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Prof. Samuel Kyei

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SCIENTIST IN SPOTLIGHT
Prof. Samuel Kyei

Prof. Samuel Kyei is an Associate Professor of Clinical Optometry, School of Allied Health Sciences, University of Cape Coast and the Founding Director of the Biomedical and Clinical Research Centre, BCRC, University of Cape Coast.

He holds a PhD in Optometry from the University of KwaZulu-Natal, Durban, South Africa, a Master of Philosophy in Pharmacology from Kwame Nkrumah University of Science and Technology, KNUST, a Doctor of Optometry Degree with BSc Ophthalmic Sciences from the University of Cape Coast. A certificate in University Teaching from the University of Hong Kong. He has participated in several workshops, training and program in higher education including academic leadership, teaching and learning in higher education, academic writing and publication, research ethics, and workshops for research supervisors. He has trained as an implementation researcher with a focus on Infectious Diseases of Poverty (IDP), a training course organized jointly by the African Regional Training Centre, University of Ghana School of Public Health and the UNICEF/UNDP/World Bank/WHO Special Program for Research and Training in Tropical Diseases (TDR). Since his appointment as a tutor in 2011, he has risen through the ranks to the level of an Associate Professor at the Department of Optometry and Vision Science, University of Cape Coast. He serves as a Visiting Professor at the Department of Optometry, Bindura University for Science Education in Zimbabwe, where he led a team in the establishment of the first Optometry program in Zimbabwe. He helped establish a maiden laboratory for the training of optometrists in BUSE and played a key role in the recruitment of young and energetic Optometry educators to run and sustain the program. He is an affiliate Lecturer at the University of Free State, South Africa.

Renowned as an esteemed Optometry educator and dedicated researcher, he has garnered accolades for his scholarly endeavors. His prominence is evidenced by being ranked among the top 10 most published researchers at the University of Cape Coast, Ghana, with an impressive Google citation record of 1525 and 664 on Scopus. Notably, he received the Best Evolving Researcher award and the Dean's Award for Best Lecturer in the Department of Optometry at the University of Cape Coast. His contributions were further acknowledged with research excellence awards, including placing 6th and 5th in the university for the total number of relevant papers in Scopus-indexed journals in distinct years, as well as being recognized for his nominal citations of papers. With over 120 peer-reviewed journal articles to his credit, his scholarly impact extends globally. His expertise is also sought internationally, having been appointed as a member of the sub-specialty working group by the World Health Organization, contributing significantly to the Package of Eye Care Interventions unveiled at the 75th World Health Assembly. His multifaceted achievements underscore his dedication to advancing research and education in Optometry while making substantial contributions to global eye care initiatives.

His previous studies into potential indigenous anti-cataract agents for the medical condition whose only approved remedy is surgery have resulted in a positive indication in preclinical studies, which is being worked further. His preclinical studies show promise in finding alternatives to surgery for cataracts, a major concern in the region. His dedication to ophthalmic public health is evident through his research, which aims to understand environmental factors affecting eye health and to develop remedial approaches for conditions like cataract, pterygium, myopia, and ocular allergic diseases. With expertise in project management and interventional studies, he has led various university projects, laying the groundwork for effective drug discovery and eye care interventions. He has also contributed significantly to the development of postgraduate curricula for Clinical Optometry and Vision Science, aiming to enhance education and professional development in the field. Furthermore, Professor Kyei's involvement with the Ghana Optometric Association underscores his commitment to advancing eye care education and training. He has served in key roles within the association, facilitating continued professional development programs and curriculum development for optometry education. Additionally, his contributions as an assessor for program accreditation demonstrate his commitment to maintaining high standards in eye care education. Through his multifaceted efforts, Professor Kyei is not only advancing research in eye care but also playing a crucial role in shaping the future of optometry education and practice in Ghana. His work stands as a testament to the importance of interdisciplinary collaboration and dedicated efforts to address the burden of eye diseases and vision impairment in underserved communities.

EDITORIAL

Overcoming The Worsening Global Health Situation: The Contribution of Biomedical Research

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Introduction

Global health is under siege by an orchestra of factors ranging from aging human population and its attendant disease vulnerabilities, food insecurity and its attendant malnutrition, onslaught of environmentally-unfriendly human activities that have given rise to climate change and its many debilitating effects on mankind, the emerged drug resistance problem secondary to emergence of resistant pathogens, and the generally weak global healthcare response system which was recently exposed by the Covid-19 pandemic. Further, global health suffers from disproportionate global investments in the area of funding for health research and its attendant widening knowledge gap with respect to risk factors of communicable and non-communicable diseases, poor disease diagnosis, lack of effective strategies (drug development, vector control, vaccine development etc) for managing human diseases as well as inadequate data-driven health policies to inform practice. Additionally, global health is negatively impacted by the unavoidable exposure of humans and animals to diverse xenobiotics including but not limited to metals and metalloids through various matrices such as air, water, soil, and food. Such xenobiotic exposures put humans and animals at a high risk of exposure-related toxicity and health consequences. For instance, many health commentators have remotely (scientific evidence still lacking) linked recent surge in the cases of kidney and liver diseases in Ghana to consumption of locally manufactured unapproved alcohol-based aphrodisiacs as well as possible repercussions from 'galamsey' activities. To deal with the worsening global health situation requires intense enquiry into all the afore mentioned health precipitating factors through cutting-edge biomedical research. Such research efforts will expand understanding and knowledge as well as provide data-driven basis for improvement of global health. As indicated earlier in the first issue of integrated health research journal (IHRJ, vol. 1, issue 1, 2023), the IHRJ provides a platform for medical and biomedical scientist/researchers to disseminate their research findings, with the hope that these findings will reach the targeted audience to generate appropriate responses to stem the worsening global health situation. The current issue (Vol. 1, Issue 2, 2023) captured interesting findings across a number of critical topics in health ranging from malaria, chronic kidney disease, mental health and pregnancy just to mention but a sample. Although malaria has been a major global health threat over many decades nonetheless knowledge on its pathogenesis remain limited, particularly the pathogenesis of *Plasmodium falciparum* (*P. falciparum*) malaria. A study elaborated the role of repetitive interspersed family (RIFIN) genes in the pathogenesis of P. falciparum malaria and its potential as a target for the development of anti-malaria pharmacotherapeutics (Duntu PE et al, 2023). Globally, chronic kidney disease (CKD) keeps increasing and there is growing suspicion of a probable involvement of non-traditional risk factors. Sowah and colleagues synthesized existing literature to etch-out the possible underpinnings of CKD of unknown origin in Africa (Sowah SO et al, 2023). It is often held that physical activity greatly impacts on human health. Indeed, regular physical activity is directly linked with improved general health and longevity. In a study, Opoku-Antwi and colleagues have shown that body mass and physical activity improved endurance and strength of both male and female teenagers (Opoku-Antwi E et al, 2023). Postpartum is a unique period in the lives of women with childbirth but presents with a high risk of postpartum depression (PD), which affects the mother, infants, and their families. In the global and Ghanaian setting, PD is considered a mental disorder that impairs maternal function; however, PD remains an indistinct concept. Yeboa and colleagues posit that defining a clear attributes and characteristics of PD will facilitate easy diagnosis of PD to inform timely identification

and management (Yeboa NK et al, 2023). Despite the adoption of prophylactic programs of iron and folate supplementation (IFAS) to prevent nutritional and iron deficiency anemia (IDA) in pregnancy, IDA continues to remain a major public health concern, especially among pregnant mothers in developing countries such as Ghana. An efficient strategy that may be helpful in establishing objectives for nutrition-based intervention may require knowledge, attitude, and practice (KAP) assessment of pregnant mothers in order to inform effective intervention. A study from a University hospital conducted by Abudulai and colleagues have shown that knowledge deficit among pregnant mothers with regards to nutrition and iron supplementation during pregnancy render such pregnant mothers highly vulnerable to risk of IDA in pregnancy (Abdulai K et al, 2023). Admittedly, the greatest threat confronting mankind is health insecurity. Although the World Health Organization (WHO) together with its sister organizations have provided frameworks and recommendations on how governments through their health ministries can establish resilient health systems to deal with health issues, nonetheless country-by-country response to these frameworks/recommendations have so far been mixed. In fact, the nature of health care system resiliency in tackling and dealing with health concerns and general improvement in health across countries sadly reflect the usual developed/under-developed dichotomy. Quest to improve global health can only be guaranteed through safe-guarding of sound and sustainable interaction between humans and the environment. This all important humane and sustainable interaction between humans and the environment can be shaped by quality and scientifically sound biomedical research. And such research efforts may yield findings good enough to elicit new scientific questions, contribute meaningfully to health education, expand understanding on health issues, inform new health policies and practices, and finally form the basis for developing new health interventions. But these outcomes hoped for will require huge health investments in the area of health research funding, removal of barriers to scientific research such as elimination of racial tendencies in scientific research/publishing, promotion of inclusivity and diversity in scientific research/publishing, promotion of open access and curtailing of exorbitant article processing charges. Biomedical research given the needed support will significantly provide the impetus to remedy the worsening global health situation.

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RESEARCH ARTICLE

Effect of Anthropometric and Physical Activity Levels on Endurance Strength: A Cross-sectional Study of University Practice Senior High School, Ghana

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Abstract

Background: The aim of this study is to determine how anthropometric variables (body weight, body height, upper and lower limb length), Body Mass Index (BMI) and physical activity (PA) levels affect the number of cycles completed in 3-Minute Burpee Test (3-MBT) among male and female teenagers of University Practice Senior High school.

Materials and methods: Thirty-two (32) males and 28 females aged 15-17 years engaged in low and moderate physical activity levels took part in the studies. International Physical Activity Questionnaire (IPAQ) short form was used to assess physical activity levels and 3-MBT was used to evaluate students' endurance strength capacity. Participants' limb lengths (for upper and lower) were measured and their BMI was calculated from their measured body height and weight according to standardized guidelines. The results were processed statistically using Pearson's correlation, independent sample t-test and simple linear regression.

Results: In both sexes, only body mass and BMI were bound by negative significant correlation ($p < 0.05$) with the number of cycles completed in the 3-MBT. Significant differences were noted between males and females engaging in 3-MBT ($p < .001$). Physical activity levels in MET significantly predicted endurance strength scores ($p < .001$) as assessed by 3-MBT. On the average, males completed 48.34 cycles/3 min and females scored 38.50 cycles/3 min. More cycles were completed by male and female students with moderate levels of physical activity compared to those characterized by low levels of PA. Males were characterized by higher anthropometric measurements excluding body mass index than females.

Conclusion: Body mass, BMI and physical activity levels in MET were the only analyzed variables that significantly had influence on endurance strength (3-MBT) of both sexes.

Keywords: Endurance strength, 3-MBT, Physical activity, Anthropometric

Introduction

Musculoskeletal fitness becomes an important act of daily living as one ages [1] and an important part of the whole-body system [2]. According to Ortega (2008) et al. [3], a potent marker of future health during childhood and adolescence is physical fitness. Endurance strength is a component of health-related fitness which helps to identify individuals who are at risk of having reduced health benefits and exercise capacity. Human health as well as biological and motor developments are influenced by physical fitness as one of its key indicators [4]. According to Rafique et al [5], the body's health status is improved by activities relating to fitness and health and in effect,

the protection obtained from these activities has its own independent effects on other health related outcomes. It is believed that fundamental motor ability is strength as it aids to start, continue or stop movement of a body as well as setting another body in motion [6]. Therefore, it is of relevance studying factors including anthropometrics and physical activity levels that can affect endurance strength abilities in adolescents. Previous works have focused on participation of athletes in sport and various group of individuals where there are established relationships between anthropometric features and endurance strength abilities [7-8]. These studies relate to previous work with the measure of selected anthropometrics and physical activity level demonstrated by other researchers using different

population samples. Muscular strength and endurance abilities are components of physical fitness that provide health benefits [9]. Obese, overweight, and underweight teenagers do not have higher physical fitness, such as speed, agility, muscular strength, or cardiorespiratory fitness, than those who are of normal weight, according to research [10-13]. Endurance strength has been defined as a type of strength that is demonstrated in tasks that demand a reasonably extended period of muscular tension with low efficiency loss [14].

