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INFORMATION

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INVESTIGATING THE CYTOGENOTOXIC EFFECTS OF FORMALIN AT VARYING CONCENTRATIONS USING THE ALLIUM CEPA ASSAY

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ABSTRACT

Formalin is a well-known aqueous solution of formaldehyde, commonly used as a sterilant and disinfectant in hospitals, laboratories, and industries. It is a known carcinogenic and genotoxic toxicant. This study examines the cytogenotoxic effects of various concentrations of formalin using the Allium cepa assay. Healthy Allium cepa bulbs were exposed to different concentrations of formalin (0.1%, 0.5%, 1%, 2%, and 5% v/v) with distilled water serving as control for 48 hours. Root growth inhibition, mitotic index (MI), and chromosomal aberrations (CAs) were microscopically assessed by staining with aceto-orcein. Formalin exposure reduced root growth and mitotic index in a concentration-dependent manner. Root growth was suppressed by more than 80% in the 5% formalin group compared to control. The mitotic index was considerably reduced, recording 12.4% and 2.3% in control and 5% formalin, respectively ($p < 0.05$). Various chromosomal abnormalities were observed, including stickiness, laggards, bridges, vagrant chromosomes, and micronuclei formation. Aberrations were concentration-dependent, with the highest frequency at 2% and 5% formalin solutions. Formalin demonstrated potent concentration-dependent cytotoxic and genotoxic effects in Allium cepa root meristems. These plant-based findings underscore the genotoxic potential of formalin and highlight the utility of the Allium cepa assay as a reliable bio-indicator for genotoxicity screening of chemical sterilant.

Keywords: Formalin, Cytogenotoxicity, Allium cepa, mitotic index, chromosomal aberrations

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INTRODUCTION

Formalin is an aqueous solution with about 37-40% formaldehyde, which is very commonly used as a sterilant and tissue preservative in hospitals, laboratories, and mortuaries because of its wide-spectrum antimicrobial action [1,2]. Nevertheless, formalin is linked to various health hazards such as irritation of the respiratory tract, sensitization of the skin, and cancer [3]. Formaldehyde is a Group 1 carcinogen in the list of the International Agency for Research on Cancer (IARC) [4]. Formaldehyde has mutagenic and cytogenotoxic effects arising from occupational and environmental exposures, where formaldehyde exposure has been shown to cause DNA-protein crosslinking, chromosomal damage, and oxidative stress effects [5,6]. As such, its possible cytogenotoxic risk at different concentrations is essential to evaluate its safety profile. The Allium cepa assay is a sensitive, inexpensive, and internationally validated test system for detecting Cytogenotoxicity [7,8]. It measures endpoints including root growth inhibition, mitotic index, and chromosomal aberration, which are valid markers of DNA and cell division dysfunction [9]. This study investigates the cytogenotoxic effects of varying concentrations of formalin using the Allium cepa assay to provide experimental data for risk assessment.

MATERIALS AND METHODS

Test Material:

Commercial formalin solution (37–40% formaldehyde in water, stabilized with methanol) was diluted to obtain test concentrations of 0.1%, 0.5%, 1%, 2%, and 5% (v/v). Distilled water was used as the negative control. Although the commercial formalin used was stabilized with methanol, a separate methanol control was not included because the methanol content in the final diluted test concentrations was negligible (less than 0.1% v/v) and thus considered unlikely to contribute significantly to the observed biological effects. Distilled water was therefore deemed adequate control for this study.

Plant Material:

Onion (Allium cepa L.) bulbs (2-3 cm in diameter) that appeared in good health and of uniform size were purchased in a local market. Bulbs were dried in the sun and 48 hours later, all outer scales were removed and dried roots were trimmed.

Experimental Procedure:

Bulbs were placed in glass beakers containing test concentrations or control water, ensuring that the basal portions were fully submerged. The exposure time was 48 hours at room temperature.

Root Growth Inhibition Test:

Five longest roots were measured in length and the mean values obtained. Relative root growth inhibition when compared to control was determined.

Cytological Analysis:

Excision of root tips (1-2 cm) occurred and was fixed in ethanol: acetic acid (3:1) 24hours after exposure, hydrolyzed 1N HCl at 60^{o}C for 5 min, and stained with 2% aceto-orcein. Microscopic examination of squash preparations was carried out as previously described [7,9].

Mitotic Index (MI):

At least 1,000 cells per slide were scored for each treatment. MI was calculated as: MI (%) = (Number of cells in Mitosis / Total number of observed cells) x 100 [8,9].

Chromosomal Aberrations (CA):

Cells in division were screened for structural and spindle abnormalities, including stickiness, bridges, laggards, vagrants, multi-polarity, and micronuclei [8,9].

Statistical Analysis:

Data were expressed as mean ± SEM. One-way ANOVA followed by Tukey's post hoc test was used ($p < 0.05$ considered significant).

RESULTS

Root Growth Inhibition: A significant reduction in root growth was observed following exposure to formalin, which exerted its effect in a concentration-dependent manner. Root lengths decreased from 4.8 ± 0.3 cm in the control to 0.9 ± 0.2 cm at 5% formalin ($p < 0.05$).

Table 1 shows the effect of varying concentrations of formalin on root growth of Allium cepa after 48 hours exposure. Values are expressed as mean ± SEM (n = 4). A concentration-dependent reduction in root length was observed, with significant inhibition at higher concentrations ($p < 0.05$ vs control).

Mitotic Index: A dose-dependent reduction in MI was observed. The control had a mitotic index of 12.4 ± 0.8%, while 5% formalin showed 2.3 ± 0.4% with $p < 0.05$.

Table 2. Effect of formalin exposure on mitotic index of *Allium cepa* root meristem cells. Values are expressed as mean ± SEM (n = 4). A significant, concentration-dependent decrease in mitotic activity was observed ($p < 0.05$ vs control).

Table 1:	
Formalin Concentration (%)	Root Length (cm) (Mean ± SEM)
Control	4.80 ± 0.30
0.1	4.72 ± 0.29
0.5	4.41 ± 0.27
1.0	4.00 ± 0.25
2.0	3.24 ± 0.23
5.0	0.90 ± 0.20

Table 2:	
Formalin Concentration (%)	Mitotic Index (%) (Mean ± SEM)
Control	12.40 ± 0.80
0.1	12.20 ± 0.78
0.5	11.40 ± 0.70
1.0	10.40 ± 0.60
2.0	8.40 ± 0.50
5.0	2.30 ± 0.40

Chromosomal Aberrations:

Diverse aberrations were also noticed on exposure to formalin. Stickiness and bridges were predominant, followed by laggards and vagrant chromosomes. Micronuclei formation was noted at higher concentrations (≥ 2%). The frequency of aberrations increased with concentration, with maximum effect at 5% formalin.

DISCUSSION

The Allium cepa assay demonstrated that formalin exerts both cytotoxic and genotoxic effects in a concentration-dependent manner on plant root meristem cells. The inhibition of root growth reflects cytotoxicity at the level of cell elongation and division, consistent with known aldehyde toxicity in plant systems [10].

This marked decrease in mitotic index is indicative of cell cycle arrest, which may be attributed to DNA-protein crosslinking and disruption of spindle fiber assembly by formaldehyde [11]. Stickiness and bridges are chromosomal aberrations that signal DNA condensation errors and clastogenic activity [12]. Spindle apparatus interference is suggested by the presence of laggards and vagrants, while micronuclei formation confirms genotoxic activity in the plant root meristem cells [13]. These findings are consistent with

previously reported genotoxic effects of formaldehyde in plant test systems [14,15].

The Allium cepa bioassay proved to be a reliable and cost-effective biomonitoring tool for identifying the cytogenotoxic potential of chemical sterilant such as formalin. However, it is important to note that these findings are limited to a plant-based model and should not be directly extrapolated to human or animal biological systems.

Limitations of study

The study used a plant-based model, which may not fully replicate human biological responses

Only acute exposure (48 hours) was assessed

Molecular mechanisms were not directly investigated

CONCLUSION

Formalin demonstrated concentration-dependent cytotoxic and genotoxic effects in Allium cepa root meristems, as evidenced by significant root growth inhibition, reduced mitotic index, and increased frequency of chromosomal aberrations. These plant-based findings confirm the genotoxic potential of formalin within the Allium cepa model system. Given the limitations of this study, including its plant-based design and acute exposure period, these results should be interpreted within the context of the Allium cepa bioassay and not extrapolated to human or animal systems without further investigation.

Conflict of interest

The authors declare no conflict of interest

Author Contributions: Boniface A. Onoja and Adeoye O. Oyewopo conceptualized and designed the study. Boniface A. Onoja conducted the investigation. Elijah A. Adepoju performed the statistical analysis. Bernard A. Alabi and Boniface A. Onoja drafted the manuscript. All authors reviewed and edited the manuscript. Adeoye O. Oyewopo supervised the study.

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FACTORS ASSOCIATED WITH HEALTH WORKERS' CLINICAL KNOWLEDGE ON MALNUTRITION IN CHILDREN UNDER FIVE YEARS AND ITS MANAGEMENT IN JIWAKA PROVINCE, PAPUA NEW GUINEA

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ABSTRACT

Malnutrition remains a major public health challenge in Papua New Guinea (PNG), particularly among children under five years of age. Health workers serve as frontline providers in addressing this burden, and play a critical role in early identification, diagnosis, and management of malnutrition. However, gaps in clinical knowledge may compromise quality of care. The aim of this study was to assess the level of clinical knowledge on malnutrition among health workers in Jiwaka Province and identify factors associated with adequate knowledge. A cross-sectional analytical study was conducted among 151 health workers in Jiwaka Province. Clinical knowledge was assessed using a structured questionnaire. Knowledge scores were categorized as low (<50%), average (50–74.9%), and good (≥75%). Independent sample t-test, one-way ANOVA, Pearson and Spearman correlations, Chi-square tests, and multivariable logistic regression were performed (Binary logistic regression). The mean knowledge score was 17.42% (SD ±2.84). Most participants demonstrated average knowledge (59.6%), while 25.2% had low knowledge and only 15.2% had good knowledge. Significant differences were observed across professional designations, with Community Health Workers scoring significantly lower than Nursing Officers and Health Extension Officers ($p < 0.001$). Attendance at malnutrition-specific training (AOR = 4.87, 95% CI: 1.61–14.75, $p = 0.005$) and university-level training (AOR = 5.76, 95% CI: 1.05–31.54, $p = 0.044$) were significant predictors of adequate knowledge. Significant gaps exist in treatment and management domains. Targeted malnutrition-specific training interventions to strengthen malnutrition management capacity are critical to improving clinical competence among health workers in Jiwaka, PNG.

Keywords: malnutrition, clinical knowledge, health workers, Papua New Guinea, capacity building, training effectiveness.

Submitted: April 2026; Accepted: June 2026

INTRODUCTION

Malnutrition remains one of the most significant contributors to morbidity and mortality in children under five years globally, with particularly severe impacts in low-and middle-income countries (LMICs) [1-2]. The World Health Organization (WHO) estimates that approximately 149 million children under five are stunted, 45 million are wasted, and 38 million are overweight globally, with malnutrition accounting for nearly 45% of all deaths in this age group [3-4]. In the Asia-Pacific region, Papua New Guinea (PNG) faces disproportionate nutritional challenges, with childhood malnutrition rates among the highest in the region [5].

In PNG, childhood malnutrition remains a significant public health challenge. According to the PNG Demographic and Health Survey (DHS) report, approximately 46% of children under five are stunted, 18% are underweight, and 5% are wasted [6]. These rates are among the highest in the Pacific region and reflect persistent nutritional inequalities. The PNG National Nutrition Policy (2016–2026) identifies malnutrition as a critical development issue affecting child survival, cognitive development, and long-term economic productivity [7]. Recent national surveys indicate that approximately 37% of children under five experience stunting, while acute malnutrition (wasting) affects 10-15% of children in this age group, with severe acute malnutrition (SAM) requiring immediate clinical intervention [8-9]. The burden is particularly pronounced in rural and remote districts, including Jiwaka Province, where access to adequate nutrition and healthcare services remains limited.

PNG's health system is characterized by a decentralized structure with limited resources, particularly in rural and provincial settings. The health workforce comprises a diverse cadre of providers, including Community Health Workers (CHWs), Nursing Officers (NOs), Health Extension Officers (HEOs), and limited numbers of physicians [10]. At the primary healthcare level, CHWs and health facility staff serve as the backbone of service delivery, often operating with minimal supervision and variable access to training and resources [11].

Geographical isolation, health workforce shortages, limited infrastructure, and inconsistent supply chains further complicate effective management of malnutrition in rural provinces such as Jiwaka [12]. Primary healthcare facilities are often staffed predominantly by CHWs, who serve as frontline providers in assessment and management of childhood illnesses [13]. Moreover, effective management of malnutrition in children requires health workers to possess comprehensive clinical knowledge across multiple domains, including assessment, diagnosis, treatment, and management of different types of malnutrition. The WHO guidelines on prevention and management of wasting and nutritional oedema in infants and children under five years provide

evidence-based recommendations that should guide clinical practice [3]. These guidelines emphasize the importance of early identification, appropriate nutritional assessment, and timely intervention to prevent mortality and morbidity.

Despite national policies and guidelines on malnutrition management in PNG's health systems, limited empirical evidence exists on health workers' knowledge of malnutrition in Jiwaka Province. Understanding the baseline knowledge levels, identifying factors associated with knowledge variation, and recognizing specific domain-specific gaps are essential to guide targeted training interventions aligned with PNG's National Health Plan (2021–2030) [14].

The aim of this study was to assess the level of clinical knowledge on malnutrition among health workers and identify factors associated with adequate knowledge. To our knowledge, this is the first study by Jiwaka Provincial Health Authority (PHA) to assess health workers clinical knowledge on malnutrition in Jiwaka Province, PNG.

METHODOLOGY:

Study setting and population:

The study was conducted in Jiwaka Province, located in the Highlands Region of PNG. Jiwaka was selected as the study site because of the significant burden of childhood malnutrition and the need for evidence to guide capacity-building efforts among frontline health workers in this resource-limited setting.

