learning disease management outcomes, enhanced patient safety, and reduced healthcare costs through IoT adoption [14]. have highlighted positive perceptions among healthcare providers, reporting improved Further reviews have demonstrated the transformative role of wearable sensors, remote monitoring devices, and AI-enabled systems in improving early detection of health deterioration and supporting clinical decision-making [13,14]. Quantitative evidence shows cost, low latency, and high energy efficiency, thereby enabling secure and scalable healthcare data exchange [10].

This study aims to address the knowledge gap by providing in-depth insights into the perceptions and use of IoT technologies in chronic care, with a focus on generating realistic, evidence-based proposals to help promote the strategic and sustainable implementation of these technologies in healthcare facilities. This is intended to guide policy decisions and shape subsequent innovations in the digital health experience.

2. Methodology

2.1 Study Design

The study was a cross-sectional study and it took place during a duration of about one month. The research involved six large healthcare centers in the Eastern Region (Martyr Mohammed Al-Maqrif Hospital Ajdabiya and Shahwan Rural Hospital, Al-Zawitina Rural Hospital, 1200 Hospital, Children Hospital, and Heart Hospital).

2.2 Study Participants

The study population included all healthcare professionals working in the aforementioned facilities. Participants included all qualified individuals, such as doctors, nurses, administrators, technicians, and other healthcare workers.

2.3 Sample and Data Collection

Data were collected using a structured questionnaire adapted from established instruments used to assess IoT applications in healthcare.. This questionnaire was modified and developed by the researchers to align with the objectives of the current study. assess the internal consistency. The resulting alpha coefficient was .86, indicating good internal consistency and reliability for the scale. The questionnaire contained close and open type of questions in Arabic, broken into number of main categories:

First: General information (gender, age, educational qualifications, job title, years of experience).

Second: Knowledge and awareness of IoT technologies in healthcare.

Third: The role of IoT technologies in chronic disease management.

Fourth: Challenges facing the application of IoT.

Fifth: Suggestions and recommendations.

The total sample size was 150 participants from various healthcare facilities, and the sample was randomly assigned to eligible participants.

2.4 Data Analysis

Statistical Package for the Social Sciences (SPSS) version 23 was used in the analysis of the collected data. The analysis involved the involvement of the descriptive statistics which have been described as frequency tables and percentages as the data which were used to summarize the characteristics of the sample and what the participants that were included in the survey answered to the questions asked. A five- point Likert scale was also the approach of asking questions on questions to determine the attitude and behavior of the participants.

2.6 Ethical Considerations

The required permission of the respective administration of healthcare facilities was sought over all prior to data collection. A full policy of anonymity was implemented to protect the privacy and confidentiality of the participants, since during the survey no personal information that would allow speculating about their information was gathered.

3. Results

This section presents the results obtained from the questionnaire administered to the study participants. The results are structured to provide a detailed demographic profile of the participants followed by examine their attitudes regarding the adoption of IoT technologies for chronic disease management. The findings are organized into two main domains: i) Demographic Characteristics: which outlines the general composition of the study population, and, ii) Attitudes toward IoT adoption: which encompass participants' familiarity with IoT technologies as well as their perceived benefits and challenges related to the integration of IoT solutions into healthcare practices.

Table1. Relative distribution of participants by age group

Age	Frequency	Percent(%)
< 30 years	38	25.3%
30 - 40	76	50.7%
41 - 50	22	14.7%
> 50 years	14	9.3%
Total	**150**	**100.0%**

Table 1 shows the age distribution of the 150 participants. It is evident that the most represented age group is 30-40 years at 50.7%, while participants older than 50 years represented the smallest proportion (9.3%).

Figure 1, delineates the occupational stratification of the study cohort, comprising 150 healthcare professionals. The distribution reveals a pronounced predominance of clinicians, with Physicians constituting the largest subgroup (n=68, 45.3%). Nursing personnel represent the secondary cohort (n=32, 21.3%), followed by Health Services Administrators (n=20, 13.3%). Health Informatics specialists (designated as IT Officers) comprise a minimal proportion (n=5, 3.3%), while a residual heterogeneous category ("Other") encompasses 16.7% (n=25) of participants, suggesting a degree of occupational heterogeneity within the sample's structural composition

The data presented in Figure 2,reveals a strikingly low level of adoption of IoT technologies for patient monitoring among the healthcare facilities represented in this study. A mere 13.3% of respondents (n=20) confirmed the active use of such technologies within their institutions. In stark contrast, the overwhelming majority 86.7% of participants (n=130) reported no current implementation of IoT-based patient monitoring systems.