An increase in body height and mass contributes to muscular strength [15], however, studies have found that endurance, relative strength and physiological capacity development are rather reduced [16,17]. Body mass, body mass index (BMI), and body height are all found to be significantly adversely linked with 3-Minute Burpee Test (3-MBT) scores among female university students, as well as average heart rate of 181.92 b.min-1 was determined where 3-MBT was regarded as a highly intense physical activity [17-18]. Low levels of physical activity have been linked to an increased risk of weight gain in females aged 25 to 55 who have a sedentary or inactive lifestyle [19]. There has been an established correlation between body mass and height and 3-MBT performance in 7-9 years old children been demonstrated [20] with similar findings for university female students [18]. According to the Oxford Dictionary, the Burpee test was developed in the 1930s and is named after American psychologist Roual H. Burpee. The exam, which consists of a sequence of so-called "burpies" – physical exercises including a squat thrust that begins and ends in a standing posture – was initially meant to assess agility and coordination [18]. The test has been popular in various sport discipline and varied version of the test has been developed [17] which has been utilized in people of all ages and genders, and last but not least in people of varying levels of physical fitness [21].

The 3-Minute Burpee Test (3-MBT) has been used to assess endurance strength skills in a variety of age groups, including elementary school kids, early education instructors, and university students [4,18,22]. Only a few studies have looked at the relationship between physical activity and 3-MBT performance [21]. However, studies by [23] presented that only physical activity levels significantly influenced strength endurance in 3-MBT performance among male and female university students. Between the ages of five and thirteen years old, a linear rise in muscular endurance has been found in males, followed by a rapid increase, but in girls, a continuous linear increase has been observed [24]. Research about the reliability and effectiveness of Burpee as exercise in sport and functional training has been demonstrated [25]. Few studies have been done to see how physical activity levels affect the number of cycles completed in the 3-MBT. Inferring from the research findings above, it is observed that endurance strength abilities and physical activity levels are of great importance. However, there is a paucity in literature regarding the study of the effect of selected anthropometric variables and physical activity levels among adolescent students in their late stage on endurance strength abilities. The purpose of this study is to see how anthropometric factors (body mass, height,

upper and lower limb length), BMI, and physical activity levels affect the number of completed cycles in the 3-MBT among teenage male and female students in their late adolescent years.

Materials and Methods

2.1. Research design

A cross-sectional descriptive research design was employed to conduct the study. The research was conducted in the Central region of Ghana at University Practice Senior High School located within the University of Cape Coast. The study was conducted from September to October (2020)

2.2. Participants

This study enrolled a total of 60 healthy adolescents, comprising 32 males and 28 females aged (15-17) of University Practice Senior High School, who did not attended obligatory physical education class. The study included 1) adolescent students between 15-17 years of age not performing any type of regular physical activity for the duration of the study other than the obligatory physical education classes, 2) adolescent students not having any medical condition that could influence the collection or interpretation of the data, and 3) adolescent students with low and moderate physical activity levels only. Students were divided into segments (level of study) in the beginning, and then a separate random sample of equal size from each stratum was selected. All participants were taught how to perform the 3-minute burpee test prior to the test.

2.3. Measurements

The techniques of International Standards for Anthropometric Assessment [26] was adopted for all the body measurements. Body mass (to the nearest 0.1kg) and body height (to the nearest 0.1cm) were measured using a portable electronic bathroom weighting scale and a well calibrated wooden meter and the results were used to calculate the BMI of all participants. Upper and lower limb length was measured with a flexible non-elastic tape. The endurance strength of the body was measured using the hybrid 3-minute burpee test and a stop watch as adapted from Podstawski et al [18]. The Procedure of the 3-MBT is as follows: Starting in a standing posture, the participant will be encouraged to go into a supported squat with both hands on the floor. The feet were held back into a plank posture with arms extended, starting from a supported squat. After that, the participant returned to a supported squat from the plank position. Finally, the participant stood up and clapped their hands with their arms stretched over their heads. The participants should complete the cycle as many times as possible under a three-minute time restriction. All participants were taught how to perform the 3-minute burpee test, where sufficient time was given for the participants to practice. Furthermore, before the test, the participants were allowed to do a 10-minute active warm-up.

International Physical Activity Questionnaire (IPAQ) short version (which comprises of four short generic items assessing walking, moderate-intensity and vigorous intensity activities and sitting time that people do as part of their daily lives) was used to assess levels of physical

activity and extensive validity and reliability has been undertaken among college students [27]. The energy expenditure associated with the task was computed and represented in Metabolic Equivalent of Task (MET) units where students were placed into three groups based on their PA levels: low (L < 600 METs-min/week), moderate (M < 1500 METs-min/week) or five or more days of any combination of walking, moderate intensity or vigorous intensity activities achieving a minimum total physical activity of at least 600 MET minutes a week and high (H ≥ 1500 METs-min/week) or seven or more days of any combination of walking, moderate intensity or vigorous intensity activities achieving a minimum total physical activity of at least 3000 MET minutes a week. [28]. The students with low and moderate physical activity levels were included in the study.

The participants answered a Physical Activity Readiness Questionnaire for Everyone (PAR-Q+) (comprises of seven general health questions and follow up questions about medical conditions when one has an issue(s) with one of the first seven general health questions) which was used to screen out individuals who have underlying medical conditions which prevented them from taking part in the study. This questionnaire has underwent validation and was found to have good measurement reliability, sensitivity, and specificity [29].

2.4. Statistical analysis

IBM Statistical Package for Social Sciences (SPSS) software Version 26 for Windows was used to compute and analyze the data obtained. The alpha level for rejecting or failing to reject the hypothesis was set at 0.05. Means, minimum and maximum values, percentages and standard deviation for independent variables (body height, body mass, BMI, length of upper and lower limbs), METs, and dependent variables (number of cycles completed in burpee test) were calculated using descriptive statistics. Pearson's correlation was used to analyze the influence of anthropometric measurements on endurance strength abilities. The association between physical activity levels in MET and the performance of the 3-minute burpee test was determined using simple linear regression. Independent sample t-test was used to compare mean differences between endurance strength abilities among the genders with low and moderate physical activity levels.

2.5. Ethical consideration

The study was approved by the Head of Department of Sport and Exercise Science (UCC), as well as the University of Cape Coast's Institutional Review Board (UCC). The study followed the principles of the Declaration of Helsinki on human subject research. Volunteers' rights were protected, as all participants were able to withdraw from the study without repercussions and were not forced to participate. Prior to the study, a written informed consent form was issued to the participants and they were briefed about the confidentiality of the study, test procedures, purpose, benefit and risks involved in the study.

Results

The average values of anthropometric measures and the number of cycles completed in 3-minute Burpee test among adolescents are presented in Table 1. The correlation between anthropometric variables and endurance strength for both genders are presented in Table 2. From Table 1, the average evaluated anthropometric measurements and metabolic equivalent task (MET) excluding body mass index (BMI) were not significantly higher in males than in females. The average BMI was within the normal range for both males (M=22.43, SD=2.64) and females (M=24.21, SD= 2.90). Males completed 48.34 cycles and females 38.50 cycles on average in the 3-MBT. The average physical activity level (MET) was in the middle range of moderate PA level for males (M=1807.09, SD=624.91) and in the lower range of moderate physical activity level (MET) for females (M=785.97, SD=538.15). Males completed more cycles in the 3-MBT compared to females.

The correlation between anthropometric variables and number of cycles completed in 3-MBT were statistically significant for body mass and body mass index for both genders excluding body height and upper and lower limb lengths from Table 2. A weak negative correlation was noted between BMI and the number of completed cycles in 3-MBT for both genders. However, (BMI) and number of completed cycles in 3-MBT was moderately negatively correlated, $r(28) = -.57$, $p < .01$ for females. From the Table 2, body mass, followed by BMI were the major factor limiting the number of cycles completed in 3-MBT. For females, BMI was noted as a major factor, followed by body mass.

Figure 1 is a representation of the scatter plot of the tested variables. A strong positive linear relationship is observed between the two variables (males/females) which was confirmed from the Pearson's correlation coefficient of 0.743 in Table 3. The relationship between PA levels in

Table 1. Anthropometric data, MET and motor ability for Males (N=32) and Females (N=28)

Parameter	Males			Females		
	Mean (±SD)	Min.	Max.	Mean (±SD)	Min.	Max.
Body mass (kg)	62.62±5.90	50.40	77.50	61.43±6.71	48.45	75.50
Body height (cm)	166.90±8.48	153.00	188.00	159.44±6.58	146.00	170.00
Body mass index (kg/m2)	22.43±2.64	17.16	26.64	24.21±2.90	19.62	29.20
Upper limb length (cm)	61.28±4.67	51.00	70.00	57.54±4.62	49.00	65.00
Lower limb length (cm)	95.00±6.38	81.00	109.00	89.32±5.87	79.00	103.00
Burpee test (No of cycles/3min) (N)	48.34±5.17	38.00	58.00	38.50±3.33	34.00	46.00
PA level (MET) units (MET-min/week)	1807.09±624.91	411.00	2904.00	785.97±538.15	247.50	2212.00

Table 2. Correlation between anthropometric variables and the number of cycles completed in 3-MBT for Males (N=32) and Females (N=28)

Parameter	Burpee test (No. of cycles/3 min) (N)	
Body mass (kg)	**-0.396*(s)**	**-0.381*(s)**
Body height (cm)	0.010	0.288
Body Mass Index (BMI) (kg/m2)	-0.365*(s)	-0.571**(s)
Upper limb length (cm)	-0.266	-0.025
Lower limb length (cm)	-0.196	0.137
Lower limb length (cm)	95.00±6.38	81.00
*p < .05, **p < .01 s = significant		
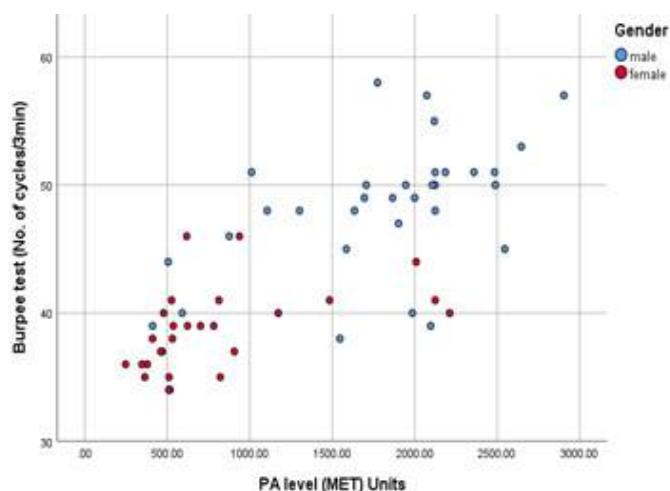
Figure 1. Scatter Plot representation of PA level (MET) Units and Burpee test (No. of cycles/3 min)
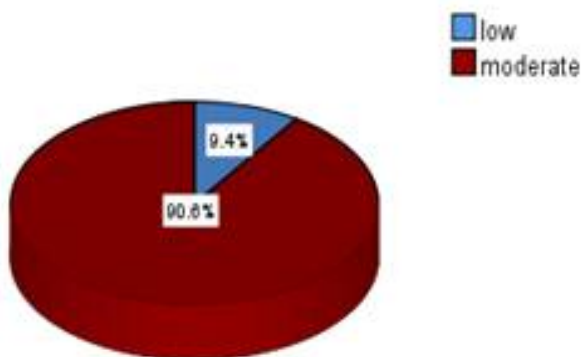
Figure 2. Number of males with low and moderate physical activity level

MET units and endurance strength (assessed by the 3-MBT) is presented in Table 3. It is evident from the table that PA levels in MET explain a significant proportion of variance in endurance strength scores, $R^2 = 0.55$, $F_{(1, 58)} = 71.39$, $p < .001$. The R^2 value shows that 55% of variation in endurance strength can be explained by the model containing only PA levels in MET. From Table 4, PA levels in MET significantly predicted endurance strength scores, $b=0.006$, $t_{(1, 60)} = 8.49$, $p < .001$. The mean value of PA levels in MET was 1330.57 and 43.75 for endurance strength. The Pearson's correlation coefficient R between the two variables revealed a strong positive correlation of 0.743. From the result, it is evident that there is significant relationship between adolescent PA levels in MET and endurance strength.

The significant difference between adolescents' endurance capacity as assessed by the 3-MBT is presented in Table 5. The results show that mean score of males (M = 48.34, SD = 5.17) was significantly higher than that of females (M = 38.50, SD = 3.33), $t(58) = 8.63$, $p < .001$ regarding the number of cycles completed in 3MBT.