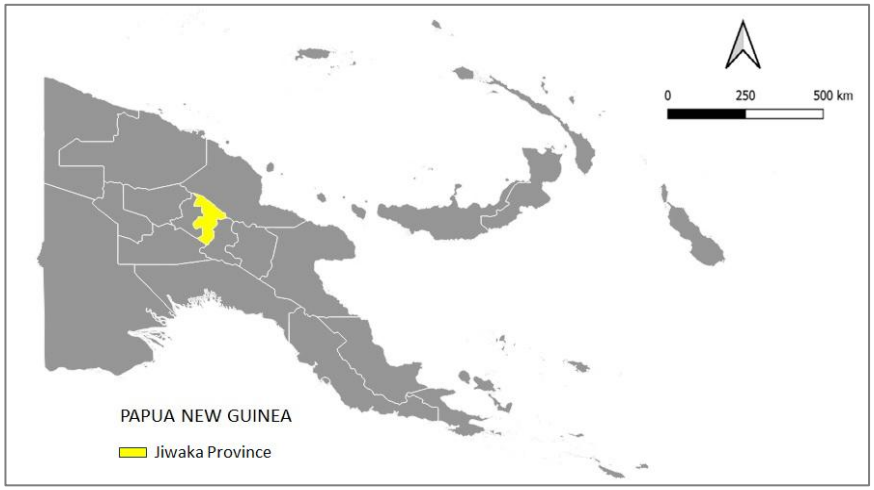

Figure 1. Study location in Papua New Guinea

The province was established in 2010 after separating from Western Highlands Province, with Banz serving as the administrative capital. It consists of three districts; North Waghi, Anglimp-South Waghi, and Jimi covering a land area of approximately 4,798 km^2. The population was 343,987 in the 2011 census and was estimated to reach 451,496 by 2021 [15].

Most residents live in rural communities and depend on subsistence agriculture, with fertile valley areas supporting coffee, tea, fresh produce, and livestock production.

Health services in the province are managed by the Jiwaka PHA, established in 2019 to strengthen health service delivery. Health care is provided through a network of government and church-run facilities, including hospital, health centres, and rural aid posts, with Kudjip Nazarene General Hospital serving as the main referral hospital.

The study population consisted of all frontline health workers employed in health facilities across Jiwaka Province, including CHWs, NOs, and HEOs. Assessing their knowledge in this context provides critical insights into the state of malnutrition management capacity at the frontline of PNG's health system and to address childhood malnutrition in the province.

Study Design:

A cross-sectional descriptive and analytical study design was used to assess the clinical knowledge of health workers on the identification and management of malnutrition among children under five years. This design enabled the collection of data from participants at a single point in time to provide a snapshot of current knowledge levels among frontline health workers.

The descriptive component summarized the socio-demographic and professional characteristics of participants, including cadre, years of experience, training background, and workplace. It also described their knowledge of key aspects of childhood malnutrition such as diagnosis, classification, and recommended management practices.

The analytical component examined the relationship between knowledge levels and selected factors, including professional category, clinical experience, prior training in nutrition, and facility type. The cross-sectional approach was appropriate because it is efficient and cost-effective, and it provides useful baseline information to inform training, policy, and capacity-building initiatives aimed at improving the management of childhood malnutrition within the health system.

Sample Size and Sampling Method:

A total of 151 health workers participated in this study. The sample comprised frontline health personnel working in government and church-run health facilities across the three districts. Participants were recruited using a combination of purposive and convenience sampling techniques**.** Purposive sampling was used to specifically target health workers who were involved in the clinical management of children, particularly those responsible for diagnosing and treating childhood illnesses such as malnutrition. Convenience sampling was then applied to recruit available and eligible health workers present at the selected facilities during the data collection period.

The inclusion criteria for participation were: (1) currently employed as a health worker in a health facility within Jiwaka Province, (2) having

at least six months of work experience in their current role to ensure familiarity with clinical responsibilities, and (3) willingness to participate and provide informed consent**.** Health workers who were on extended leave during the study period or who declined to participate were excluded from the study.

This sampling approach was considered appropriate given the logistical challenges of accessing health workers in geographically dispersed rural settings. It also allowed the study to capture practical insights from those actively delivering frontline health services in the province.

Data Collection Tool:

Data were collected using a structured questionnaire developed specifically for this study. The questionnaire comprised three main sections: 1) Demographic and Professional Information: This section collected data on gender, age, marital status, education level, professional designation, years of experience, type of health facility, and training history. 2) Clinical Knowledge Assessment: A comprehensive knowledge assessment tool was developed to evaluate health workers' understanding of malnutrition across eight specific domains*:* i) Coordination and Leadership Management, ii) General Knowledge on Malnutrition, iii) Availability of Clinical Diagnosis Tools, iv) Availability of Medical Supplies, v) Assessment of Children with Malnutrition, vi) Diagnosis of Types of Malnutrition, vii) Treatment of Malnutrition, and viii) Management of Malnutrition.

Training and Facility Factors: Questions regarding attendance at malnutrition-specific training, health training college attended, post-basic advanced training, and practical training facility type.

The knowledge assessment items were based on WHO guidelines on malnutrition management and international best practices for assessment and diagnosis of acute malnutrition in children [3]. Items were adapted to the PNG context and pretested with a small sample of health workers for clarity and relevance.

Data were collected by trained research assistants who administered the questionnaire through face-to-face interviews with consenting health workers. Each interview lasted approximately 30-45 minutes. Data collection was conducted between April-May 2024, across all three districts of Jiwaka Province.

Study Variables:

Dependent Variable: Clinical Knowledge on Malnutrition. This was assessed using a composite knowledge score derived from responses to multiple-choice questions across the eight domains. Scores ranged from 10 to 23, with higher scores indicating greater knowledge. Knowledge levels were categorized as: Low: <50% of total possible score, Average: 50–74.9% of total possible score, Good: ≥75% of total possible score.

For domain-specific analyses, a 75% competency threshold was applied to classify

knowledge as adequate or inadequate, consistent with international standards for clinical competency assessment [16].

Independent Variables: Demographic Variables: Gender, age group, marital status, years of experience, and education level.

Professional Variables: Designation (CHW, NO, HEO), health training college attended (CHW Training School, Nursing School, University), post-basic advanced training (Yes/No), and attendance at malnutrition-specific training (Yes/No).

Health System Variables: Type of health facility (day clinic, health sub-centre, health centre) and practical training facility type.

Data Management and Statistical Analysis:

All completed questionnaires were checked for completeness before data entry. Responses were coded and entered into Epi-Info version 7.2 as a database management tool [17]. Data cleaning included consistency checks and exclusion of cases with missing information to ensure data quality. Data were analysed using IBM SPSS (Statistical Package for the Social Sciences) statistics version 22 [18].

Both descriptive and inferential statistics were used to summarize participant characteristics and responses. Descriptive statistics were calculated to summarize demographic characteristics, knowledge levels, and domain-specific performance. Measures included frequencies, percentages, means, standard deviations, medians, modes, and ranges. Knowledge distribution was presented using frequency tables and summary statistics.

In inferential statistics, an independent samples t-test was conducted to compare malnutrition knowledge scores between males and females. The test examined whether gender differences in mean knowledge scores were statistically significant. A one-way analysis of variance (ANOVA) was performed to determine whether knowledge scores differed significantly across the three professional designations (CHW, NO, HEO). The F-statistic and p-value were reported. Following a significant ANOVA result, Tukey HSD (Honestly Significant Difference) post hoc tests were conducted to identify which specific groups differed significantly from one another.

Pearson correlation analysis was used to examine relationships between knowledge scores and continuous variables (age, years of experience). Spearman's rank correlation was applied to assess relationships between knowledge and ordinal variables (designation, education level).

Chi-square test was conducted to assess associations between categorical independent variables (gender, age group, marital status, education level, training college, post-basic training, malnutrition training attendance) and categorical knowledge levels (low, average,

good). Fisher's Exact Test was used when expected cell frequencies were less than five.

A multivariable binary logistic regression model was used to identify independent predictors of adequate clinical knowledge. The dependent variable was binary (adequate vs. inadequate knowledge, where 1=adequate, 0=inadequate). Independent variables included in the model were those that demonstrated significant associations ($p \leq 0.05$) in bivariate analysis: health training college attended, post-basic advanced training, and attendance at malnutrition-specific training. Crude and adjusted odds ratios (ORs) with 95% confidence intervals (CIs) were calculated to estimate the strength and direction of associations, allowing for adjustment of potential confounders. Model fit was assessed using the Hosmer-Lemeshow goodness-of-fit test. Statistical significance was set at $p \leq 0.05$.

Ethical Considerations:

The study was granted ethical approval from the PNG Medical Research Advisory Committee (MRAC # 24.10). Written informed consent was obtained from all participants prior to data collection. Confidentiality and anonymity were maintained throughout the study. Participants were assured that their responses would not affect their employment or professional standing. Participants were also informed about their right to withdraw from the study at any stage.

RESULTS:

Demographic Characteristics of participants (Table 1):

The study included 151 health workers, of whom 64.2% were female and 35.8% male. The majority were aged 26–30 years (34.4%), followed by 31–35 years (25.2%) and 36–40 years (17.9%) the others are presented in Table 1. Most participants were married (86.8%), with smaller proportions single (9.3%) or divorced/widowed. In terms of education, 62.9% had completed Grade 12, 35.1% Grade 10, and 2.0% Grade 8. Participants were distributed across districts, with Anglimp-South Waghi (43.7%) contributing the largest share, followed by North Waghi (29.8%), Jimi (20.5%), and Western Highlands Province (6.0%). The sample was predominantly composed of CHWs (61.6%), followed by NOs (33.1%) and HEOs (5.3%). Most respondents worked in health sub-centres (48.3%) and health centres (37.7%), with fewer based in day clinics (13.9%).

Clinical Knowledge Levels of Health Workers:

The clinical knowledge scores on malnutrition ranged from 10 to 23, with a mean score of 17.42 (SD ±2.84), a median of 17, and a mode of 16. As shown in Table 2, the majority of health workers demonstrated average knowledge levels (59.6%), while 25.2% had low knowledge (<50%) and 15.2% demonstrated good knowledge (≥75%).

Influence of Sociodemographic, Personal Education, and Health System Factors:

T-test Analysis:

An independent samples t-test was conducted to determine whether malnutrition knowledge scores differed between males and females (Table 3).

There was no statistically significant difference in malnutrition knowledge scores between males (M=17.1, SD=3.1) and females (M = 17.6, SD = 2.7),

$t(149) = -1.11$, $p = 0.27$, 95% CI [-1.49−0.42].

ANOVA Analysis:

A one-way ANOVA was conducted to determine whether malnutrition knowledge scores differed significantly across the three professional designations: CHWs, NOs, and HEOs.

A one-way ANOVA test was statistically significant ($F(2, 148) = 10.56$, $p < 0.001$), indicating that at least one of the three professional groups had a mean knowledge score significantly different from the others. Following the significant ANOVA result, Tukey HSD post hoc tests were conducted to determine which specific designation groups differed significantly from the others (Table 3).

Table 1. Demographic characteristics of study participants (n=151).

Variable	Frequency (n)	Percent (%)
Gender		
Male	54	35.8
Female	97	64.2
Age Group (Years)		
22–25	8	5.3
26–30	52	34.4
31–35	38	25.2
36–40	27	17.9
41–45	8	5.3
46–50	4	2.6
51–55	8	5.3
56–60	2	1.3
61–65	3	2.0
65+	1	0.7
Marital Status		
Single	14	9.3
Married	131	86.8
Divorced	2	1.3
Widowed	4	2.6
Education Level		
Grade 8	3	2.0
Grade 10	53	35.1

Grade 12	95	62.9
District of Residence		
North Waghi	45	29.8
Anglimp-South Waghi	66	43.7
Jimi	31	20.5
Western Highlands Province	9	6.0
Designation		
CHW	93	61.6
NO	50	33.1
HEO	8	5.3
Health Facility Type		
Day Clinic	21	13.9
Health Sub-Centre (HSC)	73	48.3
Health Centre (HC)	57	37.7
Total	151	100%

Table 2. Clinical Knowledge Level of Health Workers in Jiwaka Province (n=151).

Knowledge Level	Frequency (n)	Percent (%)
Low (<50%)	38	25.2
Average (50–74.9%)	90	59.6
Good (≥75%)	23	15.2
Total	151	100

Table 3. Descriptive statistics: Knowledge score by designation (n=151).

Designation	N	Mean	SD	Minimum	Maximum
CHW	93	16.65	2.72	10.00	22.00
NO	50	18.52	2.57	13.00	23.00
HEO	8	19.50	2.78	15.00	23.00
Total	151	17.42	2.84	10.00	23.00

ANOVA Results					
Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	150.95	2	75.47	10.56	<0.001
Within Groups	1057.77	148	7.15		
Total	1208.72	150			

Table 4. Tukey HSD Post Hoc Comparisons: Knowledge Score by Designation

Comparison	Mean Difference	Std. Error	p-value	95% CI
CHW vs. NO	–1.87	0.47	<0.001	–2.98 to –0.76
CHW vs. HEO	–2.85	0.99	0.012	–5.19 to –0.52
NO vs. HEO	–0.98	1.02	0.602	–3.39 to 1.43

As presented in Table 4, CHW vs. NO: CHWs scored significantly lower than NOs (mean difference = –1.87, p < 0.001). The 95% confidence interval (–2.98 to –0.76) does not cross zero, confirming that this difference is statistically reliable and clinically meaningful.

CHW vs. HEO: CHWs also scored significantly lower than HEOs (mean difference = –2.85, p = 0.012). The 95% confidence interval (–5.19 to –0.52) confirms the significance of this difference, with CHWs scoring approximately 2.85 points lower on average.

NO vs. HEO: NOs and HEOs did not differ significantly in knowledge scores (mean difference = –0.98, p = 0.602).

The 95% confidence interval (–3.39 to 1.43) crosses zero, indicating that the observed difference could be due to chance.

Pearson correlation analysis:

A Pearson correlation analysis was performed to examine relationships among malnutrition knowledge, age, and years of experience.

Knowledge vs. Age: r = –0.032, p = 0.698 (not significant). There was no statistically significant relationship between age and malnutrition knowledge.

Knowledge vs. Years of Experience: r = –0.043, p = 0.602 (not significant). Years of work experience was not significantly related to knowledge scores.

Age vs. Years of Experience: r = 0.878, p < 0.001 (highly significant). As expected, age and years of experience were very strongly correlated, indicating that older workers had more years of service.