This pronounced disparity (13.3% vs. 86.7%) signifies a substantial implementation gap within this sector. It suggests a significant lag between the availability of advanced, data-driven healthcare technologies and their operational integration into routine clinical practice among the surveyed population.

Table 2 shows .healthcare professionals' perceptions of IoT benefits demonstrate a clear hierarchy based on benefit tangibility: Strongest Consensus (70%-66% agreement): Exists for direct clinical applications continuous patient monitoring and reducing hospital visits viewed as IoT's most immediate and validated contributions. Moderate Consensus (62% agreement): Emerges for predictive and adherence functions, indicating recognized potential tempered by perceived implementation complexity.

Weakest Consensus (58% agreement): Surrounds long-term cost reduction, revealing significant skepticism about economic returns despite recognition of clinical value. This gradient suggests practitioners primarily value IoT for solving observable care delivery challenges, while remaining cautious about its indirect benefits until further evidence emerges.

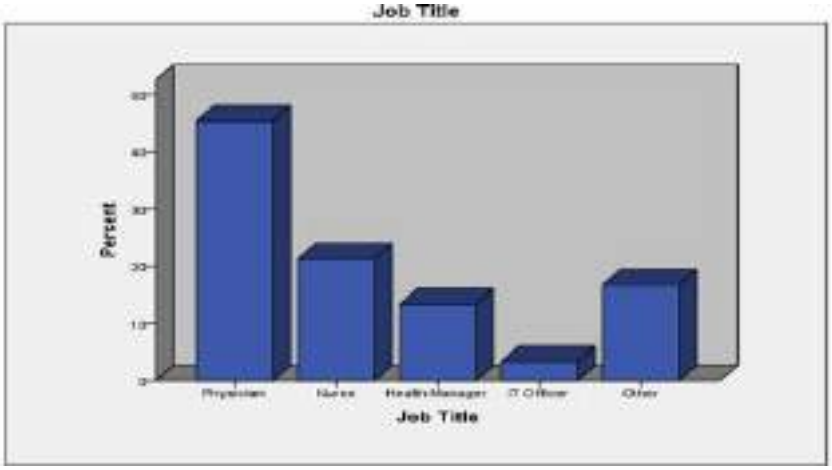


Figure 1: Relative distribution of participants by job title

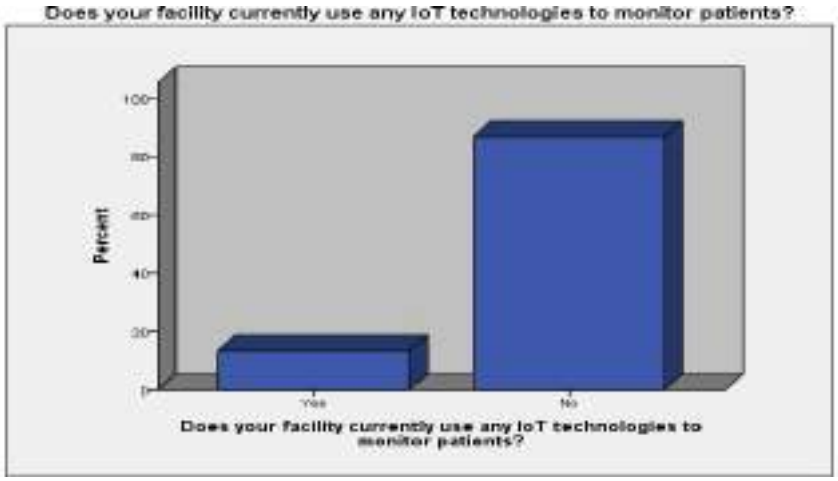


Figure 2: Relative distribution of participants by job title

	Strongly Disagree	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
- IoT technologies contribute to improving the monitoring of	2.7%	5.3%	22.0%	51.3%	18.7%

patients with chronic diseases.					
-IoT technologies help reduce the number of patient hospital visits.	2.0%	3.3%	28.0%	47.3%	19.3%
-IoT enables early prediction of patient condition eterioration.	3.3%	6.0%	28.7%	47.3%	14.7%
-IoT technologies contribute to enhancing patient adherence to treatment	3.3%	6.7%	28.0%	47.3%	14.7%
-Applying IoT reduces long-term healthcare costs	3.3%	6.0%	32.7%	40.7%	17.3%

Table 2. Participants' perceptions of the benefits of (IoT) technologies in chronic disease management.