It is evident from table 6 and figures 2 and 3 that with moderate PA level, the evaluated males had the majority number (90.6%) compared to females (46.4%). Majority of female adolescents (53.6%) were characterized by low PA level compared to males (9.4%). Females who were characterized by low PA levels had the lowest number of cycles in the 3-MBT compared to males who scored 39 - 44 for their minimum and maximum number of cycles in 3-MBT. Moreover, females had the lowest record of number of cycles in 3-MBT characterized with moderate levels of physical activity with a maximum and minimum cycle of 35 and 46 compared to males (38 and 58 cycles). Only 3 males were characterized by low physical activity compared to 15 females. Males had the highest number of individuals with moderate PA level compared to females with 13. The result shows that males are more active compared to females.

Discussion

This study was designed to determine how anthropometric variables (body weight, body height, upper and lower limb length), BMI and PA levels affect the number of cycles completed in 3-MBT among male and female teenagers. The major findings of this study showed that BMI and body mass were the limiting factor in completing 3-MBT for endurance strength assessment. Moreover, a strong positive correlation was observed between PA levels in MET and endurance strength. Moreover, a significant difference was observed between males and females regarding their endurance strength as assessed by 3-MBT.

There are several factors that influences endurance strength among adolescents. These factors are associated with the number of cycles completed in the 3-minute burpee test among adolescents of both gender [30]. International Physical Activity Questionnaire (IPAQ) short form, inelastic measuring tape,, Physical Activity Readiness Questionnaire, a digital stop watch, wooden meter and an electronic bathroom weighting scale, used in the assessment helped to determine participants anthropometric measurements, physical fitness level, health status and endurance strength abilities.

The anthropometric measurements of participants (body mass, body height, upper and lower limb lengths) were

Table 3. PA levels in MET as a predictor of endurance strength (3-MBT)

R	R Square	Adjusted R Square	Std. Error of the Estimate		
0.743	0.552	0.544	4.461		
Analysis of Variance					
Model	Sum of Squares	Df	Mean Square	F	Sig
Regression	1420.90	1	1420.9	71.39	<0.001
Residual	1154.35	58			
Total	2575.25	59			
Note: Predictors (Constant): PA level in MET Unit Dependent Variable: Endurance strength (3-MBT)					

Table 4. Regression analysis of PA levels in MET as a predictor of Endurance strength

Model	N	Mean	SD	B	B	Df	T	Sig
PA level in MET	60	1330.568	775.65	0.006	0.743	59	8.449	0.000(s)
Endurance strength (3-MBT)	60	43.75	6.61					
p < 0.05 s = significant								

Table 5. Independent sample t-test result of endurance strength for males and females

Gender	n	M	SD	SE	Df	T	Sig
Male	32	48.34	5.17	0.91	58	8.63	0.00(s)
Female	28	38.50	3.33	0.63			
p < 0.05 s = significant							

Table 6. Descriptive statistics by group (compare means) of gender, physical activity level and endurance strength

Gender	PA level	Min	Max	N	% of Total N
Male	Low	39	44	3	9.4
	Moderate	38	58	29	90.6
Female	Low	34	41	15	53.6
	Moderate	35	46	13	46.4
	Total	34	46	28	100
Total	Low	34	44	18	63
	Moderate	35	58	42	137
	Total	34	58	60	200

higher in males compared to females excluding body mass index (BMI) which could be attributed to the general observation. In the present study, the correlation observed between the numbers of cycles completed in the 3-minute burpee test and anthropometric variables is in agreement with the results of research findings in other studies. Body mass and body mass index (BMI) had a significant negative influence on the number of cycles completed in the 3-minute burpee test in both genders excluding body height, upper limb and lower limb length in these studies. Studies by Podstawski et al. [31] compared physical fitness in pre-school, early school children, female university students and early education teachers. In their studies, body mass and body mass index (BMI) was correlated with strength abilities, however, the 3-minute Burpee test was negatively affected by these variables. A significant negative correlation was observed in female university students performing 3-minute burpee test with body mass (r = -0.867), body mass index (BMI) (r = -0.779) and body height (r = -0.254) respectively, however, body height was not significant in this present studies. This could be attributed to the small sample size used in these studies. Recent studies by Podstawski et al. [30] reported correlations in their studies evaluating sex mediated differences and correlation between anthropometrics and motor abilities of university students preforming various motor test. In their studies, body mass, body height and body mass index (BMI) was significantly negatively correlated with the number of cycles completed in the 3-minute Burpee test in females (r = -0.19, -0.13, -0.11). However, body height was not significantly correlated in this current study. Moreover, significant correlation was observed for body mass and BMI excluding body height for males in the same study (r = -0.13, -0.14, 0.00) [30] which is consistent with the findings of this current studies. The results in this present study demonstrates that body mass and body mass index (BMI) decreases endurance strength as assessed by the number of cycles completed in the 3-minute Burpee test. Studies have demonstrated that high body mass and high body mass index (BMI) has a significant impact on reducing cardiorespiratory fitness and endurance [15-16]. Moreover, body mass has a significant influence on the role of relative strength in endurance training [32-33]. As a result, overcoming resistance is influenced by both

body mass and body mass index, therefore individuals with higher values are expected not to perform well in endurance strength activities such as the number of cycles completed in 3-minute Burpee test. This could account for the significantly high negative correlations observed in females compared to males with the number of completed cycles in the Burpee test. Anthropometric characteristics of body mass and BMI characterized by obesity and overweight as reported by [18] previously in university females had a significantly negative impact on the number of completed cycles in 3-MBT.

On average, males and females' physical activity levels in MET were identified in moderate physical activity level with females occupying the lowest range and males the highest range of moderate physical levels ((M < 1500 METs-min/week or five or more days of any combination of walking, moderate intensity or vigorous intensity activities achieving a minimum total physical activity of at least 600 MET and below 3000 MET minutes a week). This observation is in agreement with the general observation that males have higher physical activity levels than females [34]. The results of the PA levels in MET predicting endurance strength (as assesses by 3-MBT) gives an indication that PA levels can be considered a good measure for assessing adolescents' fitness levels. The effects of PA levels in MET values on endurance strength is in concordance with studies by [3] demonstrating that performance of physical exercise or daily physical PA is influenced by physical fitness capacity. Moreover, Podstawski and Zurek [23] also demonstrated that physical activity levels have influence on performance capacity of individuals.

The 3-Minute Burpee Test (3-MBT) has been used to evaluate endurance strength and is suggested to be more reliable for measuring endurance strength compared to various variations reported in literature lasting 30s and 60s [4,6]. In a study evaluating the relationship between strength endurance, anthropometric features, body composition and physiological parameters among university students with low or moderate physical levels of physical activity performing extreme exercise, male students completed (48.34cycles/3 min) which is 1.12 more cycles completed in the 3-minute Burpee test than in the previous studies of male university students [21]. Moreover, females completed (38.50cycles/3 min) with a smaller difference of 0.7 more cycles than in the previous female university students. Recent studies by Podstawski et al. [30] reported that males students completed more cycles (57.8cycles/3 min) than in current studies with a difference of 9.46 more cycles. Female students also completed (47.9cycles/3 min) which is 9.4 more cycles than in current studies. Moreover, a significant difference was observed with lower mean scores of 38.50 for females and 43.34 cycles for men respectively. This could probably be attributed to the sample size used in this study.

In previous studies regarding university females [17], they completed 10.8 more cycles than in current studies and in early studies [18], the noted difference was 1.35 more cycles. Comparing the above scores, it suggests a decrease in endurance strength of both males and females' adolescents. In a previous study by Podstawski, et al. [35], university males and females characterized by moderate

physical activity levels had the highest endurance strength abilities assessed by the 3-MBT than those typified with low PA levels. Our findings confirmed their observations. More cycles were completed during the 3-MBT with males having the highest scores compared to females.

The results of the 3-MBT were significantly influenced by physical activity levels as assessed by MET values, body mass and body mass index in this present study. The relationships, variations and correlations observed in present studies is an indication that low PA levels poses a risk that has an impact on health characterized by individuals living an inactive lifestyle and this has been reported in literature with physical activity associated with university students [17,18,21]. However, studies have shown that some selected health risk could be minimized when physical fitness is improved [36].

Limitations

Individuals with robust muscular development were privileged in the 3-MBT and the small sample size used in this study were the limitations of this study.

Conclusion

The findings of the study demonstrated that males were characterized by higher anthropometric measurements excluding body mass index than females. Body mass and BMI were significantly correlated with 3-MBT. In effect, the number of cycles that an adolescent can complete in 3-MBT can be predicted from the correlated variables. The significant difference observed in endurance strength capacity among both males and females were the reason for the difference observed in the performance scores of 3-MBT. Males and females characterized by moderate levels of PA completed more cycles than their sedentary counterparts. Physical education and well-planned physical fitness programs that would ensure that all students participate in physical activity to reduce risk factors associated with inactive lifestyle should be reintroduced in schools

Conflict of Interest

The authors declare no conflict of interest.

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RESEARCH ARTICLE

Effect of 16 Weeks of Core and Strength Training on Incidence of Injury Occurrence and FMS Score of Ghanaian University Basketball Athletes

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Abstract

Background: The purpose of this study is to determine if FMS scores can predict the prevalence of injury occurrence after 16 weeks of core training and strength training in a Ghanaian University basketball athlete.

Materials and methods: Ninety (90) athletes aged 18-25 years participated in the study. Athletes were randomly stratified into two groups (n=45) and participated in 16 weeks of core training and 16 weeks of strength training respectively. All athletes received questionnaires and FMS scores before and after training was recorded.

Results: Of the 90 athletes, ankle and knee were the most vulnerable parts of basketball athletes to injuries. Compared with pre-training, athletes' incidence of injury was reduced after training. When the FMS score was 14.5, the value of Sensitivity-(1-Specificity) is the largest. In addition, FMS scores could only take integers, so FMS=14 was the best critical value for predicting the risk of injury by FMS score whether it was before or after training. Fifty (50) basketball athletes had an FMS score of ≤14 before training and 40 had FMS scores >14. After training, 15 basketball athletes had an FMS score of ≤14 and 75 had FMS scores >14. There was a significant increase in FMS scores single and total scores after training compared with pre-training.

Conclusion: FMS score can effectively predict the injury risk of basketball players. Increasing strength and core training can effectively prevent basketball players from injury and improve FMS score.

Keywords: FMS score, Basketball players, Injury, Core, Strength, Training

Introduction

Functional Movement Screen (FMS), developed by Gray Cook and Lee Burton, was designed as a systematic screening guide to assist health and wellness professionals in identifying poor fundamental movement patterns in patients and clients [1]. The movements of the FMS have been specifically designed to stress an individual's functional movement limits so that one's range of motion, dynamic stabilization, and balance deficits are been exposed [2-4]. The FMS consists of seven fundamental movement patterns that include the deep squat, the hurdle step, the in-line lunge, the shoulder mobility test, the active straight-leg raise, the trunk stability push-up, and the rotary stability tests [5]. Each movement of the FMS is scored on a four-point scale of 3, 2, 1, or 0 with a total composite score (FMSTM) of 0 to 21 points possible [6]. The FMSTM as a screening tool for exposing injury risk associated with movements has a vital role in injury prevention, through the detection of pain during

movement patterns [7]. Several studies have examined FMS score and prediction of injury [5,8-11]. Researchers have reported that those with lower FMS scores are more likely to become injured or already have a history of injury [12,13].

In competitive athletes, the association between FMS and injury has been observed [14]. An FMS composite score of 14 as a threshold for predicting injury has been identified in volleyball players, college female basketball, and professional American football players [15,16]. Kiesel et al [16] studied professional football players (n=46) and found that those with a score of less than or equal to 14 had a much greater chance of serious injury during their competitive season. Research focusing on female collegiate soccer, volleyball, and basketball players (n=38) also found that a lower score on the FMS was associated with injury [15]. In this study population, 69% of the injuries sustained were by participants who scored a 14 or less.

As sport participation has continually increased over

time, the risk of incurring a musculoskeletal injury has also increased [17]. According to Teyhen et al [6], "More than 10,000 Americans seek medical treatment for sports, recreational activity, and exercise-related injuries on a daily basis". Pre-participation screenings therefore act as a preventative measure to assist with reducing the risks of injuries as it has been used in different sport [2]. Studies by [18] shows that FMS has been used to assess and reduce the risk of injury among marine officers, and among fire fighters following 8 weeks training program, an enhanced functional movement reduced time injury by 62% compared with historical injury rates [19]. For performance improvement and injury prevention, training involving strength and conditioning as well as corrective exercises are often implemented [7].