Spearman's rank correlation:

Spearman's rank correlation analysis was conducted to examine relationships between knowledge and ordinal variables (professional designation and education level) (Table 5).

Table 5. Spearman Rank Correlation Results

Correlation	rho	p-value	Interpretation
Knowledge vs. Designation	0.351	<0.001	Moderate, positive, significant
Knowledge vs. Education Level	0.163	0.046	Weak, positive, significant

Knowledge vs. Professional Designation: rho = 0.351, p < 0.001. A moderate, positive, and statistically significant relationship was found between professional designation and knowledge scores.

Knowledge vs. Education Level: rho = 0.163, p = 0.046. A weak but statistically significant positive relationship was found between level of education and knowledge.

Associations Between Clinical Knowledge and Independent Variables:

Bivariate Analysis: Chi-Square Tests: Chi-square tests and Fisher's Exact tests were conducted to assess whether demographic and training characteristics were associated with clinical knowledge level (categorized as low, average, or good).

Table 6. Chi-Square Test Results: Categorical Variables vs. Knowledge Level.

Variable	Category	χ^2 Value	p-value	Interpretation
Gender	Male/Female	0.174	0.676	No significant association
Age Group	22-25 26-30 31-35 36-40 41-45 46-50 51-55 56-60 61-65 65+ years	5.244	0.803	No significant association
Years of Experience	<1 1-5 6-10 11-20 >20 years	3.992	0.375	No significant association
Marital Status	Single/Married/Divorced/Widowed	0.875	0.884	No significant association
Education Level	Grade 8/10/12	0.296	0.883	No significant association
Health Training College	CHW Sch/Nursing Sch/University	7.937	0.019	Significant association
Practical Training Facility	Aid post/HC/District Hospital/Hospital	6.998	0.072	Approaching significance
Post-Basic Advanced Training	Yes/No	6.900	0.009	Significant association
Attend Malnutrition Training	Yes/No	8.906	0.003	Significant association

Note: Significance evaluated at $p \leq 0.05$

Non-Significant Associations: No significant associations were found for gender ($\chi^2 = 0.174$, $p = 0.676$), age group ($\chi^2 = 5.244$, $p = 0.803$), years of experience ($\chi^2 = 3.992$, $p = 0.375$), marital status ($\chi^2 = 0.875$, $p = 0.884$), or education level ($\chi^2 = 0.296$, $p = 0.883$).

Significant Associations: In contrast, several professional and training-related variables demonstrated significant associations with knowledge level.

Health Training College Attended ($\chi^2 = 7.937$, $p = 0.019$): Significant association. The institution

where initial training was received significantly influenced knowledge outcomes.

Post-Basic Advanced Training (χ^2= 6.900, p = 0.009): Significant association. Health workers who had attended post-basic advanced training demonstrated higher knowledge levels.

Attendance at Malnutrition-Specific Training (χ^2 = 8.906, p = 0.003): Significant association. This was the strongest association identified in the bivariate analysis.

Practical Training Facility (χ^2 = 6.998, p = 0.072): Approaching significance. There was a trend toward different knowledge outcomes depending on whether participants trained at an aid post, health centre, district hospital, or general hospital, though this did not reach statistical significance (Table 6).

Multivariable Analysis: Binary Logistic Regression (Table 7):

Binary Logistic Regression: A multivariable binary logistic regression model was employed to identify independent predictors of adequate clinical knowledge of malnutrition. The dependent variable was binary: adequate knowledge (≥75% of total score) versus inadequate knowledge (<75% of total score). Three independent variables identified as significant in the bivariate analysis were included in the model: (1) health training college attended, (2) post-basic advanced training, and (3) attendance at malnutrition-specific training.

Table 7. Multivariable Binary Logistic Regression: Predictors of Adequate Malnutrition Knowledge.

Variable	Category	Crude OR (95% CI)	p-value	Adjusted OR (95% CI)	p-value
Health Training College					
	CHW Training Sch*	1.00	—	1.00	—
	Nursing School	2.88 (1.08–7.74)	0.035	2.42 (0.74–7.88)	0.143
	University (DWU)	6.30 (1.20–31.35)	0.025	5.76 (1.05–31.54)	0.044
Post-Basic Advanced Training					
	No*	1.00	—	1.00	—
	Yes	3.83 (1.34–11.01)	0.013	2.56 (0.73–8.90)	0.141
Attend Malnutrition Training					
	No*	1.00	—	1.00	—
	Yes	4.34 (1.56–12.07)	0.005	4.87 (1.61–14.75)	0.005

Reference group: *CHW training Sch (Health Training College), *No (Post-Basic training), *No (Attend Malnutrition training). Note: Significance evaluated at p ≤ 0.05

Health Training College Attended: Nursing School (AOR = 2.42, 95% CI [0.74−7.88], p = 0.143): Not statistically significant after adjustment. University (DWU) (AOR = 5.76, 95% CI [1.05−31.54], p = 0.044): Significant predictor. Attending university for health professional training was associated with 5.76 times higher odds of demonstrating adequate

clinical knowledge compared to CHW-training-school graduates.

Post-Basic Advanced Training (AOR = 2.56, 95% CI [0.73−8.90], p = 0.141): Not statistically significant after adjustment.

Attendance at Malnutrition-Specific Training (AOR = 4.87, 95% CI [1.61−14.75], p = 0.005): Strong and significant predictor.

Knowledge Gaps Across Clinical Domains:

To classify knowledge or performance adequacy, a 75% cutoff was applied. Based on these criteria, all the domains (Domains 1-8) were either classified as having inadequate or adequate knowledge or performance.

Table 8. Classification of domain knowledge or performance adequacy.

Domain	N	Mean (SD±)	Range	% Achievement	Competency Status
1. Coordination and Leadership Management	151	1.64 (1.47)	0–6	27	Inadequate
2. General Knowledge on Malnutrition	151	4.68 (1.20)	1–6	78	Adequate
3. Availability of Clinical Diagnosis Tools	151	11.22 (1.97)	6–15	75	Borderline
4. Availability of Medical Supplies	151	3.22 (0.42)	2.33–4.11	78	Adequate
5. Assessment of Children with Malnutrition	151	5.33 (1.30)	1–7	76	Adequate
6. Diagnosis of Types of Malnutrition	151	2.79 (0.95)	0–4	70	Borderline
7.Treatment of Malnutrition	151	2.11 (1.07)	0–5	42	Inadequate
8.Management of Malnutrition	151	1.71 (0.60)	0–3	57	Inadequate

Domain 1: The majority of participants were classified as having inadequate performance in this domain. Domain 2: Most participants (approximately 50%) were classified as having adequate general knowledge of malnutrition. Domain 3: The mean score of 11.22 is slightly below the competency threshold, indicating moderate availability of tools. Domain 4: The mean score of 3.22 is slightly above the competency threshold, indicating adequate availability. Domain 5: Approximately 50% of participants achieved adequate assessment competency. Domain 6: Approximately 50% of participants achieved adequate diagnostic competency. Domain 7: The majority of participants were classified as having inadequate knowledge of malnutrition treatment. Domain 8: The majority of participants were classified as having inadequate knowledge of malnutrition management.

DISCUSSION:

The population for this study consisted primarily of female health workers (64.2%) and individuals in early to mid-career age groups, indicating a relatively young and developing

workforce. The high proportion of married participants reflects common demographic patterns in PNG, while the generally adequate level of secondary education suggests a reasonable foundation for clinical practice. The dominance (61.6%) of CHWs highlights their central role in frontline service delivery, particularly in rural settings, supported by a smaller proportion of NOs and HEOs. Although the distribution of participants was somewhat concentrated in the Anglimp-South Waghi district, it still provides a reasonable representation of the province despite 6% (Table 1) of the participants who are employed by Jiwaka PHA but resides in Western Highlands Province (outside Jiwaka Province). Additionally, the concentration of respondents in health centres and sub-centres aligns with the structure of the primary healthcare system in PNG, where most essential services are delivered.

This study found that the majority of health workers (59.6%) in Jiwaka Province demonstrated average clinical knowledge regarding malnutrition management in children under five years (Table 2). This finding is concerning as it indicates that fewer than two-thirds of health workers possess knowledge at or above the 75% competency threshold recommended for clinical practice. Only 15.2% achieved a good level of knowledge (≥75%), suggesting that the proportion of health workers with a comprehensive understanding of malnutrition management is limited. Conversely, a notable proportion (25.2%) exhibited low knowledge (<50%), highlighting significant gaps in understanding among a substantial minority of the workforce. The mean knowledge score of 17.42 out of 23 (approximately 76%) suggests that while health workers possess a reasonable foundation, they fall short of the 75% competency threshold in several critical domains. Given the essential role that health workers play in identifying, diagnosing, and managing malnourished children in PNG's resource-limited health system, this finding is particularly concerning.

The prevalence of average and low knowledge is consistent with earlier studies in PNG, including a 1993 study conducted in the Eastern Highlands Province, which assessed the clinical competency of CHWs and found significant gaps in knowledge and clinical skills [11]. This suggests that knowledge gaps in malnutrition management persist as a chronic challenge within the PNG health system. More recent evidence indicates that the preparedness for practice among NOs and CHWs in PNG continues to be influenced by the effectiveness of pre-service and in-service training programs [19]. The persistence of these gaps over time suggests ongoing challenges related to limitations in training, continuing professional development, and access to updated clinical guidelines.

Effective management of childhood malnutrition requires early detection, accurate classification (e.g., severe acute malnutrition, moderate acute

malnutrition), and adherence to WHO treatment protocols [15]. However, studies conducted in PNG and other low-resource settings indicate gaps in clinical competency, limited access to refresher training, and variable adherence to Integrated Management of Childhood Illness (IMCI) guidelines [12-13]. In PNG, child wasting treatment services were formally integrated into the national health system in 2014, following international advocacy and capacity-building initiatives. However, the effectiveness of this integration has been variable across provinces, with significant gaps in health worker knowledge and facility capacity documented [9-10]. Studies on the effectiveness of malnutrition training programs have demonstrated that structured educational interventions can significantly improve health professionals' knowledge, understanding, and skills in malnutrition diagnosis and management [20].

An independent samples t-test revealed no statistically significant difference in malnutrition knowledge scores between genders, suggesting that gender does not serve as a meaningful predictor of malnutrition knowledge among health workers in Jiwaka Province [19]. Although females scored on average about 0.53 points higher than males, this difference was not statistically meaningful ($p>0.05$).

A one-way ANOVA test indicated that malnutrition knowledge scores differed significantly across the three professional designations (Table 3): CHWs, NOs, and HEOs ($F (2, 148) = 10.56$, $p < 0.001$). This finding demonstrates that professional designation is a significant factor influencing malnutrition knowledge among health workers in Jiwaka Province. Following this result, a post hoc test (Table 4) showed that CHWs, who represent 61.6% of the sample and serve as the frontline health providers in rural PNG, demonstrated significantly lower knowledge compared to both NOs and HEOs ($p < 0.001$). CHWs had a mean knowledge score of 16.65, compared to 18.52 for NOs and 19.50 for HEOs. This knowledge gap is particularly concerning given the critical role that CHWs play in primary healthcare delivery and malnutrition management in rural PNG. This finding aligns with the hierarchical structure of health professional training in PNG, where CHWs receive shorter, less comprehensive training compared to nursing and health extension officer programs [19].

The similarity in knowledge between NOs and HEOs (no significant difference, $p=0.602$) suggests that these two groups, which have received higher levels of formal training, possess comparable competencies in malnutrition management. This aligns with findings from preparedness studies in PNG, which have documented that the level of pre-service training and professional qualification significantly influences clinical competencies [19]. The knowledge gap between CHWs and higher-cadre workers underscores the need for targeted capacity-building interventions specifically designed for community-level health workers.

A Pearson's correlation analysis revealed no significant relationships between malnutrition knowledge and both age (Knowledge vs. Age: r = –0.032, p = 0.698) and years of experience (Knowledge vs. Years of Experience: r = –0.043, p = 0.602). This lack of significant relationships suggests that demographic factors alone do not determine malnutrition knowledge in this sample. Knowledge acquisition and retention appear to be influenced more by the quality and relevance of training, opportunities for continuing education, and access to evidence-based resources. The absence of a positive experience-knowledge relationship indicates that years of practice without structured ongoing training and knowledge updates may not lead to improved clinical knowledge. However, it is noteworthy that age and years of experience were very strongly correlated (r = 0.878, p < 0.001), indicating that older workers had more years of service.

A Spearman's rank correlation analysis examined relationships between knowledge and ordinal variables (professional designation and education level). A moderate, positive, and statistically significant relationship was found between professional designation and knowledge scores (rho = 0.351, p < 0.001), indicating that individuals in higher designations (HEO or NO) tended to have higher knowledge scores (Table 5). Conversely, a weak but statistically significant positive relationship was found between education level and knowledge (rho = 0.163, p = 0.046), suggesting that higher educational attainment (Grade 12) is associated with slightly increased knowledge, though the effect size is small, ρ (rho)=0.163. These findings indicate that both professional qualification and formal education contribute to malnutrition knowledge, though professional designation appears to be a stronger predictor than general education level. The weak relationship with education level may reflect the fact that formal education does not specifically address malnutrition management unless supplemented with specialized health professional training.

In a bivariate analysis (Table 6), Chi-square tests and Fisher's Exact tests were performed to assess whether demographic and training characteristics were associated with clinical knowledge level (low, average, good). No significant associations were found for gender ($\chi^2 = 0.174$, p = 0.676), age group ($\chi^2 = 5.244$, p = 0.803), years of experience ($\chi^2 = 3.992$, p = 0.375), marital status ($\chi^2 = 0.875$, p = 0.884), or education level ($\chi^2 = 0.296$, p = 0.883). These results suggest that demographic factors alone do not significantly influence malnutrition knowledge levels in this sample. Gender differences were negligible (p = 0.269) as also revealed in the earlier t-test analysis, consistent with trends in many health professions where gender no longer predicts clinical competence. The lack of a significant relationship between age or years of experience and knowledge is particularly noteworthy, underscoring the importance of structured, evidence-based

training and continuing education rather than relying solely on experiential learning.