Table 5.. Areas Benefiting from IoT Implementation

Top Areas That Can Benefit from IoT	Responses N	Responses %	% of Cases
Remote cardiology	94	28.5%	66.2%
Predicting early resolution	64	19.4%	45.1%
Patient adherence to treatment	54	16.4%	38.0%
Comprehensive visits and healthcare costs	68	20.6%	47.9%
Medication management	50	15.2%	35.2%
Total	**330**	**100.0%**	**232.4%**

This gradient suggests practitioners primarily value IoT for solving observable care delivery challenges, while remaining cautious about its indirect benefits until further evidence emerges.

Highlights the most important areas that participants believe could significantly benefit from the implementation of IoT technologies are shown in Table 3. Continuous remote monitoring ranked first at 66.2%, followed by comprehensive visits and healthcare costs at 47.9%. Early prediction of solutions came next at 45.1%, followed by treatment adherence at 38%. Medication management ranked last at 35.2%.

4. Discussion

4.1 IoT Awareness and Knowledge of the Technologies

The study revealed a pronounced implementation gap between the theoretical awareness of IoT technologies and their actual utilization in healthcare settings. Despite reporting a high terminological familiarity among participants (60.7%), their self-assessed level of knowledge was predominantly described as limited or average. This discrepancy was practically embodied in the low adoption rate, with only 13.3% of participants reporting the use of these technologies within their facilities..

This finding aligns with an established research trend indicating a persistent implementation gap between technological potential and practical application in healthcare organizations [12,13].The study further provides an explanation for this gap, linking the disparity between awareness and practice to

an inability to address the associated technical and managerial complexities of implementation, as documented in prior literature.

4.2 The views on the Benefits of IoT Technologies

The research findings indicate a broad consensus among medical practitioners regarding the potential benefits of IoT technologies in managing chronic diseases. A majority of participants affirmed the utility of these technologies for patient monitoring (70%), minimizing hospital visits (66.6%), and facilitating the early identification of health deterioration (62%).

These findings are largely congruent with prior research. The potential of IoT technologies to refine disease management outcomes, enhance patient safety, and reduce healthcare expenditures has been corroborated in another study [9]. Furthermore, the current study's results particularly the emphasis on the significance of continuous remote monitoring (66.2%) align with findings related to the implementation of remote monitoring tools and artificial intelligence for preventing early clinical deterioration [12,13]. Additionally, the participants' prioritization of "remote cardiac monitoring" as the most considerable area of benefit corresponds with results from a previous investigation, which identified cardiovascular diseases and diabetes as the most relevant clinical domains for such interventions [11].

5.3 Towards the Difficulties Affecting the Introduction of IoT Technologies

The identification of challenges by the study is one of the most notable findings, as it highlights the direct hindrances to the adaptation of these technologies. The findings indicated that there was a strong agreement that the existing shortage of competent staff and poor technical infrastructure are the highest issues at hand, both standing at 79.3%.Such results support what is found in the literature. Ethical concerns, privacy concerns, and data bias were mentioned by the study participants as the main privacy concerns (55.4%), issues which were also highlighted in a systematic review [10]. The studies aimed at creating options like the LoRaChainCare system guarantees that poor infrastructure and safety points are actual problems scientists attempt to mitigate [8]. Clear regulations are also significant, according to the outcomes of the research in question (76.7%), and this point can be viewed as a major step towards a full operation of these kinds of technologies. Overall, the findings of the current study are quite in line with the global trends that have been discussed by other works. They outline the supposed gains of using the IoT in the medical sphere, as well as outlining a series of basic problems that still prevent the full and successful implementation of such technologies. These findings collectively fulfill the research objectives of addressing the existing knowledge gap and providing a foundation for evidence-based suggestions to promote the strategic application of IoT technologies.

5. Conclusions

This study indicates that healthcare providers are cognizant of the advantages of IoT technologies in chronic disease management, particularly for improving patient monitoring, decreasing hospitalizations, and enabling early intervention. Nonetheless, adoption is hindered by key barriers such as workforce shortages, infrastructural deficits, and concerns over cost, regulation, and data security. This benefit-implementation gap suggests that IoT integration remains at an early phase, requiring systematic planning for successful deployment.

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Conflict of Interest

The authors declare no conflicts of interest.

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