Based on current research available, it was unknown if Functional Movement Screen following core and strength training could predict the prevalent risk of injury in basketball among athletes' competing at the university level in Ghana. More research on a threshold FMS score for endurance and contact sports is still needed. Sports such as basketball where contact and overused injuries are more common and needs further research regarding use of the FMS [5,16] is of importance. Thus, the purpose of this study is to determine if FMS scores can predict the prevalence of injury occurrence after 16 weeks of core and strength training and to identify FMS predictive value for injury in Ghanaian University Basketball athletes.

Materials and Methods

2.1. Participants

The study employed a quasi-experimental, separate-sample pre-test/post-test research design. This study involved a total of 90 Ghanaian university basketball team athletes between the ages of 18-25 years. A random sampling method using the FMS was used to select participants. Basketball athletes were randomly stratified into two groups (n=45) with a deficiency on the FMS scale and underwent 16 weeks of core training in one group and 16 weeks of strength training in another group. The study excluded 1) athletes who had sustained an injury 30 days or less prior to FMS testing which will prevent them from participating in strength and conditioning, practice, competition, 2) if they have had recent surgical intervention that will limit their participation in sport due to physician restriction. A pre and post basketball injury questionnaires produced by Shanghai Sport Institute were distributed to all participating athletes in both groups.

2.3. Research method

Before and after the experiment, the students were uniformly investigated, the basic situation of the 90 students was understood and questionnaires were distributed. The contents of the questionnaire include: height, weight, age, and years of basketball. Ten (10) expects in the field of basketball were employed to evaluate the validity of the structure, content and overall validity of the questionnaire. Five grades of indicators were selected to evaluate the questionnaire (a) perfect (b) perfect (c) perfect (d) imperfect (e) imperfect. Following the

preliminary review, the experts put forward an insightful commentary. To ensure the validity of the questionnaire, the author incorporates the advice of the experts and further enhances and revises the questions. The questionnaire for this study had high levels of recognition from ten experts for their overall validity, structure and content. While 60% believes it is the most perfect, 40% believes it is perfect. This study reliability test adopted the retesting method. Before the official questionnaire was distributed, using a survey sample, this study pre-tested fifty (50) ordinary college basketball fans. The correlation coefficient of the two measurement scores of the questionnaire before and after the first filling of the scale was 0.993.

The FMS test consists of three exclusive tests and seven basic action mode tests which effectively test subjects' basic abilities such as overall motion control, body stability, flexibility, balance and proprioception. The seven basic action mode tests are deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability push-up and rotary stability. The three exclusive test actions include deep squat, hurdle step and shoulder mobility. Athletes do not warm up before the test starts. The scoring criteria were divided into four grades. 0 points: pain in any part of the test; 1 point: subjects cannot complete the whole action or maintain the starting posture; 2 points: subjects can complete the whole action, but the quality of completion is not high; 3 points: subjects can complete the action with high quality. The total score of the seven basic movements was 21 points and 14 points are passing lines. The higher the score, the better the quality of the athletes' functional movements and the lower the risk of injury in training or competition. If pain occurred in the exclusive test, the excluded action scored 0. For hurdle step, in-line lunge, shoulder mobility, active straight leg raises and rotary stability, these movements were tested on both sides of the body where the final score of the basic movements is the lower score in the two-side test. The test is performed three times and scored according to the specific scoring criteria and recorded.

The Strength training included; 1) Wall squats, 30 seconds; 2) Overhead squats, 30 seconds; 3) Wall squats, 30 seconds; 4) Squat with in heel raise, 30 seconds; 5) Overhead squats, 30 seconds. 3 sets/time, 4 times/week. The Core training included; 1) Bicycle crunch, 20 reps; 2) Crunch on stability ball, 20 reps; 3) Long lever crunch, 20 reps; 4) Static plank with leg raise, 20 reps; 5) Side bridges, 20 reps. 3 sets/time, 4 times/week.

2.3. Statistical analysis

Data was entered using Epidata 3.1, a database was created, and IBM Statistical Package for Social Sciences (SPSS) 17.0 software was used to analyze the data obtained. The measurement data was described by

mean ± standard deviation, and the count data was described by percentage. Paired sample t-test was used to determine statistically significant differences in FMS scores. A receiver operator characteristic (ROC) curve was used to plot sensitivity verses 1-specificity to determine the best critical value (cut-off) score. A table was developed to divide athletes with injury sites >1 and those with injury

Table 1. Incidence of Athletic Injury in Basketball Athletes before and after Training

Injury site	Participants		Incidence (%)	
	Before Training	After Training	Before Training	After Training
Finger	12	2	13.33	2.22
Wrist	6	0	6.67	0
Elbow joint	8	3	8.89	3.33
Shoulder joint	6	4	6.67	4.44
Back & spine	14	4	15.56	4.44
Knee joint	17	9	18.89	10
Ankle joint	28	9	31.11	10

Table 2. Area under the curve (ROC curve) before the training and after training

	AUC	SD	P-value	95%CI Lower	95%CI Upper
Before Training	0.818	0.043	<0.001	0.734	0.903
After Training	0.802	0.056	<0.001	0.693	0.911

sites ≤ 1, as well as those who were above and below the critical value (cut-off) score of the FMS. Chi-square test was used to determine any significant difference in the occurrence of injury between basketball athletes with FMS score ≤ 14 and FMS score > 14. The statistical significance for all statistical tests was set at p<0.05. The FMS score predicted the effectiveness of basketball players' sports injuries by sensitivity, specificity and index.

2.4. Ethical consideration

The study was approved by the University of Cape Coast's Institutional Review Board (UCC). All participants were able to withdraw from the study without repercussions and were not be forced to participate. Prior to the study, a written informed consent form was issued to the participants and they were briefed about the confidentiality of the study, test procedures, purpose, benefit and risks involved in the study.

Results

As shown in Table 1, before the training, the incidence of ankle injury in basketball athletes before training was 31.11%, the incidence of knee injury was 18.89%, and the incidence of back and spine injury was 15.56%. In addition, the incidence of finger, elbow, wrist and shoulder injuries were 13.33%, 8.89%, 6.67%and 6.67%, respectively.

Also as shown in Table 1, after the training, the incidence of knee and ankle injury in basketball athletes both were 10%, and the incidence of shoulder and back& spine injury were 4.44%. In addition, the incidence of finger, elbow, wrist injuries were 2.22%, 3.33% and 0, respectively.

As shown in Figure 1 and Table 2, when the injury risk of basketball athletes was predicted by FMS score, the area under the ROC curve was 0.818 [95%CI (0.734-0.903)] before training, the area under the ROC curve was 0.802 [95% CI (0.639-0.911)] after training, which had certain predictive value. When the FMS score was 14.5 as shown in Table 3, the value of Sensitivity-(1-Specificity) is the largest. In addition, FMS scores could only take 79 integers, so FMS=14 was the best critical value for predicting the risk of injury by FMS score whether it was before or after training.

As shown in Table 4, before training, there were 50 basketball athletes with an FMS score of ≤14, of which 24 athletes had injury sites >1, 26 athletes had injury

sites ≤1, and 40 basketball athletes had FMS scores >14. Among them, there were 8 athletes with a lesion of >1 and 32 with a lesion of ≤1. After chi-square analysis, there was a significant difference in the occurrence of injury between basketball athletes with FMS score ≤ 14 and FMS score > 14 (χ2=7.603, P=0.006). From Table 5, after training, there were 15 basketball athletes with an FMS score of ≤14, of which 5 athletes had injury sites >1, 10 athletes had injury sites ≤1, and 75 basketball athletes had FMS scores >14. Among them, there were 1 athlete with a lesion of >1 and 74 with a lesion of ≤1. After chi-square analysis, there was a significant difference in the occurrence of injury between basketball athletes with FMS score ≤ 14 and FMS score > 14 (χ2=20.571, P=0.006).

Table 3. The log-log plot of ROC for predicting the risk of injury by FMS score

	FMS	Sensitivity	1-Specificity
Before Training	7.0000	1.000	1.000
	8.5000	1.000	0.983
	9.5000	1.000	0.966
	10.5000	1.000	0.915
	11.5000	1.000	0.864
	12.5000	1.000	0.627
	13.5000	0.935	0.441
	14.5000	0.774	0.271
	15.5000	0.516	0.169
	16.5000	0.258	0.068
	17.5000	0.194	0.000
	18.5000	0.065	0.000
	20.0000	0.000	0.000
After training	11.0000	1.000	1.000
	12.5000	1.000	0.920
	13.5000	1.000	0.680
	14.5000	0.985	0.440
	15.5000	0.815	0.400
	16.5000	0.692	0.360
	17.5000	0.538	0.160
	18.5000	0.338	0.080
	19.5000	0.138	0.000
	21.0000	0.000	0.000

Before training	After training
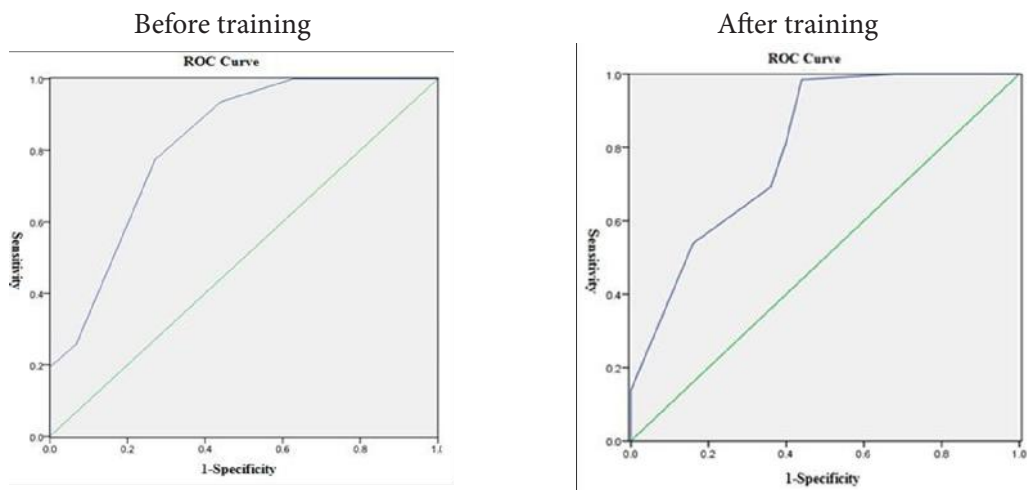
Figure 1: The ROC curve before the training and after training

As shown in Table 6, the average scores of deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability push-up and rotary stability of 90 basketball athletes before training were 1.98, 1.86, 2.00, 2.00, 1.96, 2.32 and 2.03, respectively, and the average score of FMS was 14.14; the average scores of deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability push-up and rotary stability of 90 basketball athletes after training were 2.40, 2.30, 2.52, 2.44, 2.39, 2.44 and 2.32, respectively, and the average score of FMS was 16.82. There were significant differences between FMS single and total scores before and after training (P<0.05).

Table 4. Comparison of the Actual Number of Injured Athletes and the Number of Injured Athletes Judged by the Critical Value of 14 before Training

FMS scoring	Number of athletes with injury sites>1	Number of athletes with injury sites≤1	Total
≤14 points	24	26	50
>14 points	8	32	40
Total	32	58	90

Table 5. Comparison of the Actual Number of Injured Athletes and the Number of Injured Athletes Judged by the Critical Value of 14 after Training

FMS scoring	Number of athletes with injury sites>1	Number of athletes with injury sites≤1	Total
≤14 points	5	10	15
>14 points	1	74	75
Total	6	84	90

Discussion

The FMS test is one of the most frequently utilized methods that researchers use to evaluate the risk of injuries in sport [20]. Accordingly, this study was designed to determine if, after 16 weeks of core and strength training, FMS score can predict the frequency of injuries in addition to finding the FMS predictive value for injury in Ghanaian university basketball players.

Table 6. FMS Scoring of Athletes before and after Training

Item	Before Training	After training
Deep Squat	1.98±0.89	2.40±0.65*
Hurdle Step	1.86±0.77	2.30±0.74*
In-line lunge	2.00±0.95	2.52±0.58*
Shoulder Mobility	2.00±0.75	2.44±0.58*
Active Straight Leg Raise	1.96±0.73	2.39±0.59*
Trunk Stability Push-Up	2.32±0.68	2.44±0.66*
Rotary Stability	2.03±0.64	2.32±0.56*
Total	14.14±2.23	16.82±2.17*
Note: Compared with pre-training, *P<0.05.		