In contrast, several professional and training-related variables demonstrated significant associations with knowledge level. The institution where initial training was received significantly influenced knowledge outcomes (χ^2 = 7.937, p = 0.019), suggesting that the quality and content of pre-service training programs vary across different training institutions in PNG. Efforts to standardize and strengthen malnutrition content in pre-service curricula could have broad-reaching impacts on workforce competence. Additionally, health workers who attended post-basic advanced training demonstrated higher knowledge levels (χ^2 = 6.900, p = 0.009), indicating that continuing professional education is associated with improved knowledge. Attendance at malnutrition-specific training showed the strongest association identified in the bivariate analysis (χ^2 = 8.906, p = 0.003), highlighting the importance of targeted, disease-specific training interventions.

In a multivariate analysis (Table 7), a binary logistic regression model was employed to identify independent predictors of adequate clinical knowledge of malnutrition. University-level pre-service education was identified as a significant independent predictor of adequate malnutrition knowledge (AOR = 5.76 95% CI [1.05−31.54], p = 0.044), suggesting that broader educational foundations enhance health workers' ability to acquire and apply specialized knowledge. In contrast, attendance at malnutrition-specific training remained the strongest predictor of adequate clinical knowledge (AOR = 4.87, 95% CI [1.61−14.75], p = 0.005), demonstrating that targeted, disease-specific training is more effective than general professional development in improving knowledge of malnutrition management.

Domain Specific Analysis (Domains 1−8):

To classify knowledge or performance adequacy (Table 8), a 75% cutoff was applied to assess knowledge gaps across different clinical domains [16]. For instance, given a maximum score of 6, scores ≤ 4 were classified as inadequate, while scores ≥ 5 were classified as adequate. The analysis of domain-specific knowledge revealed several critical patterns:

Domain 1: Coordination and Leadership Management: The mean score of 1.64 out of 6 indicates that participants achieved only approximately 27% of the expected performance level, reflecting a significant area of concern requiring immediate attention. This suggest that that most health workers demonstrated minimal understanding of coordination and leadership principles in malnutrition management. This domain, which likely assesses health workers' ability to coordinate care, communicate with supervisors, and demonstrate leadership in health facility management, represents a significant area of concern requiring immediate attention [21]. Overall Coordination and Leadership

Management competencies are inadequate in this sample. This gap may reflect limited training in management and leadership skills, as well as the typically hierarchical and supervisory structures in PNG's health system where frontline workers may have limited autonomy or responsibility for coordination.

Domain 2: General Knowledge of Malnutrition: The mean score of 4.68 out of 6 indicates that participants achieved approximately 78% of the expected knowledge level, which exceeds the 75% competency threshold. This suggests that health workers in Jiwaka Province possess a reasonable foundational understanding of malnutrition concepts, including its definition, causes, types, and general consequences [22]. This finding is more encouraging than the low performance in other domains and suggests that basic malnutrition awareness and knowledge are relatively well-distributed among the workforce. General knowledge of malnutrition is adequate in this sample. This competency may reflect the prominence of malnutrition as a health issue in PNG and the inclusion of basic malnutrition content in pre-service health worker training programs.

Domain 3: Availability of Clinical Diagnostic Tools: The average score of 11.22 out of a maximum of 15 indicates that participants achieved approximately 75% of the expected availability level. The mean score of 11.22 is slightly below the competency threshold, indicating moderate availability of tools. This reflects fairly moderate availability of clinical diagnostic tools at the facilities where health workers are employed. However, the range (6–15) and standard deviation (1.97) indicate uneven distribution, with some facilities having substantially fewer diagnostic tools available (score = 6) while others have more comprehensive availability (score = 15). This suggests that resource disparities exist across health facilities in Jiwaka Province, with some facilities well-equipped while others lack essential diagnostic equipment [8-9]. Availability of clinical diagnostic tools is moderate and variable across facilities. This represents a significant health system constraint that may limit health workers' ability to effectively assess and diagnose malnutrition, even if their knowledge is adequate. Efforts to strengthen health facility infrastructure and ensure equitable distribution of diagnostic equipment are needed.

Domain 4: Availability of Medical Supplies: The mean score of 3.22 indicates that participants reported moderate to good availability of medical supplies, with an achievement level of approximately 78% of the ideal. The low variability (SD = 0.42) suggests relatively consistent resource levels across facilities, which is encouraging. The median and mode of 3.22 indicate that most respondents reported similar levels of supply availability. While minor shortages exist (lowest score = 2.33), the

general supply situation appears stable and reasonably adequate. This finding suggests that PNG's health system, despite resource constraints, has achieved reasonable consistency in the distribution of essential medical supplies across provincial facilities. Availability of medical supplies is adequate and relatively consistent across facilities. This represents a relative strength in the health system's capacity to support malnutrition management at the facility level [19,22].

Domain 5: Assessment Practices: Approximately 50% of participants achieved adequate assessment competency (mean score = 5.33 out of 7), reflecting generally strong assessment practices. The mean score of 5.33 out of 7 indicates that participants reported performing approximately 76% of the recommended assessment activities when managing children with malnutrition, which exceeds the 75% competency threshold. The scores ranged from 1 to 7, suggesting that while many health workers perform nearly all required assessments (score = 7), a few perform very few assessment activities (score = 1). This indicates variable assessment practices across the workforce [10]. Assessment competencies are generally satisfactory, with most health workers demonstrating knowledge of essential assessment procedures [13]. This may reflect the relative straightforwardness of assessment techniques (such as anthropometric measurements) compared to more complex clinical tasks. However, the range and moderate variability suggest that a minority of participants conduct incomplete assessments, indicating a need for targeted supervision and training for lower-performing individuals. Assessment practices are generally strong, though variable. While overall performance is satisfactory, a small number of participants may need additional training or supervision to ensure comprehensive assessment practices.

Domain 6: Diagnostic Ability: Diagnostic ability is moderately good. The mean score of 2.79 out of 4 suggests that respondents correctly diagnosed malnutrition types approximately 70% of the time, which is slightly below the 75% competency threshold, meaning that many participants demonstrated reliable ability to identify different malnutrition types (such as severe acute malnutrition [SAM], moderate acute malnutrition [MAM], stunting, and wasting) [16]. However, the standard deviation of 0.95 and range (0–4) indicate substantial variation in diagnostic competence. Some participants diagnosed malnutrition types very accurately (scores 3–4), while others struggled significantly (scores 0–2). The presence of participants with scores of 0 indicates that some health workers could not correctly diagnose any malnutrition types, representing a critical gap. While the group performs at approximately the competency threshold overall, a subset of participants requires additional diagnostic training. This variation in knowledge and clinical

skill may relate to differences in training quality, experience, facility support, and access to diagnostic tools and guidelines [23]. Diagnostic competence is satisfactory on average but unevenly distributed. Targeted training in malnutrition classification and diagnosis is needed for lower-performing health workers.

Domain 7: Treatment Knowledge: Treatment knowledge was assessed as low. The majority of participants were classified as having inadequate knowledge of malnutrition treatment. The mean score of 2.11 out of 5 indicates that participants achieved only approximately 42% of the expected knowledge level, substantially below the 75% competency threshold. This represents a critical knowledge gap, as appropriate treatment is essential for improving child outcomes in malnutrition. Treatment of malnutrition, particularly severe acute malnutrition, requires knowledge of specialized nutritional products (such as ready-to-use therapeutic foods [RUTFs]), appropriate feeding protocols, management of complications (such as refeeding syndrome), and monitoring of clinical response [24-25]. The low performance in this domain suggests that health workers lack comprehensive understanding of these critical treatment principles. Knowledge of malnutrition treatment is inadequate in this sample. This represents a major knowledge gap requiring urgent attention through targeted training programs. The WHO guidelines on malnutrition management provide evidence-based treatment protocols that should be disseminated and implemented across PNG's health system [2-4].

Domain 8: Management Knowledge: Management knowledge was assessed as very low. The majority of participants were classified as having inadequate knowledge of malnutrition management. The mean score of 1.71 out of 3 indicates that participants achieved only approximately 57% of the expected knowledge level, substantially below the 75% competency threshold. This represents a critical gap in knowledge of the holistic management of malnutrition, which extends beyond treatment to include follow-up care, monitoring, prevention of relapse, and integration with other health services. Comprehensive malnutrition management requires understanding of the continuum of care, from prevention and early identification through acute treatment to rehabilitation and long-term follow-up [3-4, 26-27]. The very low performance in this domain suggests that health workers lack this broader, integrated understanding of malnutrition management. Knowledge of malnutrition management is inadequate in this sample. This represents another critical knowledge gap, suggesting that health workers understand individual treatment interventions but lack the broader systems-level understanding needed for comprehensive malnutrition management. This gap may contribute to incomplete treatment pathways and inadequate follow-up of malnourished children.

The domain-specific analysis revealed a critical pattern: while health workers demonstrated adequate foundational knowledge and assessment skills, they exhibited severe deficiencies in treatment and management of malnutrition. In contrast: General knowledge of malnutrition was adequate (78% achievement), Assessment skills were adequate (76%), Diagnostic skills were borderline (70%). This pattern suggests that health workers understand the basics of malnutrition and can perform simple assessments, but lack the detailed clinical knowledge needed for appropriate treatment and the broader systems understanding needed for comprehensive management. In PNG, most cases of SAM and MAM are identified at level 2 and 3 facilities and referred to level 4 and 5 hospitals for specialized care. However, limited or insufficient knowledge among rural health staff may affect the quality of referral, follow-up, and ongoing management when patients return to these facilities, disrupting continuity of care. This gap between foundational knowledge and applied clinical skills is a critical concern, as it suggests that health workers in Jiwaka Province may be unable to effectively translate their basic understanding into appropriate clinical actions.

The WHO guidelines on malnutrition management provide detailed protocols for treatment, including the use of specialized therapeutic foods, micronutrient supplementation, management of complications, and monitoring protocols [3-4]. The low performance of health workers in this domain suggests that these guidelines have not been effectively disseminated or implemented across PNG's health system. The very low performance in coordination and leadership is concerning because malnutrition management requires effective coordination among health workers, communication with supervisors and referral facilities, and leadership in implementing evidence-based practices. This gap may reflect limited training in management and leadership skills, as well as organizational constraints that limit health workers' autonomy and responsibility for coordination.

While this study focused on health worker knowledge, the domain-specific analysis also revealed important health system constraints that may limit the impact of improved knowledge. Clinical diagnostic tools were available at only 75% of the optimal level, and availability varied substantially across facilities. This suggests that even if health workers possessed adequate knowledge, they might be unable to implement it due to lack of essential equipment. However, medical supplies were available at approximately 78% of the optimal level with relatively consistent distribution across facilities, indicating that PNG's health system has achieved reasonable consistency in supply distribution. This relative strength could be leveraged to support improved malnutrition management if combined with improved health worker knowledge.

The knowledge levels documented in this study are consistent with findings from other LMICs. Research on health worker knowledge in malnutrition management in Africa and South Asia has similarly documented gaps in treatment and management knowledge, with health workers often demonstrating better foundational knowledge than applied clinical competencies [8]. The finding that specialized training significantly improves knowledge is also consistent with global evidence demonstrating the effectiveness of focused capacity-building interventions [20]. However, the particularly low performance in treatment and management domains in this study suggests that malnutrition training in PNG may not adequately address these critical clinical areas. Comparison with training programs in other countries that have achieved higher treatment and management knowledge might provide insights for improving PNG's training curricula.

Study Strengths and Limitations:

Study strengths include sufficient sample size (N = 151) with good representation across districts and facility types, Comprehensive assessment across multiple knowledge domains, Rigorous statistical analysis including multivariable modelling, and focus on a critical health issue in PNG with limited existing evidence.

Study limitations include the cross-sectional design, which limits causal inferences, as data collected at a single point in time cannot assess changes in knowledge. Self-reported data; knowledge was assessed through self-reported responses, which may be subject to bias (recall). Sampling method; purposive and convenience sampling may introduce selection bias. Geographic scope; findings are limited to Jiwaka Province and may not be generalizable to other regions.

CONCLUSION:

This study provides important evidence on the clinical knowledge of health workers regarding malnutrition in children under five years in Jiwaka Province. The findings lay the groundwork for developing and implementing evidence-based capacity-building programs to strengthen malnutrition management in PNG.

Future research should include longitudinal studies to assess the sustained impact of training interventions and qualitative studies to understand barriers to knowledge application in practice. Strengthening pre-service education in malnutrition management across all training institutions and ensuring equitable access to in-service training opportunities are critical priorities for PNG's health system.

Recommendations:

Targeted interventions are needed in the following areas; 1) Targeted Training is Essential**:** Prioritize targeted, disease-specific training programs to address critical knowledge gaps, 2) CHWs Require Priority Attention: Given their lower knowledge levels, targeted capacity-building programs should prioritize CHWs, 3)

Training Content Must Be Comprehensive: Programs must extend beyond general knowledge to include detailed treatment protocols and management frameworks guided by WHO guidelines, 4) Ongoing Training is Necessary: Regular training and knowledge updates are essential to maintain and improve competencies, and 5) Health System Support is Critical**:** Improved health worker knowledge must be complemented by health system strengthening, including the availability of diagnostic tools and therapeutic supplies.

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ARTIFICIAL INTELLIGENCE IN HEALTHCARE AND DENTISTRY: APPLICATIONS, CHALLENGES AND RESPONSIBLE CLINICAL INTEGRATION

Running title: AI in Healthcare and Dentistry

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ABSTRACT

Artificial intelligence (AI) is becoming a practical clinical technology rather than a distant computational concept. Across medicine and dentistry, AI systems are increasingly used to analyse electronic health records, medical and dental images, pathology slides, genomic data, patient-reported outcomes and operational datasets. These tools have the potential to support earlier diagnosis, risk prediction, treatment planning, documentation, patient communication and resource allocation. This narrative review provides a concise but expanded overview of the current applications of AI in healthcare, with a dedicated emphasis on dentistry, and discusses the ethical, validation and implementation requirements necessary for safe clinical integration. AI has shown promising performance in diagnostic imaging, clinical decision support, nursing workflows, mental health screening, drug discovery and administrative automation. In dentistry, AI is particularly relevant to radiographic interpretation, caries detection, periodontal assessment, endodontic diagnosis, cephalometric analysis, implant planning, prosthodontic design, oral lesion screening, patient triage and dental education. However, much of the current evidence remains retrospective, single-centre or based on curated datasets, and reported performance may not translate directly to daily clinical practice. AI should be adopted as an assistive, auditable and clinician-supervised tool. Successful implementation requires high-quality data, external validation, transparent reporting, bias assessment, data governance, clinician training, patient-centered consent processes and post-deployment monitoring. When these safeguards are embedded into practice, AI can improve efficiency and consistency while preserving professional judgment, accountability and the human relationship at the centre of care.

Keywords: Artificial intelligence; healthcare; dentistry; machine learning; deep learning; clinical decision support; dental radiology; ethics; validation; generative AI

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INTRODUCTION

Artificial intelligence (AI) refers to computational systems that can perform tasks commonly associated with human intelligence, including pattern recognition, classification, prediction, reasoning and language generation. In healthcare, the growth of AI has been driven by the digitisation of clinical records, rapid advances in imaging, wider use of genomic and other omics technologies, and the development of algorithms capable of learning complex relationships from large datasets. Contemporary AI includes machine learning, deep learning, natural language processing, computer vision and generative AI. These techniques are being investigated for diagnostic support, prognosis, treatment selection, workflow redesign and patient engagement [1, 2, 3, 4].

The appeal of AI is especially strong in areas where clinicians must interpret large volumes of data under time pressure. Algorithms can highlight suspicious findings on radiographs, segment anatomical structures, detect deterioration from vital signs, identify patients at high risk of complications and summarize clinical documentation. Used appropriately, these functions may reduce cognitive burden and improve consistency. Used inappropriately, they may create new forms of error, worsen inequities or lead to uncritical automation of clinical decisions. Therefore, the central question is not whether AI will enter healthcare, but how it can be integrated in a way that is safe, fair, transparent and clinically useful.

Dentistry provides a particularly relevant example of AI translation. Dental practice generates structured and unstructured data through intraoral radiographs, panoramic imaging, cone-beam computed tomography (CBCT), intraoral scans, photographs, periodontal charts, treatment notes and laboratory workflows. Many dental diagnoses also depend on repeated visual interpretation, which makes the field well suited to computer vision. At the same time, dental care is highly operator dependent and patient centered; therefore, AI must support rather than replace clinical judgment. This review expands the previous concise overview into a submission-ready narrative article by summarizing major healthcare applications, adding a dedicated dentistry component, and outlining practical principles for responsible implementation.

Core technologies and data sources

AI in healthcare depends on the interaction between data, algorithms and clinical context. Traditional machine learning methods can analyze tabular variables such as age, laboratory values, comorbidities and coded diagnoses. Deep learning is particularly useful for high-dimensional inputs such as radiographs, histopathology images, retinal

photographs, CBCT volumes, electrocardiograms and free-text notes. Natural language processing can extract information from clinical narratives, generate summaries and support documentation. Generative AI, including large language models and large multimodal models, can produce text, images or other outputs from complex prompts, but its fluent responses require careful verification because generated content may be inaccurate or unsupported [5, 6, 7].

Electronic health records (EHRs) have become a central data source for longitudinal risk prediction. Models trained in repeated measurements can identify patients at risk of diabetes, kidney disease, circulatory disorders, mental health deterioration or hospital readmission before overt clinical presentation [8]. In imaging, AI can classify disease, detect lesions, quantify anatomical structures and prioritise abnormal examinations. Multimodal approaches that combine images with EHR variables, symptoms or laboratory data often outperform single-modality systems because they approximate the way clinicians integrate information in practice [9]. However, each data source also introduces limitations: missing values, inconsistent coding, imaging artefacts, class imbalance, demographic skew and changes in equipment or clinical workflow can all reduce model reliability.

Clinical applications across healthcare

The strongest early evidence for AI has emerged from image-rich specialties. In radiology, dermatology, ophthalmology, pathology and oncology, deep learning systems have been developed to detect lesions, segment tumours, classify disease patterns and support triage. In some experimental settings, AI systems have matched or exceeded specialist-level performance for narrowly defined tasks, such as image classification or detection of predefined abnormalities [10, 11, 12]. These results should be interpreted cautiously. High performance on curated datasets does not automatically indicate safety in varied clinical environments where disease prevalence, image quality, patient demographics and operator skill differ.

Prediction models are another major area of application. AI can estimate the likelihood of clinical deterioration, sepsis, perioperative complications, cardiovascular events or treatment response. When embedded into decision support systems, these models may prompt earlier review, additional testing or preventive intervention. In nursing practice, AI-enabled tools can support monitoring, documentation, workload allocation, fall-risk prediction, pressure-injury prevention and remote patient follow-up [13, 14]. The value of such tools depends not only on statistical accuracy but also on alert fatigue, usability, integration with clinical routines and clarity about

responsibility when AI recommendations are accepted or rejected.

Mental health applications illustrate both promise and concern. AI can analyse questionnaire data, speech, text, activity patterns or EHR variables to identify risk of depression, anxiety, self-harm or relapse. Chatbots and conversational agents may improve access to low-intensity support, psychoeducation and monitoring, particularly when human services are overstretched [15]. Nevertheless, mental health care requires empathy, contextual interpretation, safeguarding and escalation pathways. AI tools in this area must therefore be designed with clear limits, clinician oversight and robust crisis protocols.

AI also supports biomedical discovery. Machine learning and deep learning are used in drug target identification, virtual screening, protein structure prediction, radiomics and personalised medicine. These applications may accelerate research pipelines and assist in matching patients to therapies. In health-system administration, AI can optimise appointment scheduling, coding, billing, inventory, discharge planning and workforce deployment. Generative AI may assist with clinical letters, referral summaries, patient information sheets and education material. Such administrative uses may reduce professional burnout, but quality assurance is essential because errors in documentation can directly affect patient care, legal records and reimbursement.

Artificial intelligence in dentistry

Dentistry is increasingly recognised as a distinct domain for AI development. Dental diagnosis relies heavily on imaging, pattern recognition and longitudinal monitoring, and many dental procedures are planned to use digital workflows. AI is being studied in oral and maxillofacial radiology, cariology, periodontology, endodontics, prosthodontics, orthodontics, implantology, oral medicine, oral surgery and dental education [16, 17, 18]. This breadth makes dentistry an ideal field for integrated clinical AI, but it also creates a need for rigorous validation across equipment types, patient groups and practice settings.

Dental radiology is the most mature area. Computer vision systems can assist in detecting caries, periapical radiolucencies, periodontal bone loss, impacted teeth, anatomical landmarks, cystic or tumour-like lesions, maxillary sinus findings and root morphology. A recent meta-analysis of AI platforms for caries detection reported wide variability in performance across systems and modalities, with 45 included studies, accuracy ranging from 41.5% to 98.6%, and pooled estimates showing promising but heterogeneous results [19]. These findings support the use of AI as a second reader or triage aid rather than an autonomous diagnostic authority. In routine practice, the

clinician must still correlate AI-highlighted findings with clinical examination, symptoms, caries risk, vitality tests and patient preferences.

Endodontics offers another practical use case. AI may assist in identifying periapical lesions, locating canals, assessing root canal morphology, estimating working length from images, detecting vertical root fractures and predicting outcomes. However, endodontic diagnosis is rarely radiographic alone. Pulp status, tenderness to percussion, periodontal probing, restorability, occlusion, cracks, previous treatment and patient history all influence decisions. Therefore, AI tools that detect radiographic patterns should be positioned within a broader diagnostic process rather than treated as definitive evidence.

In periodontology, AI can support measurement of alveolar bone levels, classification of periodontal staging, detection of calculus or furcation defects, and prediction of disease progression. In orthodontics, AI is used for cephalometric landmark identification, skeletal classification, growth assessment, aligner planning and treatment monitoring. In implant dentistry and oral surgery, AI can help segment CBCT data, identify anatomical structures such as the inferior alveolar canal, estimate bone availability, support virtual implant positioning and assist in surgical guide design. In prosthodontics and restorative dentistry, AI-enabled computer-aided design can propose crown morphology, occlusal anatomy and smile-design options, potentially improving efficiency in digital laboratories.

Oral medicine and oral pathology are emerging areas with high clinical importance. AI-assisted image analysis may support early screening of potentially malignant disorders and oral cancer using photographs, cytology, histopathology or multimodal data. The potential benefit is substantial because earlier recognition of suspicious lesions can shorten referral pathways. However, these systems require caution. Oral lesions are influenced by ethnicity, mucosal pigmentation, tobacco and areca nut habits, inflammation, trauma, candidiasis and image capture conditions. A false reassurance from AI could delay biopsy, while excessive false positives could overload specialist services. Dental AI for oral lesion screening should therefore be evaluated prospectively and linked to clear referral protocols.

Dental education and communication are also being reshaped by AI. Generative tools can create case-based quizzes, explain procedures in patient-friendly language, simulate viva questions, draft reflective notes and support student feedback. For experienced clinicians, AI may assist with literature searching, treatment-plan comparison and patient information leaflets. Nevertheless, students and practitioners must be trained to verify AI outputs, identify hallucinated references, protect patient confidentiality and understand that professional accountability cannot be delegated to software.

An AI-generated explanation may be useful, but the dentist remains responsible for diagnosis, consent, treatment and follow-up.

Dental AI may also have a public health role. If validated responsibly, algorithms could help prioritise school dental screening, identify communities with high untreated caries burden, support teledentistry triage and monitor outcomes across preventive programmes. These uses are attractive in regions with limited access to dental specialists; however, they also raise equity concerns. A model that performs well in privately insured or urban populations may be less reliable for rural, paediatric, elderly or medically compromised patients. Dental public health applications should therefore be evaluated with community representation, culturally appropriate consent processes and clear pathways for referral and follow-up.

Table 1. AI used in clinical dentistry

Dental domain	Potential AI contribution	Key caution before clinical use
Dental radiology and cariology	Detection of proximal caries, periapical lesions, bone loss, impacted teeth and anatomical landmarks on intraoral, panoramic and CBCT images.	Validate across imaging devices, exposure quality, dentition stage and local disease prevalence.
Endodontics	Support for periapical lesion detection, canal morphology assessment, fracture suspicion and outcome prediction.	Do not replace clinical tests, history, periodontal assessment and restorability evaluation.
Periodontology	Automated bone-level measurement, staging support, risk stratification and longitudinal monitoring.	Ensure periodontal definitions, radiographic angulation and demographic bias are addressed.
Orthodontics and implantology	Cephalometric landmarking, aligner monitoring, CBCT segmentation, anatomical nerve-canal detection and virtual planning.	Confirm recommendations against clinician planning, patient goals and surgical/anatomical constraints.
Prosthodontics and restorative dentistry	Digital smile design, crown morphology proposals, occlusal design and laboratory workflow efficiency.	AI-generated designs require occlusal, aesthetic, biological and material assessment by the dentist.
Oral medicine and oral pathology	Screening support for potentially malignant disorders, oral cancer triage and lesion documentation.	False reassurance can delay biopsy; referral pathways and prospective validation are essential.

Ethical, legal and validation challenges

The responsible use of AI in healthcare begins with data governance. AI systems often require large datasets, but clinical and dental data are sensitive. Consent, privacy, cybersecurity, de-identification, storage, cross-border transfer and secondary use must be addressed before model development or deployment. In dentistry, intraoral photographs, radiographs, facial scans and CBCT images may be identifiable, particularly when combined with demographic or appointment information. Data governance should therefore cover not only EHR records but also imaging archives, laboratory files and cloud-based digital dentistry platforms.

Bias is a persistent concern. AI models learn from the data used to train them; if those data under-represent certain age groups, ethnicities, socioeconomic groups, disease severities or imaging devices, the model may perform unequally. Bias can be particularly relevant in oral healthcare because caries, periodontal disease, oral cancer risk and access to care differ across populations. A model developed in a specialist academic centre may not generalise to a community dental clinic or a low-resource setting. Ethical analyses in dentistry have highlighted the need for prudence, justice, data protection, responsibility, participation and solidarity when AI is introduced into practice [20].

Explainability and transparency are also important. Many deep learning systems are described as black boxes because their internal reasoning is difficult to interpret. Heatmaps, confidence scores and case-based explanations may help clinicians understand why a model has flagged a finding, but these aids are not perfect explanations. A visually persuasive heatmap may still be misleading. Clinicians need information about the intended use, training data, validation data, performance metrics, limitations, contraindications and update history of the software. For dental AI, this should include details about imaging modality, radiographic projection, exposure quality, age range, dentition stage and disease definitions.

Validation is the central bridge between technical promise and clinical adoption. Many AI studies are retrospective and evaluate performance on archived images or records. Although such studies are useful for early development, they cannot establish real-world benefit. External validation across independent sites, prospective evaluation, workflow assessment and post-market monitoring are required. The healthcare AI community has developed reporting frameworks to improve transparency, including CONSORT-AI and SPIRIT-AI for clinical trials, TRIPOD+AI for prediction models, CLAIM for imaging studies, DECIDE-AI for early-stage decision-support evaluation, and STARD-AI for diagnostic accuracy studies [21, 22, 23, 24, 25]. Dental AI studies should increasingly align with these standards.

Implementation framework for responsible clinical integration

A practical implementation framework should begin with a clearly defined clinical problem. AI should not be adopted merely because it is novel. The intended use must specify the patient population, data input, decision point, output, user and expected action. For example, a dental caries detection tool may be intended to highlight suspected proximal lesions on bitewing radiographs for review by a dentist, not to diagnose caries independently or prescribe restoration. Clear scope prevents overuse and supports safe consent and training [26].

The second step is local validation. Before implementation, the software should be tested on data from the intended setting. Dental clinics should evaluate whether the tool performs adequately with their sensors, panoramic machines, CBCT protocols, patient demographics and record systems. Metrics should include sensitivity, specificity, positive predictive value, negative predictive value, calibration, false-positive burden, time impact and user acceptability. For clinical decision support, the relevant question is not only whether the AI is accurate, but whether it improves decisions, outcomes or efficiency compared with existing practice [27,28].

The third step is workflow design. AI outputs should appear at the right time and in a format that supports clinical reasoning. Poorly timed alerts may be ignored; excessive prompts may increase fatigue; unclear confidence scores may confuse users. Dental applications should allow clinicians to accept, reject or annotate AI findings and should preserve a record of final human interpretation. Patient communication should be transparent: clinicians may explain that AI-assisted tools were used to support image review or planning, while making clear that responsibility remains with the treating professionals [29,30].