The major findings of this study showed that 16 weeks of strength and core training help athletes recover from injury and significantly improve their FMS scores. In addition, an FMS score of 14 was the most accurate critical value for estimating the likelihood of injury based on FMS score, whether it occurred before training or after training.

Zhang [21] used the method of questionnaire to investigate the injury status and causes of 386 college students who often participated in basketball. The results of the study showed that, total prevalence of sports injuries was 60.88%. The location of sports injuries was fingers, ankles, knees, fingers, waist and back, thighs. The common types of injuries were joint sprain, muscle strain and soft tissue injury. The causes of injuries were inappropriate preparatory activities, violation of competition rules, technical errors, poor venue and excessive exercise load. Chen [22] conducted an epidemiological survey on 367 athletes (211 men and 156 women) who participated in the 2006-2007 CBA and WCBA professional leagues. The results showed that the morbidity rate reached 72.75% in the six-month race, 74.41% in males and 70.51% in females; lumbar muscle strain (12.3%), ankle ligament injury (9.42%) and knee meniscus injury (8.64%) ranked among the top three injury categories; the incidence of injury was knee joint injury (34.55%), lumbar injury (21.2%) and ankle injury (16.75%). The age group with high incidence of injury was 23-26 years old. Studies by Feng [23] used questionnaire to investigate the injuries of NBA professional athletes

Through the analysis of the statistics of professional basketball matches in the quarter of 2013-2014, it can be seen that among the injured parts of NBA professional athletes, the proportion of hand and finger is the smallest, only 1%; while the proportion of knee joint injuries is the largest, 23.8% followed by ankle injuries accounting for 23.8%. Ye et al [24] analyzed the injuries of national men's and women's basketball athletes who participated in the training from 2006 to 2007. The results showed that the incidence of knee (22%), ankle (15.3%) and waist (16%) injuries was higher. The injury was mainly caused by the special position characteristics of basketball athletes.

In the Ghana University basketball athletes, the incidences of ankle injury and knee injury were 31.11%, 18.89% before training and both 10.00% after training. The result of this study is consistent with the studies of other researches. This showed that ankle and knee are the most vulnerable parts of basketball athletes which is similar to other research studies. This was mainly because basketball requires regular running, and in the process of basketball players' knees rarely appear upright state, which will increase. The incidence of lumbar and spinal injuries was 15.56%, suggesting that the injuries in the core of the body should not be neglected. In addition, the incidence of finger, elbow, wrist and shoulder injuries were 13.33%, 8.89%, 6.67% and 6.67%, respectively. After 16 weeks of training, the injury rate of basketball athletes in all parts was significantly lower than that before training, indicating that strength training and core training can help athletes recover from injury.

Kiesel et al. [16] first proposed the "threshold" of FMS injury risk. Kiesel et al tested 46 rugby athletes and monitored them during the 4.5-month season by using the ROC Subject Work Characteristic Curve. It was found that the injury risk of athletes whose test score was less than or equal to 14 was much higher than that of athletes whose test score was greater than 14.

Li, et al. [25] studied 33 ice hockey athletes' injury and functional movement screening, and found that the FMS score of ice hockey athletes was 13.12, which was lower than the recognized 14-point threshold, indicating that the potential injury risk of athletes was higher [16].

Gao et al. [26], discussed the application value of FMS in the risk assessment of sports injury of rugby athletes in China. They took active national and provincial rugby athletes as subjects, collected data by standard FMS test, and tracked and investigated non-contact injury of rugby athletes. They evaluated the value of relevant indicators of FMS test to assess the risk of sports injury and determined the best cut-off point of total score of FMS by using statistical methods such as ROC curve and OR. The area under the curve is 0.780, and the best cut-off point for the total score of FMS is 13.5. Chi-square test showed that the prevalence of positive group (the total score of FMS is less than the corresponding cut-off point) was significantly higher than that of negative group (the total score of FMS is greater than the corresponding cut-off point). It shows that in rugby athletes, the total score of FMS has a strong correlation with non-contact sports injury and can be used as an index for risk assessment of non-contact sports injury [26]. Wang et al. [27] selected 45 main shooting 97 athletes of our country as the test subjects to carry out FMS function test. After data analysis, it was found that the area under ROC curve calculation curve was 0.745 and the difference was statistically significant, indicating that the total score of FMS test had evaluation value for shooting athletes' injuries. Through Youden index, the cut-off point is determined to be 15 points. Its sensitivity is 0.750, specificity is 0.609, pre-test probability is 0.410, post-test probability is 0.571, and the total score of FMS is less than 15. The proportion of possible injuries of athletes will increase from 41% to 57.1%. This shows that this new test method has good predictive ability for shooters.

This study also confirmed by ROC curve method that the area under the curve of FMS score predicting basketball athletes' injury risk is more than 0.7, which shows that FMS score method has certain value. Both before training and after training judging the sensitivity and specificity in Table 3, when the FMS score is 14.5, the sensitivity - (1- specificity) reaches the maximum. However, the FMS scores are all integers, so the optimal threshold value is 14, which is consistent with the results of most researchers. We further compared the injuries of basketball athletes whose FMS score was less than 14 and whose FMS score was more than 14 as shown in Table 4 and 5. We found that the injuries of basketball athletes whose FMS score was less than 14 were obviously more than those of basketball athletes whose FMS score was more than 14. This proves that FMS score has certain value in predicting the risk of sports injuries of basketball athletes and is worth popularizing. The potential damage risk of different projects and groups cannot be judged simply by referring to the conclusions of previous studies at home and abroad as the "gold standard", but should be adjusted according to the research conclusions in the field of practice.

The functional movement screen (FMS) was created as a pre-season and pre-participation examination [28]. Lin et al. [29] selected 16 table tennis students (2.5 years of special sports) from the Institute of Physical Education of Yangtze University as the research subjects for functional action screening. The results showed that the average score of FMS for college table tennis students was 15.86, with the average score of 2.71 for squatting, 1.86 for hurdling step, 2.43 for squatting in straight line, 2.71 for shoulder flexibility, 2.00 for active leg lifting, 2.29 for trunk stability push-ups and 1.86 for body rotation stability. Studies by Zhao et al. [30] selected 77 athletes from 6 teams in Xi'an to participate in FMS screening. The results of the study showed that the mean FMS score was 14.76 in this screening, and the number of people who scored high scores during screening was small. Most athletes scored between 14 and 18, and the mean value of the body stability of the trunk was the highest. The stability of the push-up mode has the lowest mean value, and some athletes have differences in the left and right-side limb. Some athletes had pain during screening and there was sports injury. No linear relationship between the athlete's age, training period and FMS scores and the 7 action patterns was observed. In this study, the average scores of deep squats, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability push-up and rotary stability of 90 basketball athletes before training

were 1.98, 1.86, 2.00, 2.00, 1.96, 2.32 and 2.03, respectively, and the average score of total FMS score was 14.14. This score is moderate, which is close to that reported by Zhao et al. [30], but it also suggests that basketball athletes have a certain risk of injury. However, there was significant improvement in FMS scores after training compared with pre-training as shown in Table 6.

Conclusion

This research study demonstrated that the ankle and the knee are the most vulnerable parts of basketball athletes, and the injuries in the core of the body, such as lumbar and spinal also should not be neglected. An FMS score of 14 was the best value for effectively predicting the injury risk of basketball players and this provides a reference value for screening university basketball athletes before participation. Strength training and core training can effectively prevent basketball players from injury and improve FMS score.

Conflict of Interest

The authors state no conflict of interest.

Author contribution.

Dr Opoku-Antwi conducted a literature search, read every reference, evaluated every article and exported the data. The paper was initially written by JAK, and then it was edited by both authors. The final manuscript was reviewed and approved by all authors.

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RESEARCH ARTICLE

Postpartum Depression In The Ghanaian Context: A Concept Analysis

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Abstract

Background: Postpartum is a unique period in the lives of women with childbirth but presents with postpartum depression, which challenges the mother, infants, and families. In the global and Ghanaian setting, postpartum depression is a mental disorder that impedes maternal function; however, it is an indistinct concept. This article analyses the concept of postpartum depression using the Avant and Walker strategy.

Objective: The article aims to analyse the concept of postpartum depression and determine the defining attributes, antecedents and consequences.

Materials and methods: Analysis of postpartum depression was done using the Avant and Walker strategy of concept analysis.

Results: Deductive analysis was employed to find the defining attributes of postpartum depression which were mood changes, tiredness, inability to sleep, low self-esteem, tearfulness, loss of appetite, feelings of inadequacy, irritability, loss of interest and enjoyment, reduced energy, distress, detachment from baby, worry about injury to the infant, and feeling of guilt about motherhood role performance. The identified antecedents were the presence of pregnancy, labour, childbirth and its physiological and psychological stress. The consequence of postpartum depression was poor cognitive function of the infant, nutritional defects, mortalities associated with deprived infant care, maternal self-care deficit, social interaction impairment and inability to perform parental roles.

Conclusion: The defining attributes and consequences can improve the identification of women with postpartum depression in Ghana and subsequently increase diagnosis and treatment.

Keywords: Concept analysis, postpartum depression, Ghana, mood changes, childbirth, postpartum period.

Introduction

Postpartum depression is a maternal mental disorder that presents a crucial challenge for mothers, their infants and their families. Worldwide, postpartum depression affects 17% of mothers of all ages and is a cause of disability among mothers in the postpartum period (WHO, 2017; Wang et al., 2021). Postpartum depression has negative consequences for the mother and infants, and despite the adverse effects posed by postpartum depression, the definition is relative and arguable. Postpartum depression has been defined as mood disorders that persist more than two weeks after childbirth (O'Hara & Mc Cabe, 2013). The definition of postpartum depression has been established as a mental disorder among mothers after childbirth; however, the onset of postpartum depression has been a controversial issue in literature with varying suggestions on the time the disorder starts (Alzahrani et al., 2022; Chen et al., 2022). Evidence from studies has reported different times of onset of postpartum depression, such as two weeks and any point of time within one year (Wang et al., 2021; Thapa et al., 2014). Studies have also suggested that, in extreme cases, postpartum depression can also occur one year after childbirth (Moraes et al., 2017; Abadiga,

2019; Necho et al., 2020). The Ghanaian setting might also have a similar onset that is worth exploring. Despite the arguable nature of the onset of postpartum depression, a distinct differential attribute of postpartum depression is its occurrence in the postpartum period (Mughal et al., 2022).

The measurements of postpartum depression vary in the literature, and examples of the tools used are the Edinburgh postpartum depression scale, Beck postpartum inventory tool, Patient Health questionnaire versions two and nine, Diagnostic Statistical Manual of Mental Disorders version five for detection of depression, Screening Protocol for Antenatal Depression (SPADe). The different tools utilised different cutoff scores for screening and diagnosis of postpartum depression, which might have brought disparities in the prevalence (Özcan et al., 2017; Cui et al., 2022). Evidence has also suggested that some attributes of postpartum depression, such as fatigue, tiredness, and loss of appetite, might be present in postnatal blues, a transient mode disorder that resolves after two weeks postpartum (Chasanah et al., 2022). Therefore, it is challenging to distinguish the attributes of postpartum blues from postpartum depression. Although the attributes have been reported in studies, variation occurs depending on the individual mother's experience, geographical setting and cultural influences (Rodríguez et al., 2020; Smorti et al., 2019; Wang et al., 2021).

Mothers with postpartum depression suffer the consequence of the inability to care for themselves and the infant and social withdrawal, and in extreme cases, suicide and infanticide can occur (Cui et al., 2022; Anokye et al., 2018). Although there might be similarities in the adverse effects of postpartum depression in Ghana and other settings, the mothers' experiences may differ. The attributes of postpartum depression have been reported in other settings in the literature and show significant variations in different contexts. Even though postpartum depression is a common phenomenon, the concept of postpartum depression is easily confused with other similar concepts, such as postpartum blues and postpartum psychosis, which may interrupt prompt interventions. Therefore, the purpose of this analysis is to identify and clarify the definitions and attributes of postpartum depression in the context of Ghana to provide a clearer understanding of the concept.

The analysis will focus on the definition, attributes, antecedents, and consequences of postpartum depression as well as measurements and samples of a model, borderline, illegitimate, invented and contrary cases in order to differentiate between the concepts of postpartum depression employing the Walker and Avant's (2011) concept analysis methodology.

Materials and Methods

Concept Analysis

This article used a concept analysis approach, and the Avant and Walker strategy was employed with the recommended steps followed (Walker & Avant, 2011). The steps were identifying the concept and determining the defining attributes of postpartum depression till saturation was reached. The eight steps of the process of concept analysis by Walker and Avant (2011) can be found in Table 1.

The concept identified for the analysis in this article was postpartum depression. The model case was presented to determine all the defining attributes connected with postpartum depression. Related, contrary, borderline and illegitimate cases were also presented to help differentiate postpartum depression from other concepts to enhance a better understanding of the concept. Empirical referents illustrate the current theoretical perspective of the postpartum depression concept.

Data Sources

Data was collected through online resources such as dictionaries, published articles, reviews, reports, and meta-analyses from Google, Google Scholar, CINAHL, HINARI, OpenDOAR, and PubMed. The search was done from articles published in English. The search terms used were postpartum depression, childbirth, postpartum period, Ghana, postnatal depression, and maternal mental disorders. Recent articles included in the analysis were between 2016 and 2022. However, a few articles, one published in 1984 and a few from 2009 to 2014, were used in the analysis to provide a clear understanding of the concept and to demonstrate the relevance of how the concept of postpartum depression has evolved over the

Table 1: Process of concept Analysis

Steps	Process	Description and Purpose
1	Identifying the concept	Concept selection for analysis determines what is being analysed
2	determining the purpose of the analysis	Focus on the intention of the concept analysis to identify need
3	identifying the applications of the concept	Identify many uses of the concept to identify the current uses
4	determining the defining attributes of the concept	Establish commonly uses of the attribute to analyse current usage
5	Construct a model case	Use an example to explain all the defining attributes to ensure better understanding of the concept
6	Construct additional cases to	Provide examples to illustrate what the concept does not define.
7	Identify antecedents and consequences	Antecedence are events occurring prior to the concept. Consequences are the results emanating from the occurrence of the concept. Both antecedents and consequence explain the valid usage of the concept.
8.	Define empirical referents	Phenomena existing to create the occurrence of the concept and helps to validate the concept.

years. Most of the articles used were original and peer-reviewed.

A total of 30 articles were included in the analysis of the postpartum depression concept. In addition, some articles were cited because of their relevant information about the concept and provided a clearer explanation of postpartum depression.

Postpartum depression, as defined by the online Oxford dictionary, was used in this article. Additionally, articles by Putnam et al., O'Hara et al., Mughal et al., Nurul, Wisner, Rezaie-Keikhaie et al. Hung et al., Solomon et al., Batt et al. and Ding et al. provided a clear and useful definition of postpartum depression. The definition was used to identify postpartum depression from published articles.

The theoretical perspective of postpartum depression was described using articles such as Adamu et al., Gelay et al., Adeyemo et al., Kariuki et al., Gebregziabher et al., Anokye et al., Paddy et al., Sefogah et al., Wemakor et al. Antecedents and consequences of postpartum depression were identified and described to enhance understanding and improve identification of mothers with the disorder in Ghana.

Definition of postpartum depression

Postpartum depression is crucial when considering maternal health in the postpartum period. This section will discuss the definition of postpartum depression and its onset in the postpartum period. The central focus of this section will be on how postpartum depression has been defined in literature, as well as the onset of the disorder in general and in the context of Ghana.

Some authors with different dimensions have widely defined postpartum depression, which remains controversial. Postpartum depression was previously defined as postpartum affective psychosis after childbirth (Hopkins et al., 1984). In recent times, theoretical development and further research have led to a more distinct definition of postpartum due to its link with maternal blues and classification as a psychotic illness, which hindered treatment (O'Hara & Swain, 2009; Dadi et al., 2020). Postpartum depression is defined in the dictionary as depression suffered by a mother following childbirth, arising from hormonal changes, psychological adjustment to motherhood, and fatigue (Oxford Languages, 2022). Postpartum depression has been described as a mood disorder occurring four weeks in the postpartum period (Putnam et al., 2015). Some authors agree that postpartum depression is a significant mood disorder that persists two weeks after childbirth (O'Hara & McCabe, 2013; Mughal et al., 2022). However, Mughal et al. (2022) emphasise that postpartum blues, a transient mood disorder, can occur and is characterised by crying, tiredness and difficulty in sleeping in the immediate postpartum period but resolves by the second week of the postpartum period. The transient nature of postpartum blues differentiates it from postpartum depression; however, other studies also argue that the blues resolve after several weeks, making the diagnosis of postpartum depression difficult (Alfiyah, 2019; Rezaie-Keikhaie et al., 2020). The inconclusive evidence on when postpartum blues resolves makes the definition and diagnosis of postpartum depression challenging. A study examining the definition of postpartum depression and its onset established that postpartum depression is a mood disorder; meanwhile, the actual onset of the disorder in the study was not established (Wisner et al., 2010). Although there is consensus on postpartum depression as a mood disorder, geographical disparity may present different meanings of postpartum depression worth exploring in the African background.

Postpartum depression in the African setting has been defined as a mood disorder starting a few weeks into the postpartum period (Hung et al., 2014). Again, postpartum depression has also been defined in other studies as a mood disorder which is a consistent, distinct character in the postpartum period among women in Africa (Adamu & Adinew, 2018; Gelaye et al., 2013; Adeyemo et al., 2020). Postpartum depression in Ghana also follows the same trend of definition, being a disorder with mood distortions of varying degrees in the woman after childbirth (Anokye et al., 2018). While evidence suggests similarity in the definition of postpartum depression, the earlier mentioned authors have inconsistency with the onset. Hence, the onset of postpartum depression remains debatable and worth exploring.

Onset of Postpartum Depression

The onset of postpartum depression varies in different studies globally. The reported trends in the onset of depression among postpartum women show onset ranging from two weeks to twelve months after delivery (Wang et al., 2021). The description of the onset of postpartum depression in Africa is not definite. Studies have reported evidence of onset in variable periods, which is consistent with the evidence in literature from other continents (Kariuki et al., 2022; Gebregziabher et al., 2020). For example, a study reported postpartum depression onset at four weeks, while others reported occurrences of postpartum depression at six weeks, eight weeks, and up to twenty-four- four months in the postpartum period. A meta-analysis conducted among mothers with postpartum depression in Africa reported variations in the onset of postpartum depression, which was described as a limitation in the studies used in the review and meta-analysis (Necho et al., 2020; Nweke et al., 2022). It is convincing that there are variations in the onset of postpartum depression among women in the postpartum period. Therefore, it is essential to explore the onset of postpartum depression further to clarify the inclusion of the onset and provide a shred of conclusive evidence in the different settings. The onset of postpartum depression in the Ghanaian context has also shown significant variations, with some women experiencing postpartum depression at two weeks postpartum and others at any point within the first year after childbirth (Sefogah et al., 2020; Anokye et al., 2018).

Characteristics of postpartum depression

The characteristics that identify that a mother has postpartum depression have been reported as mood changes, tiredness, inability to sleep, low self-esteem,

tearfulness, loss of appetite, feelings of inadequacy, irritability, reduced energy resulting in diminished activity, withdrawal from the family, distress, detached from baby, worry about injury to the infant, and feeling of guilt about motherhood role performance in the postpartum period (Solomon et al., 2016; Batt et al., 2020; Ding et al., 2020). The characteristics of postpartum depression, such as low self-esteem, feelings of inadequacy and guilt about the poor maternal role, might be the manifestations of some mothers in the postpartum period that may go unnoticed without careful attention to their presentation and assessment in the postpartum period because of its instinctive nature (Alfiyah, 2019). Literature shows that the characteristics cut across different settings, including Africa (Damtie et al., 2021).

Evidence from a study reported anxiety, stress, guilt about maternal role performance resulting from lack of social support and distress from marital dissatisfaction among Ghanaian women (Paddy et al., 2021). Another characteristic among Ghanaian postpartum women is detachment from the infant, resulting in growth challenges such as stunting (Wemakor & Mensah, 2016). The signs and symptoms of postpartum depression can range from minor to severe, which may warrant interventions and hospitalisation among women in Ghana (Gold et al., 2013). Evidence from literature has extensively established postpartum depression as a mood disorder in the postpartum period. However, the severity of postpartum depression varies among women. The definition of postpartum depression, its onset and its characteristics give an understanding of the nature of postpartum depression; however, the measurements of postpartum depression are a vital component of the concept of postpartum depression.

Measurements of postpartum depression

The accuracy of a tool to screen or diagnose postpartum depression is a controversial and debatable subject in literature. It is worth noting that an accurate tool for

diagnosing and screening for postpartum depression is arguable; meanwhile, the performance of a tool for screening and diagnosis of postpartum depression is dependent on factors such as time of administration, geographical setting and type of measurement (Ukatu et al., 2018). The most widely used tool among the lots for measuring postpartum depression is the Edinburgh postnatal depression scale with translation into several languages (Montazeri et al., 2007; Shrestha et al., 2016; Blackmore et al., 2021). In the Ghanaian setting, the most widely used tool for assessing postpartum depression is the patient health question version nine, which has shown more acceptability and good internal consistency (Weobong et al., 2009). Two of the studies in Ghana used a cutoff for postpartum depression at a total score of five or more on the scale, and another study used a cutoff score of 11 to diagnose postpartum depression (Weobong et al., 2009; Sefogah et al., 2020; Guo et al., 2013). In the studies conducted in Ghana, it is not arguable that the concept of postpartum depression was measured at different periods with varying cutoff points, considering the lack of consensus on the actual time for screening and diagnosis of the condition.

Operational Definition

In Ghana, the concept of postpartum depression is established as a mood disorder; however, the onset is not definite. The characteristics vary from person to person, with a disparity in severity. The tools and measurements are also different in Ghana, and these differences hinder the diagnoses and interventions for postpartum depression.

The summary of the results of the definition, characteristics, onset, and diagnostic tools in the Ghanaian and global contexts is provided in Table 2.

Determining the defining attributes

The defining attributes are the signs and symptoms that characterise and help to differentiate the concept of postpartum depression. The defining attributes from the

Table 2: Summary of results for the concept of postpartum depression

	Ghanaian Context	African/Global Context
Definition	Disorder with mood distortions of varying degrees in the mother after childbirth (Anokye et al., 2018, Sefogah et al., 2020,)	Mood disorder after child birth (O'Hara & McCabe 2013, Mughal 2022, Wisner et al., 2010, Adamu & Adinew, 2018, Gelaye et al., 2013, Adeyemo et al., 2020)
Characteristics	Anxiety, stress, guilt about maternal role performance resulting from lack of social support, distress from marital dissatisfaction and detachment from the infant (Paddy et al., 2021, Wemakor & Mensah 2016)	Mood changes, tiredness, inability to sleep, low self-esteem, tearfulness, loss of appetite, feelings of inadequacy, irritability, reduced energy resulting in diminished activity, withdrawal from the family, distress, detached from baby, worry about injury to the infant, and feeling of guilt about motherhood role performance in the postpartum period (Solomon et al, 2016, Batt et al, 2020, Ding et al, 2020
Onset	No definite onset: two weeks postpartum and others at any point within the first year after childbirth (Sefogah et al., 2020, Anokye et al., 2018)	Variable onset; four weeks, six weeks, eight weeks and up to twenty- four months (Necho et al., 2020, Nweke et al., 2022)
Diagnostic tools	Most frequently used postpartum diagnostic tool is the Patient Health Question (PHQ) version nine (Weobong et al., 2009, Sefogah et al., 2020, Guo et al., 2013)	Most widely used postpartum depression tool is the Edinburgh postnatal depression scale (Montazeri et al., 2007, Shrestha et al., 2016, Blackmore et al., 2021)

empirical analysis are as follows: mood changes, tiredness, inability to sleep, low self-esteem, tearfulness, loss of appetite, feelings of inadequacy, irritability, loss of interest and enjoyment, reduced energy, distress, detachment from baby, worry about injury to the infant, and feeling of guilt about motherhood role performance. Some of the defining attributes are explained for better understanding and clarity.

Mood changes: Mood changes is the variation in a person's emotional state. Mood changes significantly affect the mother's ability to cope with situations in the postpartum period, requiring midwives and health teams to intervene for effective coping (Alba, 2021). Mothers with postpartum depression benefit from the support and coping strategies provided by midwives at the health facility and follow-up, which consequently reduces and prevent depression during the postpartum period (Ruiz et al., 2017).