The fourth step is governance after deployment. AI performance can drift when patient populations, equipment, software versions or clinical protocols change. Organisations should monitor errors, near misses, user feedback, demographic performance and update logs. There should be a process for reporting concerns, pausing use if safety issues emerge and retraining staff when systems change. For generative AI, additional safeguards are needed: patient-identifiable information should not be entered into unsecured public tools, generated clinical content should be reviewed before use, and references or medical claims should be verified. [30,31].

Future directions

The future of AI in healthcare and dentistry is likely to be multimodal, personalised and increasingly embedded in routine software. Rather than isolated algorithms that perform one narrow task, future systems may combine radiographs, photographs, scans, periodontal data, notes, risk factors and patient-reported outcomes to support longitudinal care. In dentistry, integrated AI could help identify patients at high risk of caries or periodontitis, monitor orthodontic progress remotely, detect implant complications, support maintenance scheduling and personalise preventive advice. [26,28,32].

Research should move beyond technical accuracy toward patient-centred outcomes. Important questions include whether AI reduces missed disease, improves communication, shortens referral delays, decreases unnecessary treatment, improves access in

underserved areas or reduces clinician burnout. Dental AI also requires better shared datasets, common annotation standards, external validation cohorts and prospective trials. Collaboration among clinicians, dental educators, computer scientists, regulators, patients and industry will be necessary to ensure that AI tools are clinically meaningful and ethically acceptable.

CONCLUSION

AI is transforming healthcare by improving the analysis of complex data, supporting diagnostic and predictive tasks, streamlining documentation and opening new possibilities for personalized care. Dentistry is a major area of opportunity because dental practice is increasingly digital and image based. AI can support radiographic interpretation, caries detection, endodontic and periodontal assessment, orthodontic analysis, implant planning, prosthodontic design, oral lesion screening and education. However, the profession should avoid both exaggerated enthusiasm and unnecessary resistance. Current AI systems are best understood as assistive tools that can enhance consistency and efficiency when supervised by trained clinicians.

Safe adoption requires robust data governance, external validation, transparent reporting, bias assessment, clinician training, patient-centered communication and continuous monitoring. The goal is not to replace healthcare professionals, but to strengthen their ability to deliver timely, accurate, equitable and compassionate care. For dentistry, the most successful AI systems will be those that respect the complexity of oral diagnosis, integrate smoothly into clinical workflows and preserve the dentist-patient relationship as the foundation of care.

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CANNABIS SATIVA-INDUCED OXIDATIVE STRESS IN MALE AND FEMALE WISTAR RATS: AMELIORATIVE EFFECT OF MELATONIN

Running title: Melatonin ameliorates *Cannabis sativa*-induced oxidative stress in rats

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ABSTRACT

Cannabis sativa (CS) has been utilized for medicinal purposes since ancient times due to its phytochemical content, hence the quest to prevent its antioxidant effects in the body. This study investigated the effects of co-administration of melatonin and CS on oxidative stress (OS) in male (m) and female (f) Wistar rats. CS and melatonin were administered orally for three weeks. All the animals were provided with equal access to food and water and were sacrificed after the third week. OS markers were quantified following standard protocols. The results revealed a significant ($p<0.05$) increase in Lactate dehydrogenase (LDH) and malondialdehyde (MDA), with a significant ($p<0.05$) decrease in catalase, glutathione reductase (GSH), glutathione peroxide (GPx), total anti-oxidant capacity (TAC) and superoxide dismutase (SOD) was observed in the groups treated with high-dose of CS (6mg) with no significance differences observed in the low-doses (2 mg and 4 mg) treated groups when compared with the control in both sexes. However, Co-administration of CS and melatonin showed no significant differences in all the markers across the groups treated with both low and high-doses of CS in both sexes when compared with the control. This study concluded that co-administration of CS and melatonin could prevent OS associated with CS at high-dose. However, males exhibited more pronounced effects than females. Therefore, this study suggests that melatonin may be used as supplement to prevent CS-induced oxidative stress.

Key words: *Cannabis sativa*; Co-administration; High-dose; Low-dose; Melatonin; Oxidative stress

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INTRODUCTION

Cannabis sativa (CS) has been used medicinally for centuries, owing to its rich phytochemical composition [1]. This drives the interest in preventing its effect on the antioxidant defense system in the body. Globally, this substance is commonly abused as an illicit drug [2]. When cellular redox homeostasis is disturbed, reactive species (peroxides and free radicals) accumulate, damaging key biomolecules (proteins, lipids and genetic materials) [3].

Oxidative stress (OS) arises from a disequilibrium between pro-oxidants and antioxidants [4]. The balance can shift due to heightening reactive oxygen species (ROS) or impaired antioxidant protective mechanisms [5]. OS can also result from disequilibrium in the oxidizing system, comprising ROS, free radicals, and reactive nitrogen species (RNS) [6]. Antioxidant mechanisms are essential to mitigating free radicals, whose unchecked activity leads to harmful outcomes [7].

Melatonin is predominantly secreted at night, aligning with the dark period of the light/dark rhythm [8]. Studies have confirmed that it can scavenge free radicals effectively in multiple contexts, including hydrogen peroxide (H_2O_2), hydroxyl radical (OH^-), nitric oxide (NO), superoxide anion (O^{2-}), singlet oxygen (O), peroxynitrite anion ($ONOO^-$), hypochlorous acid (HOCl), among others [9-12]. Previous studies [13-14] revealed that CS has detrimental effect on oxidative stress. It has also been discovered that the effect of CS on oxidative stress is dose dependent and gender specific [15]. A study also revealed that melatonin could ameliorate the effect of CS on oxidative stress in female rats [10]. However, within my limit of research, how melatonin co-treatment with CS (at differences doses) influences gender-specific outcomes is still lacking. This study therefore aimed to bridge this area by examining the influence of CS in a cohort of male and female Wistar rats, so as to explore sex-related variations and investigate oxidative biomarkers(Lactate dehydrogenase (LDH), catalase, superoxide dismutase (SOD), glutathione reductase (GSH), glutathione peroxide (GPx), malondialdehyde (MDA) and total antioxidant capacity (TAC)),to assess the influence of co-administration of melatonin and CS, considering its dose dependent modulation in relation to OS. The selected oxidative stress markers were evaluated due to their ability to reflect the body's antioxidant defense status.

The objectives were to investigate the influence of co-administration of melatonin and CS on OS using male and female Wistar rats as subjects by considering its dose dependent modulation; and to evaluate the differential impacts of co-administration of melatonin and CS on OSin male versus female Wistar rats by considering its dose dependent modulation. The core hypotheses underpinning this study were: co-

administration of melatonin and CS would not affect OS in male versus female rats (null); and co-administration of melatonin and CS would affect OS in male versus female rats (alternative).

METHODOLOGY

Sampling procedure

CS leaves were provided by the National Drug Law Enforcement Agency (NDLEA), Nigeria, exclusively for research use.

Extraction of *Cannabis sativa* leaves

CS extraction was performed using Soxhlet apparatus, with 800g of dries CS leaves macerated in 98% ethanol for 48 hours. Following filtration, the filtrate was collected in a round-bottom flask mounted on a rotary evaporator under reduced pressure. The extract was concentrated to dryness via evaporation and cooled, affording 55 g of crude dried leaves of CS [15].

Experimental animals

Twenty male rats with mean weight (180g ± 1.89) and twenty female rats with mean weight (165g ± 1.23) used for this study were sourced from Temilade Animal Venture, Ogbomoso, Oyo State, Nigeria. They were housed at ambient temperature with ad libitum access to feed and water, under a standard 12-hour light/dark cycle. The principles of humane laboratory animal care (NIH publication No. 85-23, revised 1985) were followed throughout the study.

The experimental protocol was approved by Ethical Committee of University of Ilesa, Ilesa, Osun State, Nigeria with approval number (UNILESA/ERC/2026/016).

Experimental protocol

Following a 2-week period of acclimatization, male (m) and female (f) animals were separately randomized into four groups (n=5 per group per sex). Corresponding male (1m, 2m, 3m, and 4m) and female (1f, 2f, 3f, and 4f) groups received distilled water (control), 2 mg/kg body weight (bw) of CS, 4 mg/kg bw of CS, 6 mg/kg bw of CS, 4 mg/kg bw of melatonin, 2mg/kg bw of CS+4 mg/kg bw of melatonin, 4mg/kg bw of CS+4 mg/kg bw of melatonin, and 6mg/kg bw of CS+4 mg/kg bw of melatonin respectively, between 8:00 am to 10:00 am, orally, once daily for three weeks with free access to feed and water. Following the 21st daily dose, the rats were humanely sacrificed for experimental analysis.

Preparation of serum samples

Rats were humanely sacrificed using ketamine anesthesia (80mg/kg bw) via intraperitoneal injection. Blood samples were collected via cardiac puncture into experimental bottles. Blood samples were incubated for 30 min to clot followed by centrifugation at 625×*g* for 10 min in a Uniscope Laboratory Centrifuge (Model SM800B, Surgifield Medicals, Essex, England) to obtain the serum. The sera were transferred into plain bottles using a Pasteur pipette.

Prepared sera were immediately stored at -5°C and analyzed within 12 hours to preserve sample integrity.

Drug and assay kits

Lactate dehydrogenase (LDH) activity was determined spectrophotometrically (Spectramax Plus; Molecular Devices, Sunnyvale, CA, USA) according to the kit manufacturer's guidelines (product code BXC0243; Fortress Diagnostics, UK). Serum SOD concentration was measured using a colorimetric SOD colorimetric assay kit (Fortress Diagnostics Ltd., Antrim, UK; Product code: BXC0531), according to the kit manufacturer's guidelines. The amount of serum GPx was measured using GPx colorimetric assay kit (BioVision Inc., Milpitas, CA, USA), according to the kit manufacturer's guidelines. In line with the kit manufacturer's guidelines, total anti-oxidant capacity (TAC) in the serum was measured using a spectrophotometric microplate reader (Spectramax Plus, Molecular Devices, Sunnyvale, CA, USA) with the help of Oxi-Select TAC assay kit which involved the use of a single electron transfer mechanism (Cell Biolabs, Inc. San Diego, CA. cat no: STA-360). Catalase activity was measured using spectrophotometric reading [16]. The method used by [17] was adopted for GSH measurement. The assay procedure of [18], was used for Malondialdehyde (MDA) which was modified by [19].

Statistical analysis

Data was presented as the mean ± SEM. It was calculated using a two-way ANOVA, subsequently by the LSD post-hoc test to assess the level of significant in the samples with the help of graph pad, version 9.0. *P*-values less than 0.05 differences were considered statistically significant.

RESULTS

Table 1: Showing oxidative stress markers of rats (male (m) and female (f)) for control and treated (2.0 mg/kg bw CS, 4.0 mg/kg bw CS, 6.0 mg/kg bw CS, 4.0 mg/kg bw melatonin, 2.0 mg/kg bw CS + 4.0 mg/kg bw, 4.0 mg/kg bw CS + 4.0 mg/kg bw and 6.0 mg/kg bw CS + 4.0 mg/kg bw melatonin) groups.

Treated groups	LDH (u/l)	MDA (umol/l)	Catalase, (u/l)	GSH (u/l)	GPx (mmol/l)	TAC (umol/l)	SOD (U/L)
Control (m)	600±15.01	22.34±1.05	29.00±1.12	100.00±2.76	3.50 ±0.34	85.21±1.64	180.00±6.43
Control (f)	500±19.76	20.13±1.21	26.34±0.97	60.00±2.16	2.50 ±0.51	75.41±1.08	150.00±4.08
2mg/kg CS (m)	650±11.76	23.27±3.11	27.12±2.11	95.00±2.54	3.20 ±1.01	80.41±1.92	175.00±4.61
2 mg/kg CS (f)	550±8.94	21.00±1.52	25.87±1.67	57.00±1.54	2.4±0.10	72.21±0.96	140.00±2.95
4 mg/kg CS (m)	670±16.43	23.98±1.23	27.79±0.56	90.00±2.15	3.10 ±1.32	78.31±1.05	172.00±1.74
4 mg/kg CS (f)	580±21.32	22.67±2.01	24.78±1.59	61.00±1.75	2.20 ±0.84	63.32±1.23	137.00±3.74
6 mg/kg CS (m)	980±25.75#	28.00±1.97#	18.65±1.32#	62.00±1.89#	1.20±0.04#	52.98±1.84#	145.00±4.21#
6 mg/kg CS (f)	850±22.76#	26±3.11#	16.98±0.79#	40.00±3.21#	0.40±0.13#	45.39±0.98#	115.00±4.01#

4mg/kg melatonin (m)	600±15.01	22.34±1.05	29.00±1.12	100.00±2.76	3.50 ±0.34	85.21±1.64	180.00±6.43
4mg/kg melatonin (f)	500±19.76	20.13±1.21	26.34±0.97	60.00±2.16	2.50 ±0.51	75.41±1.08	150.00±4.08
2 mg/kg CS + 4 mg/kg melatonin (m)	580±12.25	21.86±1,13	28.20±1.52	98.50±3.15	3.47 ±0.42	80.22±1,72	170.76±4.45
2 mg/kg CS + 4 mg/kg melatonin (f)	495±15.76	19.75±1.32	25.00±1.02	59.00±1.98	2.28 ±0.86	74.34±1.63	148.00±4.11
4 mg/kg CS + 4mg/kg melatonin (m)	576±10.65	19.08±1.25	28.19±1.42	98.12±1.96	3.42 ±1.01	80.21±1.75	167.00±6.12
4mg/kg CS + 4 mg/kg melatonin (f)	486±13.75	19.43±1.20	25.00±1.20	57.45±2.63	2.14 ±0.48	72.98±0.75	145.00±4.42
6 mg/kg CS + 4 mg/kg melatonin (m)	980±25.75#	28.00±1.97#	18.65±1.32#	62.00±1.89#	1.20±0.04#	52.98±1.84#	145.00±4.21#
6 mg/kg CS + 4 mg/kg melatonin (f)	850±22.76#	26±3.11#	16.98±0.79#	40.00±3.21#	0.40±0.13#	45.39±0.98#	115.00±4.01#
Values were expressed as mean ± SEM; *P< 0.05 vs control and other treatment groups (M and F); #P< 0.05 vs CS-treated groups (M and F)							

The results obtained are presented in Table 1. There was a significant ($p<0.05$) increase in Lactate dehydrogenase (LDH) and malondialdehyde (MDA), with a significant ($p<0.05$) decrease in catalase, glutathione reductase (GSH), glutathione peroxide (GPx), total anti-oxidant capacity (TAC) and superoxide dismutase (SOD) was observed in the groups treated with high-dose of CS (6 mg) with no significance differences observed in the low-doses (2 mg and 4 mg) groups when compared with the control in both sexes. However, co-administration of CS and melatonin showed no significant differences in all the markers across the groups treated with both low and high-doses of CS in both sexes when compared with the control.