Low self-esteem: Low self-esteem is the negative thought and lack of confidence about oneself that prevents one from doing what one wants (Fennell, 2005). Maternal low self-esteem hinders the care she needs to provide for herself and the infant. Low self-esteem is a character that demands behavioural therapy to help the mother elevate their esteem in the postpartum period (Jidong et al., 2021)

Distress: Distress is the expression of extreme anxiety, sorrow or pain and can be physical, emotional and psychological (Kita et al., 2015). Maternal distress in the postpartum period is a factor that requires attention by midwives to reduce its symptoms in the postpartum mother (Obrochta et al., 2020).

Detachment from baby: Detachment from the baby is disengagement or separation from the baby by the mother, which results in a decrease in love for the baby during the postpartum period (Hill & Flanagan, 2020). The detachment from the baby deprives the baby of breastfeeding, bonding and care from the mother. Maternal attachment, nutrition and bonding are essential for infant growth (Mathews et al., 2019). Hence the mother needs therapy and support to attach well to the baby.

Guilt about the maternal role: Maternal role is the process where the mother nurtures, protects, takes care of the baby and manages home activities (McNamara et al., 2019). The role becomes overwhelming with the presence of a new baby, unplanned activities and lack of support from family (Shrestha et al., 2019). Mothers feel guilty when they cannot assume their roles after childbirth or when the roles are overwhelming. Hence postpartum mothers need support and education from midwives and experienced family members to perform their roles with minimal stress (Heydarpour et al., 2022).

The defining attributes mentioned help to clarify the concept of postpartum depression. The defining attributes of the concept of postpartum depression peculiar to Ghana are distress, guilt about the maternal role, stress and anxiety. The cases, antecedents and consequences are also worth exploring for more understanding.

Model case

A model case depicts all the concept's attributes under analysis in actual life situations. The model case clarifies the concepts' attributes and provides a better understanding (Walker & Avant, 2011). Below is a model case for the concept of postpartum depression.

Mrs Eyemamekra Adom, a 20-year-old woman presented at the health center following the birth of her first child. Mrs Adom reported that although she is usually a cheerful person, since the birth of the child she had started feeling sad and anxious especially when taking care of the baby. She reported that she finds herself overwhelmed about selfcare, housework and caring for the baby. As a result, she felt guilty about her inability to perform her maternal role effectively. She was also distressed about her poor relationship with her husband. Mrs Adom was tearful and could sometimes cry, but she could not disclose it to anyone or report it to the midwife at the health center. She became detached from the baby and some of the family members. She could not sleep well and also lost her appetite for food. Mrs Adom was always tired with low energy levels. She felt inadequate about herself, with low self-esteem and worried about the baby. She lost interest in and enjoyment of activities.

Analysis: Mrs Adom started having mood changes, feeling anxious about the baby, guilty about her inability to perform her maternal role, and stressed; she was also distressed. She became detached from the baby. She could not sleep and lost her appetite for food. She felt tired with low energy levels. She felt inadequate and worried about the baby. She lost interest and enjoyment in activities. All these attributes exhibited by Mrs Adom depict the concept of postpartum depression.

Related case

Mrs Doyina Mayenka, a 28-year-old mother, started having attitude changes after discovering that her husband was cheating on her. Mrs Mayenka felt angry, inadequate and neglected her self-care and the house chores. She experiences pain about her poor relationship with her husband. Mrs Mayenka was upset and could shout at times and became detached from the family members. She slept less and was always weary with little energy levels. She felt inferior with low esteem, lost awareness and satisfaction with activities.

Analysis: Mrs Mayenka had attitude changes after discovering her husband was cheating on her. She felt angry, inadequate and neglected her self-care and the house chores. She experienced pain, upset and shouted at times. She slept less and was weary with little energy. She felt inferior, with low esteem and lost awareness. The attributes, in this case are not related to childbirth, but are synonymous with the concept of depression, which makes it a related case.

Contrary case

Contrary cases show the opposite side of the defining attributes and help to differentiate the concept of postpartum depression from other concepts. Below is a contrary case of postpartum depression.

Madam Ama Durowa, a 30 years old mother in the postpartum period, reported no stress from childbirth;

meanwhile, she was happy and enjoying her role due to support from significant others and family. She has a good appetite for food and usually eats. Madam Durowa reported to the midwife that she has a good relationship with her husband, which satisfies her with her marriage and enables her to get partner support and male involvement at the health facility. Madam Durowa reported a suitable attachment with her baby and has no course for worrying about the baby.

Analysis: In this case, Madam Durowa, a postpartum mother, reported no stress but was happy and enjoying her role as a mother due to the support family support she received. She eats well and normally. She received partner support and did not worry about her baby. The attributes, in this case, are contrary to the attributes of the concepts of postpartum depression.

Borderline case

A borderline case does not contain all the defining attributes. Furthermore, below is a sample of a borderline case.

Madam Josaa Anidaso, a 25-year-old mother, started experiencing mood changes, tearfulness and crying most of the time after childbirth. She reported assuming her role as a mother adequately with no guilt. Although she was stressed at some points in the postpartum period, it resolved due to the presence of social support offered by people in her community. Madam Anidaso recounted positive experiences about her labour and the postpartum period.

Analysis: Madam Anidaso experienced mood changes, tearfulness, crying and stress in the case. Although the attributes in the case are representative of the concept of postpartum depression, some of the attributes were absent, and this makes it a borderline case.

Illegitimate case

Illegitimate cases do not resemble the defining attribute, but help understand the concepts of interest. Below is a sample of an illegitimate case.

Ms. Asomdwe Nyame is 31-year-old women who gave birth to her first child by spontaneous vaginal delivery without complications. Ms. Asomdwe following child birth engages in substance abuse and start to smoke. She was visited by the community health nurse because she missed her postnatal care. The community nurse finds her sleeping while the baby was crying. She reported that she cannot cope with the baby and the housework. She felt weak, lethargic and had no appetite for food.

Analysis: This case is illegitimate because although Ms. Asomdwe shows signs of depression such as sleeping while the baby is crying, inability to cope with baby and housework, feeling weak, lethargic and poor appetite. The signs of depression were self-induced and will disappear if she stops the substance abuse.

Antecedents and consequences

The antecedents to the concept of postpartum depression exist in the presence of pregnancy, labour, childbirth and its physiological and psychological stress that translate into postpartum depression when it is not managed well in the postpartum period (Mokwena & Masike, 2020). Hormonal changes have also been reported as a forerunner for postpartum depression (Schiller et al., 2015). Evidence from studies in Ghana has also reported anxiety and stress in the postpartum period as a precedent for postpartum depression (Paddy et al., 2021). The prior occurrence of factors such as extremes of maternal age, marital dissatisfaction and blood transfusion after childbirth has predisposed some women to have postpartum depression in the Ghanaian context (Anokye et al., 2018; Sefogah et al., 2020). Birth complications, stillbirth, neonatal death, newborn ill health and delivery seasons have preceded postpartum depression among women in Ghana (Weobong et al., 2015). The factors leading to postpartum depression also affect the woman, infant and the entire family.

The consequences of postpartum depression are poor cognitive function of the infant, nutritional defects, and mortalities associated with deprived infant care (Slomian et al., 2019). The adverse effects of postpartum depression experienced by women have been reported to be a self-care deficit, social interaction impairment and inability to perform parental roles (Bhusal & Bhandari, 2018). The consequence of postpartum depression also negatively affects the women's ability to care for themselves and the infant resulting in care deficits and distorted activities of daily living in the postpartum period. In the Ghanaian setting, postpartum depression adversely affects infant nutrition, the women's ability to function in physical activities, socialise with members of the family and community and psychological well-being (Paddy et al., 2021; Wemakor & Mensah, 2016). Despite the seriousness of the adverse effects of postpartum depression that pose a challenge to the women and the family, the measurements of the concept to facilitate diagnosis and intervention lack consensus.

Empirical referents

Empirical referents are evident, confirmable, quantifiable aspects of a specific concept (Walker & Avant, 2011). The empirical referent of the concept of postpartum depression can be derived from the clear and observable phenomena of postpartum depression that can be ascertained through the observation of the characteristics exhibited by the women in the postpartum period through observation, conducting interviews and self-reported signs and symptoms.

Theoretical perspectives have also reported on other several tools for the measurement of postpartum depression. Beck postpartum inventory tool, Patient health questionnaire versions two, Diagnostic Statistical Manual of Mental Disorders version five for the detection of depression and Screening Protocol for Antenatal Depression (SPADe) are valid and reliable tools that directly assess the attributes and referents that characterise and measures postpartum depression (Chorwe-Sungani et al., 2022; Levis et al., 2020; Ukatu et al., 2018; Tolentino & Schmidt, 2018)

Clearly defining the attributes of the concept of postpartum depression might lead to establishing interventions to improve maternal mental health. Clarifying the attributes of postpartum depression provides better understanding

by midwives in the clinical area; hence assessment of the women will be done for prompt intervention and health outcome. More nursing and midwifery diagnoses on attributes of postpartum depression should be included in the diagnosis list to enhance the use of the concept in the clinical area.

Discussion

The discussion presents a comprehensive analysis of the concept of postpartum depression according to Walker and Avant (2011). The concept of postpartum depression is central to maternal mental health in Ghana and clear understanding is crucial for diagnoses and treatment. The analysis of the concept analysis of postpartum depression identifies the operational definition of the concept in the context of Ghana as a mood disorder in the postpartum period with onset two weeks after childbirth. It can occur at any time within the first year after childbirth (Anokye et al., 2018; Sefogah et al., 2020).

The defining attributes and characteristics of postpartum depression determined in the analysis were fifteen, which clearly show the symptoms that manifest when a postpartum woman has postpartum depression. The characteristics identified will enable health workers to recognise women with the disorder for prompt management and care. Identification of mothers with postpartum depression provides timely interventions to curtail the menace in the postpartum period. Evidence suggests that the introduction of early intervention in women with postpartum depression facilitates recovery and better maternal health outcomes (Jannati et al., 2021; Hahn et al., 2021). Ghana, like other resource-limited settings, has high levels of postpartum depression, according to studies mentioned earlier in the analysis. However, knowing and understanding the features of postpartum depression will provide midwives and doctors with innovative ways of prevention, identification of more women with the symptoms and early intervention. Studies have reported that finding innovative ways of identifying symptoms and providing interventions for women with postpartum depression, such as electronic health means, provides a unique opportunity for reducing postpartum depression (Lackie et al., 2021; Huh et al., 2023). Consequently, there would be enhanced maternal role performance, health, and well-being of the infant and the entire family when appropriate measures are employed in managing postpartum depression (Lin et al., 2023).

Despite the inclusion of postpartum depression as one of the topics in nursing and midwifery education, the skills and competencies in identifying women with postpartum depression are questionable. Students might have a superficial understanding and means to identify and provide adequate care for women with postpartum depression. Studies suggest that continuous education and research on postpartum depression improves screening and treatment outcomes (Clevesy et al., 2019; Sudhanthar et al., 2019). Hence this analysis might expand the knowledge and professional competencies of midwives and other related health professional in the care provision for women with postpartum depression. Furthermore, the concept analysis may set the pace for embracing postpartum depression as a priority area for health intervention due to the nature, consequence and unidentified tool for measurement by the health sector in Ghana. Concept analysis has proven to clarify concepts for better understanding and has evolved in tool development. Evidence from studies is conclusive that concept analysis enhances clarification of the concepts and provides dimensions for management (Sun et al., 2023).

The antecedents in this analysis suggest that postpartum depression occurs in the presence of pregnancy, labour, childbirth and its physiological and hormonal changes, anxiety, physical and psychological stress that translate into postpartum depression when it is not managed well in the postpartum period (Mokwena & Masike, 2020; Schiller et al., 2015; Paddy et al., 2021).

The existence of these antecedents will provide healthcare workers with a guide for the surveillance of postpartum women, early detection of symptoms, and prompt management.

The consequence identified in the analysis peculiar to the Ghanaian setting in terms of postpartum depression are infant malnutrition, maternal inability to function in physical activities, poor socialisation with members of the family, community and psychological unwellness. Postpartum women experiencing the consequences of postpartum depression need prompt attention to prevent morbidity and mortality. Early detection and management of postpartum depression are crucial for better treatment outcomes (Nweke et al., 2022). Furthermore, there is a need to create awareness about the characters, antecedents and consequences of postpartum depression to all childbearing women, families and communities for early recognition. Again, training and development of health workers' skills and competencies are necessary to recognize and manage postpartum depression. The screening and diagnostic tools used for postpartum depression are effective in screening and diagnosing postpartum; however, there can be errors (Levis et al., 2020; Ukatu et al., 2018). Management strategies include counselling, cognitive behavioural therapy and pharmacological modalities (Liu et al., 2022).