DISCUSSION

Oxidative stress (OS)is the disequilibrium between the reactive ROS and the ability of a biological system to rapidly neutralize reactive species and mitigate their harmful effects [20]. When a cell's redox equilibrium is disturbed, peroxides and free radicals are generated. These molecules destroy the biomolecules (proteins, lipids, and DNA), and other parts of the cell resulting in harmful outcomes [21]. OS, generated via oxidative metabolism, causes lesions in DNA strands and base pairs [22]. ROS which includes hydrogen peroxide (H_2O_2), hydroxyl radical (OH), and superoxide radical (O^{2-}) majorly cause base damage indirectly [23]. Earlier studies have identified melatonin as a pro-oxidant role [24, 9-10, 25-26, 11, 27-29].

Melatonin's critical role includes acting as a free radical scavenger, mitigating OS [30].

OS is implicated in the development of the listed conditions: Alzheimer's disease, myocardial infarction, infectious diseases, heart failure, fragile X syndrome, Parkinson's disease, lichen planus, autism, cancer, atherosclerosis, and chronic fatigue syndrome [31, 11].

Previous studies revealed that CS induced OS by disrupting the antioxidant defense system [13-14]. Additionally, it was found that the effect of CS on OS was dose dependent and also depends on gender differences since the effect was more obvious in male than in female [15]. Consistent with earlier findings, it was observed that melatonin could ameliorate the effect of CS on OS in female rats by obstructing the binding of CS with its receptors [10].

In this study, co-administration of melatonin and CS at both low and high-doses abolished the effect of CS on OS in both male and female rats. This suggests that melatonin has the antioxidant potential to mitigate OS induced by CS. This aligns with findings from [10, 32] who reported decrease in oxidative stress following co-administration of melatonin and CS in animals. An increase in the LDH observed in this study after CS was administered could be due to high-dose of CS and this was consistent with the findings of [11, 28] who reported that administration of CS stimulated OS by increasing LDH in both sexes. This may be attributed to LDH's key role in producing nicotinamide adenine dinucleotide phosphate (NADPH), an intermediate that fuel ROS generation [33]. However, melatonin was able to mitigate the effect of CS on OS (LDH) at both low and high-doses. This was in line with the findings of [10, 15] who observed decreased in LDH level in male and female rats CS followimg administration of melatonin.

Additionally, results also showed increase in MDA levels in both sexes at the high-dose of CS but not at low-doses. These findings correspond to those of [14, 34] who both observed an increase in MDA level following administration of CS in rats. This finding suggests that CS if not well treated may induce lipid peroxidation of polyunsaturated fatty acids, which are degraded by ROS [35]. More so, findings from this study also indicated a decrease in GSH, catalase, and GPx, TAC and SOD levels at high-dose for both male and female rats. This may result from elevated lactate dehydrogenase activity in these animals, driving the ROS buildup in them. These were in line with the findings of [15, 36] who both observed a decrease in antioxidant enzymes following administration of CS in rats at high-dose. However, the oxidative stress caused by CS in the groups treated with high-dose was ameliorated by melatonin possibly by acting as a hormone, neutralizing free radicals via directly and/or indirectly pathways [37-38], also enhancing the capacity of antioxidant enzymes to neutralize most of the ROS generated [39]. Generally, this study revealed that there were gender differences in response to the effect of co-administration of melatonin and CS on OS

which were more pronounced in males than in females. These could be due to various factors. One of the factors could be via the expression of cannabinoid receptor and signaling pathway. Cannabinoid receptors are more abundant in males compare to females [40]. CS may also induce epigenetic changes via altered global deoxyribonucleic acid (DNA), potentially driving cannabis-induced immunosuppression, and particularly in the male blood cells [41]. The study limitations are, it is not known whether administration is done in the afternoon or evening could produce different results compared to the time (morning) the administration was done in this study; it is also not known whether melatonin produced by the body at night could interfere with the administered melatonin.

Conclusion

Co-administration of melatonin and CS appeared to attenuate CS-associated OS at high-dose. The observed effects were more pronounced in males compared to females, indicating a sex-dependent response. Therefore, this study suggests that melatonin may be used as supplement to prevent CS-induced oxidative stress.

Complementary human studies are also required to broaden the understanding and explore therapeutic potential of cannabinoid-melatonergic systems in modulating OS.

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CANNABIS SATIVA EXACERBATES KIDNEY TOXICITY IN MALE WISTAR RATS: A DOSE DEPENDENT STUDY

Running title: Toxic effect of *cannabis sativa* on kidney in male Wistar rats.

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ABSTRACT

The kidneys play a critical role in removing waste and excess water from the blood, as well as maintaining the normal body's chemical balance. Damage to the kidneys can pose serious health risks. *Cannabis sativa* (CS) is one of the most abused substances worldwide and has been associated with adverse health effects. This study investigated the effects of CS on kidney function in male Wistar rats. Twenty male rats were randomly assigned into four groups of five animals each. Groups 1, 2, 3, and 4 received orally 1.0 ml of distilled water, CS (2 mg/kg), CS (4 mg/kg), and CS (6 mg/kg), respectively, for three weeks with free access to food and water. Kidney function parameters, including urea, creatinine, induced protein (IP), albumin, sodium (Na), and potassium (K), were measured using standard laboratory methods. CS administration significantly ($p<0.05$) increased urea and creatinine levels in the high-dose (4 and 6 mg/kg) treated groups compared with the control and low-dose (2 mg/kg) treated groups. Conversely, induced-protein (IP), albumin, sodium, and potassium levels were significantly ($p<0.05$) decreased in the high-dose treated groups. Additionally, the group treated with 6 mg/kg CS revealed more toxic effects in all the parameters when compared to 4 mg/kg CS treated group.

The effects of CS on kidney function were dose dependent. This study suggests that high-dose CS consumption may impair renal function. Therefore, withdrawal from CS consumption may be recommended to prevent its deleterious effects on kidney health.

Keywords: *Cannabis sativa*, Kidney toxicity, Low dose, High-dose, dose dependent

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INTRODUCTION

Cannabis (C) is a genus of flowering plants in the family *Cannabaceae*. Three species are commonly recognized: *Cannabis sativa*, *Cannabis indica*, and *Cannabis ruderalis*. Some researchers consider *C. ruderalis* as part of *C. sativa*, and all three species may be treated as subspecies of a single *C. sativa* species [1]. Cannabis is widely used as an illicit substance worldwide [2], and its consumption has been associated with adverse effects on human and animal health. Numerous studies have documented the negative consequences of CS consumption or smoking on various physiological systems [3-15].

The kidneys are paired organs located in the posterior abdominal wall. Their primary functions include the elimination of toxic metabolites and waste products from the blood, as well as the regulation of fluid and electrolyte balance in the body [16]. Previous research has reported both beneficial and deleterious effects of CS on kidney function in humans and animals [17-19]. However, these studies did not examine the potential impact of different doses of CS on kidney toxicity.

This study aimed to address this gap by investigating the effects of CS on kidney function in male Wistar rats, with a focus on dose-dependent effects. Specific kidney parameters including urea, creatinine, induced protein (IP), albumin, sodium, potassium, and total protein were evaluated, as they provide critical information about renal function.

The objectives of this study were: to investigate the effects of CS on kidney toxicity in male Wistar rats; and to explore dose-dependent effects of CS on kidney toxicity. The study was guided by the following hypotheses:

Null hypothesis (H_0): CS does not exacerbate kidney toxicity in male Wistar rats.

Alternative hypothesis (H_1): CS exacerbates kidney toxicity in male Wistar rats.

MATERIALS AND METHODS

Sample collection

Cannabis sativa (CS) leaves were donated by the National Drug Law Enforcement Agency (NDLEA), Nigeria, for research purpose only.

Extraction of *Cannabis sativa* leaves

Extraction of *Cannabis sativa* (CS) was done with Soxhlet apparatus by soaking 300 grams of CS in 98% ethanol for 48 hours. It was filtered and the filtrate was poured into a round-bottom conical flask fixed with a rotary evaporator. The filtrate was evaporated and cooled. The dried yield of the extract was 24g (weight of the extract obtained after drying) [7].

Experimental animals

Twenty male rats with average mean weight (160g ± 1.98) that were used for this research were obtained from Temilade Animal Venture, Ogbomoso, Oyo State. They were housed at room temperature with unrestricted access to diet and water and maintained on a daily light/dark cycle. Principles of laboratory animal care (NIH publication No. 85-23, revised 1985) were followed. The experimental protocol was approved by Ethical Committee of University of Ilesa, Ilesa, Osun State, Nigeria with approval number (UNILESA/ERC/2025/021).

Experimental protocol

After 2 weeks of acclimatisation, the animals were separately and randomly assigned into four groups of five animals each.

The rats in groups 1, 2, 3, and 4 were administered orally (in the morning) 1.0mL of distilled water (control), 2.0mg/kg body weight (bw) of CS, 4.0mg/kg bw of CS and 6.0mg/kg bw of CS respectively, once daily via oral gavage between 8:00 am and 10:00 am for twenty-one (21) days. The animals had access to food and water ad-libitum and were sacrificed after day 21.

Preparation of serum samples

The rats were sacrificed under ketamine anesthesia. The blood was collected by cardiac puncture into properly labeled sample bottles. The blood was left for 30 min to clot and thereafter centrifuged at 625×*g* for 10 min using a Uniscope Laboratory Centrifuge (Model SM800B, Surgifield Medicals, Essex, England).

Each of the serum was collected into plain bottle with the aid of a Pasteur pipette. Sera were stored in a freezer maintained at -5 °C and used within 12 hours of preparation.

Determination of albumin and IP

Albumin and IP activity were determined spectrophotometrically (Spectramax Plus; Molecular Devices, Sunnyvale, CA, USA) following the kit manufacturer's procedures (product code BXC0243; Fortress Diagnostics, UK).

Determination of Urea

Urea was determined by urease method [20]:

Urea was hydrolyzed by urease to produce ammonia and carbon(iv)oxide. The ammonia released reacted with a phenol-hypochloride reagent in an alkaline medium to form blue-coloured indophenols dye. The intensity of the blue colour was measured spectrophotometrically and this was directly proportional to the urea concentration in the sample.

Determination of creatinine

In an alkaline medium, creatinine reacts with picric acid to form an orange-red colored complex

(creatinine-picrate complex). The intensity of the color produced is directly proportional to the creatinine concentration in the sample [21].

Determination of Sodium

The method is based on the reaction of sodium with a selective Chromogen producing a chromophore whose absorbance is directly proportional to sodium concentration in the sample [22].

Determination of Potassium

Potassium reacts with sodium tetraphenyl boron in a specially prepared buffer to form a colloidal suspension. The amount of turbidity produced is directly proportional to the concentration of potassium in the sample [23].

Statistical analysis

Results were expressed as the mean ± standard error of mean. Data was analyzed using a two-way Analysis of Variance, followed by the LSD post-hoc test to determine significant differences in all the parameters, graph pad, version 9.0. Differences with values of $P<0.05$ were considered statistically significant.

RESULTS

The results obtained are presented in Table 1. CS administration significantly ($p<0.05$) increased urea and creatinine levels in the high-dose groups (4 and 6 mg/kg) compared with the control and low-dose treated groups (2 mg/kg). Conversely, a significant ($p<0.05$) decrease in induced-protein (IP), albumin, sodium, and potassium levels was observed in the high-dose treated groups relative to the control and low-dose treated groups. Furthermore, the group treated with 6 mg/kg CS revealed more toxic effects in all the parameters when compared to 4 mg/kg CS treated group.

Table 1: Kidney parameters of male rats for control and treated (2.0 mg/kg bw CS, 4.0 mg/kg bw CS, and 6.0 mg/kg bw CS) groups.

Groups	Urea (U/dl)	Creatinine (µmol/L)	Induced protein	Albumin (g/dl)	Sodium ion (Na^+) (mmol/l)	Potassium ion (K^+) (mmol/l)
Control	24±0.94	74.34±2.56	5.00±1.02	19.20±2.21	85.00±0.49	8.00±3.11
2 mg/kg CS	28±0.82	79.45±1.21	5.00±o.42	18.80±1.67	82.00±1.42	7.40±1.96
4 mg/kg CS	33±0.75#	87.20±0.98#	4.00±0.71#	12.60±0.86#	65.00±1.53#	4.20±1.71#
6 mg/kg CS	42.8±0.32#µ	93.67±1.06#µ	3.20±0.92#µ	10.80±1.74#µ	50.00±1.37#µ	3.20±1.90#µ

Values are expressed as mean ± SEM; #P< 0.05 vs control and 2.0 mg/kg bw CS groups; µP< 0.05 vs 4.0 mg/kg bw CS group.

DISCUSSION

The use of cannabis may have significant implications for kidney health. Research suggests that heavy cannabis use is associated with an increased risk of chronic kidney disease (CKD) [24], a condition characterized by the gradual loss of kidney function over time [24-26]. Cannabis can influence renal blood flow dynamics, potentially altering kidney function [26]. Δ9-Tetrahydrocannabinol (THC), the primary psychoactive compound in cannabis, can affect blood vessel dilation and constriction, thereby impacting renal blood flow and filtration [26]. Cannabis use has also been linked to changes in urinary parameters, including increased urine volume and frequency, which may reflect its effects on hydration status and renal function regulation [27].

In the kidney, cannabinoid receptor 1 (CB_1) and cannabinoid receptor 2 (CB_2) play key roles in regulating renal blood flow, glomerular filtration rate (GFR), glomerular permeability, interstitial collagen production, and tubular function [28]. Our study showed that urea and creatinine levels increased in a dose-dependent manner, with no observable changes in the low-dose group. This aligns with previous studies [29-30], which reported elevated urea and creatinine levels in rats treated with CS. The potential mechanism underlying this effect may involve alterations in renal blood flow and GFR [29], thereby impairing the kidney's ability to filter and excrete urea and creatinine, which are waste products of protein and muscle metabolism [31].

These findings contrast with those of [32], who reported decreased biliary urea and creatinine in rats. The discrepancy may be attributed to differences in sample type, as their study measured bile rather than blood. Additionally, the observed reductions in induced-protein (IP), albumin, sodium, potassium, and total protein in the high-dose groups suggest abnormal loss of these substances from the kidney into urine rather than retention in the blood. This effect may be mediated by CS activation of CB_1 and CB_2 receptors in the kidney and renal vasculature, leading to excretion and filtration of these parameters [33]. These results are consistent with prior reports of [34] who revealed that CS-induced nephrotoxicity.

Our study has some limitations. First, it is unclear whether prolonged administration of low-dose CS (2.0 mg/kg body weight) would produce effects similar to those observed with higher doses (4.0 and 6.0 mg/kg body weight). Second, it is unknown whether administration at different times of the day (e.g. afternoon or night) would yield results comparable to the morning treatments used in this study.

CONCLUSION

This study concluded that *Cannabis sativa* (CS) may impair kidney function by activating cannabinoid receptors, which in turn may alter renal blood flow and key kidney parameters, including urea, creatinine, induced-protein, albumin, sodium, and potassium. The effects of CS on kidney toxicity were found to be dose dependent. Therefore, withdrawal from CS consumption may be recommended due to its potential deleterious effects on renal health. Further research is warranted to explore strategies for preventing CS-induced kidney toxicity, particularly at high doses, in the context of both medicinal and recreational use.

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HOME-BASED NURSING SERVICES IN BRUNEI: A SITUATION ANALYSIS

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ABSTRACT:
Brunei is a country in Southeast Asia with a rapid rate of ageing. Home-based nursing (HBN) is a service in Brunei originally providing community visits for dependent people who require changes in nasogastric tubes and indwelling catheters. Since 2015, the role of HBN has expanded to include a standardised assessment approach, wound assessment and management for pressure injuries. The HBN components strengthened with geriatrics involvement included comprehensive geriatric assessment, pressure injuries, pain assessment, palliative care, and medical support, particularly during the Covid-19 pandemic. There is ongoing work required to ensure HBN provides quality services through educational initiatives and improved multidisciplinary team collaborative work.

Keywords: Brunei, Geriatrics, Home care, Older People
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INTRODUCTION:

Brunei is a small country in Southeast Asia with a population of approximately 450,000 people. According to the World Health Organisation (WHO) population projections, Brunei has a very rapid rate of ageing [1]. Thus, home-based services are essential to provide care for these patients as well as support ageing in place. In this paper, an overview of home-based services is provided as a country update of Brunei, describing how home-based care evolved and the components of care that are important for the service.

Geriatric Medicine services in Brunei started in 2009 by a physician trained in Geriatrics and Palliative Care. This is based in Raja Isteri Pengiran Anak Saleha (RIPAS) hospital, a 1260-bedded tertiary hospital in Brunei. In 2015, the arrival of a new Geriatrician led to further service development and a corresponding increase in the number of patients admitted under the service. Multidisciplinary teams were formed with weekly case conferences to discuss patients, especially discharge planning. Community nursing was also strengthened, with geriatric medicine taking over home-based nurses (HBN). This increased the feasibility to

scale up the provision of home visits to dependent patients, which initially relied on hospital -based nurses from Geriatrics and Palliative care services.

A retrospective study of Geriatric medicine admissions in 2015 showed that over 3 months, there were 76 admissions with a median age of 85 years old [2]. Two-thirds had severe functional impairment, more than a third had dementia, while almost half were bed-bound or transfers only [2]. Given the high burden of comorbidities, dementia and poor functional status, the development of community support services to manage dependent patients after discharge was warranted.

In the same year, an orthogeriatric liaison service was started. This provided routine reviews of hip fracture patients under orthopaedics to assess their risk of falls and fractures, pre-operative optimisation, post-operative rehabilitation as well as discharge planning. A separate multidisciplinary team and case conference was held weekly. An audit of hip fractures in 2014 found that a quarter of patients were conservatively managed and not operated on, thus were unlikely to regain their mobility, with a prolonged length of stay in hospital and associated increased rate of mortality [3]. These patients also required community-based visits for follow-up.

Initially, HBN was under the management and supervision of the Director of Nursing. These were community-based nurses, whose main role were technical replacement of nasogastric tubes and indwelling catheters for dependent patients. They were unfamiliar with geriatrics assessment, palliative care or managing other issues unrelated to these tubes. As these patients were bedbound, they could not attend clinics easily and follow-up was preferably provided as than home visits. Thus, HBN was taken over by Geriatrics and were taught how to carry out comprehensive geriatric assessment and manage common medical issues affecting dependent patients (in addition to their current roles of tube changes).

From 2015 to 2019, there was also an annual progressive increase in the number of patients and clinical encounters for dementia. The mean number of clinical encounters for dementia was 500 annually, with a mean of 115 new patients annually [4]. This demographic change in dementia is actively monitored to plan service provision for people with dementia; this neurodegenerative condition is associated with increasing dependence, with a likely need to access HBN services in advanced stages.

Comprehensive Geriatric Assessment:

The main challenge for HBN staff to adapt to their increased scope of services in managing dependent older people was to learn about

comprehensive geriatric assessment. Training sessions were provided to ensure a systematic approach and handover during the case conferences. An assessment proforma was provided, which ensured screening for common geriatric conditions, such as malnutrition, delirium, falls, pressure injuries and pain. In addition to history taking, these conditions should be proactively reviewed during the clinical examination. For example, all dependent patients should have their buttock, sacrum and heels routinely checked for pressure injuries during the home visits. The Identification, Situation, Background, Assessment and Recommendation (ISBAR) was used for handover [5].

There were several areas that were identified as concerns for community patients. Firstly, nutritional needs should be provided to ensure the well-being of patients. A study among Geriatrics and Palliative inpatients found that more than half of the older people had BMI below 20 kg/m^2, while two-thirds of the palliative inpatients had more than a 5% weight loss in the previous six months [6]. This is a problem, as weight loss and undernutrition are associated with a poor prognosis.

The dependent older people were also observed to have recurrent admissions with chest infections. It was found that these patients also had poor oral health, which may contribute to pneumonia [7]. Oral care and maintaining dental hygiene is another aspect of care that HBN found often neglected among the care of dependent older people [8].

Finally, medication reconciliation and review should be performed during the home visit. As older people have many medications and are at risk of polypharmacy, it is important to check how patients keep the medications, whether they have problems taking medications (for example, dysphagia may make it difficult to swallow tablets) and whether there is a discrepancy between expected supply and remaining number of medications [9].

Pressure Injuries:

Given the increasing number of older inpatients in RIPAS hospital, a retrospective review of medical inpatient charts was performed to assess the risk factors for pressure injuries in 2017. It was found that less than 40% of the patients had the assessment forms completed, while among those with forms completed, one in five had pressure injuries [10]. The most common sites were buttock, sacrum and heel.

Several initiatives to improve the situation were initiated: firstly, guidelines for pressure injury risk assessment and management for inpatients were developed. These recommendations were advised and reinforced by geriatrics nurses

while in hospital, as well as the home-based nurses during visits in the community [11].

Workshops were also given to nursing staff including HBN regarding how to manage wounds. It was found that equipment and supplies were limited to gauze and primapore, making it difficult to follow international wound management recommendations [12]. Some patients were unable to acquire hospital beds or pressure relieving mattresses; thus, a list of suppliers was obtained for people to access them. Sponsors were obtained to stock these items in an equipment library; for those unable to afford them, they were provided after a financial review by the medical social worker [12].

Pain:

Pain is a symptom associated with a poor quality of life that should be managed in all patients, regardless of whether they are in hospital or at home. This was found to be poorly managed in older people in Brunei. A retrospective review of electronic health records for older people under Geriatrics and Orthopaedics found that documentation of pain as a symptom, descriptions of pain and severity should be improved. The response to pain relief (if given) and side effects were also poorly monitored [13].

A survey of 287 healthcare professionals in medical and surgical wards in Brunei hospitals found that pain assessment was not carried out regularly despite a high knowledge of pain assessment, awareness of the importance of pain assessment tools and availability of these tools [14]. Thus, there was a need to standardise the approach to pain assessment and utilisation of these tools in Brunei.

When clinicians were asked regarding barriers and solutions for improving pain management practices, it was found that there was some apprehension among patients and healthcare practitioners limiting the appropriate use of tailored pain medications. There was also a need to improve teamwork among clinicians to ensure adequate assessment and management, as well as adapting guidelines for local or cultural preferences [15].

To this end, assessment tools for evaluating pain severity and types of pain in older people were developed and disseminated to staff in hospitals and the community [16]. Pain descriptors were difficult to apply locally, given the language and cultural differences in using these tools.

The Short Form McGill Pain Questionnaire 2 (SF-MPQ-2) was translated with 21 pain descriptors adapted for use in Brunei. It was found that this tool was more likely to elucidate complaints of pain from local patients, compared to the visual analogue scale [17].

COVID-19 pandemic:

The pandemic required adjustments to many services, including HBN services in Brunei. While many services were suspended to cover COVID-related services, there was a delay in recognising that it was not possible to hold off these community services for dependent patients, particularly the scheduled tube changes. Eventually, HBN were also provided access to personal protective equipment (PPE) or mask fitting sessions to ensure they were adequately protected while wearing N95 (FFP2) masks. These were initially reserved for front-liners managing emergency services.

A protocol was developed requiring patients and family members to have negative antigen rapid tests (ARTs) before a home visit. Patients had their change of indwelling catheters and nasogastric tubes extended from four weeks to six weeks. To reduce multiple encounters, HBN contacted for tracheostomy or gastrostomy tubes were advised to contact relevant specialty nurses based in the tertiary hospital [18].

Rehabilitation and allied health professional input was reduced in hospital during the pandemic. The reduction in contact with family also meant that preventive measures for reducing risk of pressure injuries were less adhered to, both by family members and staff. Unfortunately, during the pandemic, there was an observed increase in severe pressure injuries, a few resulting in osteomyelitis, requiring prolonged admission for intravenous antibiotics and regular bedside debridement of the wounds [19]. HBN were advised to monitor for changes in functional status and advise self-management, including provision of exercise sheets to reduce the risk of functional decline in patients [20].

It was also important to monitor for mental health sequalae among patients and family members during the pandemic [21]. Out of necessity, the roles of HBN were expanded further to ensure holistic care of these dependent patients. By the end of December 2022, it was found that the number of patients under HBN remained high, with 123 male patients and 131 female patients under their care [22].

Palliative Care:

As HBN provide care for dependent older patients, palliative care knowledge was essential, as it may be appropriate to consider palliation at home rather than a review in hospital if a patient worsens. Palliative care is an essential skill, with a recognised need for a national palliative and end of life care policy in Brunei [23]. The concept of trajectory of illness was taught to HBN, which enabled clinicians to recognise where the patient is at, predict likely prognosis and offer appropriate treatment decisions. Such decisions required clinicians to balance the pros and cos of aggressive curative

intent versus a focus on symptomatic management only, which could be done at home [24].

The Gold Standards Framework is used by primary care to identify patients that would benefit from a palliative approach [25]. This provides a list of medical conditions that are associated with a short life expectancy. Once the goal of palliative care has been determined, ongoing discussions on treatment goals and continuity of care should be done by HBN. There is ongoing work to improve advance care planning (ACP) and how to broach these sensitive discussions with patients and family. A particular challenge in Brunei is adapting the ACP discussions towards a localised approach; cross-cultural adaptations were necessary to ensure that participants remained engaged in ongoing conversations regarding their direction of treatment and care [26]. Documentation of these discussions in the clinical records also needs to be improved, as shown in a local audit of ACP for Alzheimer's disease in Brunei [27].

The COVID-19 pandemic highlighted the need for discussions on goals of treatment, ACP and palliative care, as many patients did not want to go to hospital because of COVID-19 infections [28]. These efforts should continue despite the endemic situation, as the public have better awareness regarding the concept of palliative care, not only for terminal patients but also as part of the continuum of care for all patients.

Way Forward:

After the COVID-19 pandemic settled and usual clinical services resumed back to normal, HBN services were decentralised to respective health centres. In Brunei, primary care is provided through a network of community health-centres, each covering a specific geographical area. This would allow improved continuity of care; general practitioners would provide medical support for patients in the community when they become more dependent, rather than refer to hospital-based geriatric medicine services to oversee HBN care.

The quality of care provided by HBN should meet appropriate standards. A recent survey utilised the Patient Satisfaction with Nursing Care Quality Questionnaire (PSNCQQ), which found that there was an overall high satisfaction rate from caregivers regarding HBN services [29]. The nursing care aspects rated excellent include "concern and caring by nurses", "helpfulness" and "skill and competence of nurses", while the lowest-scoring aspects were "informing family or friends", "instructions" and "consideration of your needs".

Areas for future improvement included information for care recipients and interventions to promote better transfer of information towards care recipients [29].

As HBN patients are dependent on caregivers, it is also important to recognise the importance of caregiver's health and well-being. A study of HBN caregivers found that there was a high rate of caregiver burden in terms of general strain, isolation and disappointment [30]. Further work needs to be done to collaboratively develop care plans with primary caregivers accounting for both patient and caregiver well-being.

Ongoing educational sessions to upskill HBN knowledge and technical expertise is also required. Problem-based learning particularly from challenging cases brought up in the case conference, as well as interprofessional education with other allied health professionals may help promote collaborative working and team building [31]. For example, a patient with purple urine bag syndrome stimulated discussions regarding the condition, which encouraged scheduled teaching sessions for HBN [32].

Finally, teleconsultation or virtual clinics were introduced by Geriatrics services during the second wave of COVID-19 in Brunei. While there is currently a shortage of geriatric medicine doctors to provide community visits, there is the possibility of joint consultations with HBN present in person with the patient for teleconsultation reviews. This may help facilitate family meetings, discussions of treatment goals and ACP.

CONCLUSION:

HBN are an essential service providing community-based reviews of dependent older people in Brunei. HBN components strengthened with geriatrics involvement included comprehensive geriatric assessment, pressure injuries, pain assessment, palliative care, and medical support, particularly during the pandemic. There is ongoing work to ensure HBN provides quality services through educational initiatives and improved multidisciplinary team collaboration.

Conflict of Interest:

The author has no conflicts of interests to declare.

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