Limitations

The concept analysis of postpartum depression has the limitation of including studies published in English, which restricted the scope of the concept analysis.

Conclusion

The concept analysis of postpartum depression identifies the operational definition of the concept in the context of Ghana as a mood disorder in the postpartum period with onset two weeks after childbirth and at any time within the first after childbirth. This analysis suggests that the attributes are clearly defined, distinguishing postpartum depression from maternal blue and psychosis. The factors contributing to postpartum depression, the antecedents and consequences, and the measurements differ from other conditions.

Authors contribution

Naomi Kyeremaa Yeboa (NKY) and Ellen Chirwa (EC) conceptualized and designed the study, extracted literature,

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RESEARCH ARTICLE

Knowledge, Attitudes, and Practices Regarding Anaemia Among Pregnant Women Attending Antenatal Clinic at the University of Cape Coast Hospital in the Cape Coast Metropolis, Ghana

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Abstract

Background: Despite the adoption of prophylactic programs of iron and folate supplementation (IFAS) to prevent nutritional anaemia in pregnancy, iron deficiency anaemia (IDA) in pregnancy remains a public health issue, especially in developing countries. An efficient strategy that may be helpful prior to establishing the objectives of any nutrition intervention is to assess the knowledge, attitudes, and practices (KAP) of pregnant women before implementing any intervention.

Objective: This assessed KAP of pregnant mothers attending antenatal clinic at the University of Cape Coast Hospital.

Materials and Methods: A descriptive cross-sectional study involving 225 pregnant mothers who visited the antenatal clinic at the University of Cape Coast Hospital in the Cape Coast Metropolis, Ghana was employed. A structured questionnaire from the United Nations' Food and Agriculture Organization was used to evaluate participants' KAPs with reference to anaemia. A simple random sampling method was used to select participants for the study. IBM SPSS Statistics version 26 was used to conduct descriptive statistical analysis, which was summarized by frequency and percentages. A chi-squared test was used to determine the relationship between categorical variables at a significance level of P = 0.05.

Results: Overall, a greater proportion of the participants, 124 (55.1%), had poor knowledge on nutritional anaemia in pregnancy. A statistically significant association (P = 0.003) was found between the knowledge and attitudes of the pregnant women regarding anaemia.

Conclusion: Findings from this study suggest there is a knowledge deficit among pregnant women attending antenatal clinic at the University of Cape Coast Hospital. The positive attitudes of the study participants regarding anaemia may not translate into their knowledge concerning a health situation.

Keywords: Knowledge, Attitude, Practice, Anaemia, Anaemia in Pregnancy, Pregnant mothers

Introduction

Globally, anaemia is regarded as the most critical health condition confronting pregnant women both in developing and developed countries (Habib et al., 2018; Karami et al., 2022). The World Health Organization (WHO) considers maternal anaemia as a severe public health significance if its prevalence is ≥40% (WHO, 2008). A systematic review

and meta-analysis on the global prevalence of anaemia in pregnant women indicated an overall prevalence of 36.8% (Karami et al., 2022). Karami et al., (2022) further reported that the highest prevalence (48.8%) of anaemia occurred in the third trimester of pregnancy. Again, a comparison across regions worldwide, revealed that pregnant African women bear the greatest brunt of anaemia with the highest prevalence of 41.7% (Karami et al., 2022). Hence, anaemia

in pregnancy can be described as an endemic health problem particularly in sub-Saharan Africa (SSA) as reported by several systematic reviews and meta-analysis (Dorsamy et al., 2022; Geta et al., 2022; Getaneh et al., 2021; Fite et al., 2021). For example, the systematic review and meta-analysis by Fite et al., (2021) that included 15,061 pregnant women reported the pooled prevalence of anaemia in pregnancy in Sub Saharan Africa (SSA) to be 35.6%.

The Centers for Disease Control and Prevention (CDC) and WHO defines anaemia during pregnancy as a decrease in hemoglobin (Hb) levels, < 11.0 g/dl in the first trimester, < 10.5 g/dl in the second trimester, and < 11.0 g/dl in the third trimester (Di Renzo et al., 2015). Evidence suggests that iron-deficient women have shorter pregnancy durations, preterm delivery, low birth weight (LBW) babies, and intrauterine growth retardation (IUGR) (Acheampong et al., 2018). According to a joint report from the United Nations Population Fund (UNFPA), WHO, United Nations Children's Fund (UNICEF), and the World Bank, over 800 women die daily from pregnancy complications and childbirth with 99% of these mortalities occurring in developing countries (WHO, 2019).

Ghana is among the West African nations that have implemented preventive iron and folate supplementation (IFAS) programmes to combat nutritional anaemia in pregnant mothers (Yip, 2002). Clinical trials have consistently documented the program's effectiveness (Ahamed et al., 2018; Karakoc et al., 2020; Milman, 2022). Anaemia prevalence is still unacceptably high, albeit in Ghana (Bhatnagar & Padilla-Zakour, 2021). According to the latest Ghana Demographic Health and Survey (GDHS) report in 2014, the prevalence of anaemia among pregnant women in Ghana was 42% (Ghana Statistical Service, 2014). Similarly, the 2017 Ghana Micronutrient survey reported an overall prevalence of anaemia among pregnant women to be 42%. The Ghana micronutrient survey further revealed some differences with respect to the prevalence of anaemia among pregnant women between the three main belts of Ghana – southern belt (50.8%), middle belt (32.1%), and northern belt (43.5%) (University of Ghana, GroundWork, Wisconsin-Madison, KEMRI-Wellcome Trust, UNICEF, 2017). Clearly, the two surveys conducted in 2014 and 2017 suggest that Ghana is not making any substantial progress in reducing the prevalence of anaemia among pregnant women. Among the several causes of anaemia, the WHO highlights that one of the non-nutritional determinants of anaemia among pregnant women is their poor nutritional knowledge levels (WHO, 2020). Hence, perhaps an efficient strategy that will be helpful prior to establishing objectives of any nutrition intervention is to assess knowledge, attitudes, and practices (KAP) of pregnant women before implementing any intervention (Stoltzfus and Dreyfuss, 1998). The body of knowledge regarding anaemia in Ghana, however, has been skewed toward its prevalence and risk factors among pregnant women, according to our evaluation of the literature on anaemia in pregnancy. Studies on the knowledge, attitudes, and practices regarding anaemia among pregnant women in Ghana are limited. The purpose of this study was to evaluate the KAP regarding anaemia among pregnant women who visit an antenatal clinic in the southern belt of Ghana.

Materials and Methods

Ethical statement

This study received approval from the University of Cape Coast Institutional Review Board (IRB) under approval number (UCCIRB/CHAS/2022/126). Permission was also sought from the health facility's administration prior to the commencement of the data collection. Study participants signed or thumb-printed an informed consent form prior to the commencement of data collection.

Study design

A cross-sectional descriptive study was employed to determine KAP of pregnant women regarding iron deficiency anaemia.

A total of 225 pregnant women who visited the antenatal clinic of University of Cape Coast Hospital during the study's data collection period were included in the study. Pregnant women between the ages of 15 and 49 years were included. The data collection process lasted for eight weeks (5th September, 2022 –28th October, 2022).

Study area

Cape Coast Metropolis is an urban area in the Central Region of Ghana, known for its rich history and cultural significance. It is a hub of education and tourism, featuring landmarks such as the Cape Coast Castle, a prominent historical site in the trans-Atlantic slave trade. The region is characterized by a mix of urban and rural landscapes, with a diverse population engaged in various economic activities, including fishing, tourism, and commerce. The metropolis has educational institutions ranging from primary to tertiary levels, including the University of Cape Coast. The population of Cape Coast according to the 2021 census data for the Cape Coast Metropolitan area is approximately 189,925. This represents an increase from the 169,894 recorded in the 2010 census.

Sampling procedure

The pregnant women chosen for the study were selected using a simple random sampling strategy at the time of the data collection period. A preliminary investigation had revealed that an average of 30 pregnant women visit University of Cape Coast Hospital on antenatal clinic (ANC) days. 20 participants were randomly selected through balloting on each of the ANC clinic days at University of Cape Coast Hospital until the required number of 225 was attained. Saturation was achieved in the last week of the data collection period; all antenatal patients that visited the health facility met the researchers and had earlier participated in the sampling process. For each of the clinic days, potential study participants who met the inclusion criteria were made to randomly pick from a box containing folded pieces of paper in which was written either "YES' or 'NO', the number of YESs were 20. The rest of the papers contained NO. Anyone who picked YES, and consented to take part in the research was recruited.

Research instrument

The United Nations' Food and Agriculture Organization questionnaire for assessing KAP on anaemia was used for the study (Fautsch Macas et al., 2014). Food choices in the original FAO KAP questionnaire to assess the knowledge of the participants were modified to meet Ghanaian food sources. Exotic foods not known in Ghana were eliminated. The research instrument was pretested with 15 study participants to check its validity. There were no changes made after the pretest of the questionnaire. The questionnaire comprises both open-ended and closed-ended questions. The questionnaire was composed of sections including sociodemographic information, knowledge, attitudes, and practices of pregnant women regarding iron deficiency anaemia. There were eight questions in the section of the questionnaire assessing the knowledge of pregnant women. The knowledge section included themes on awareness, consequences, causes, prevention of anaemia, and food sources of iron. A three-point Likert scale was used for the themes of 'perceived susceptibility', 'perceived severity', 'perceived benefits', and 'perceived barriers' to assess the attitudes of the pregnant women. The dietary practices section comprised four main questions. After the interviews, the questionnaires were checked for completeness at the end of the administration to ensure there were no missing data. The pretested, structured questionnaire was prepared and distributed in the English language.

Data analysis

Descriptive statistics tests were run using IBM SPSS Statistics version 26, and the results were summarized into frequencies and percentages. Chi-squared test was used to determine the relationship between categorical variables. Knowledge score criteria of 'know' and 'don't know' were used to grade the participants' knowledge regarding IDA. A participant was said to have knowledge of a question if she was able to give a correct answer to the question. The overall knowledge performance of the participants was computed by treating the knowledge responses as a continuous variable. Each correct response to a question was awarded a point, and the total sum of correct responses was found. A mean score value was then calculated for each participant by dividing the sum of correct responses by the total number of knowledge questions asked (eight questions). A mean value of knowledge score was found for all the study participants. Participants that scored a mean (knowledge) below the study population mean (knowledge) were classified as having 'poor knowledge', and those with a value higher than the study population mean (knowledge) were classified as having 'good knowledge'. Similarly, the attitudes of participants regarding IDA were assessed as a continuous variable. A positive response (a desired response) was given a point of three, a neutral two points, and a negative one point. The total score for each participant was summed and divided by the total attitude questions (four questions) to find a mean value. Each participant was then classified as having a positive, neutral, or negative attitude using the range for a three-point Likert scale, where the lower range was said to be a negative attitude and the highest range was a positive attitude. The attitudes of the participants' regarding IDA were classified

into positive, negative, and neutral categories. A thematic description of the participants' practices regarding IDA was employed. A p-value <0.05 was considered statistically significant at the 95% confidence level.

Results

Socio-demographic characteristics of participants

Socio-demographic characteristics on the study participants is presented in Table 1. The study included 225 pregnant women attending the antenatal clinic of University of Cape Coast Hospital. The average maternal age of the participants was 30.3 ± 5.0 years.

Table 1: Socio-demographic characteristics of study participants

Sociodemographic variable	Frequency (n)	Percentage (%)
Marital status		
Single	46	20.4
Married	167	74.2
Cohabiting	12	5.3
Occupation		
Working	188	83.6
Housewife	37	16.4
Educational level		
None	2	0.9
Primary	18	8
Secondary	97	43.1
Tertiary	108	48
Gravida		
First pregnancy	83	36.9
Second Pregnancy	63	28
Others	79	35.1
Gestational stage		
First trimester	33	14.7
Second trimester	72	32
Third trimester	120	53.3

Knowledge of participants regarding iron deficiency anaemia

The results of the knowledge of participants regarding iron deficiency anaemia (IDA) is presented in Table 2. Out of the 225 pregnant women that were asked if they have heard about IDA, the majority, 177 (78.7%), had heard about IDA. A greater proportion of participants, 173 (76.9%), had no idea on the consequences of IDA in infants and young children. The majority of participants, 206 (91.6%), did not know about foods that decrease iron absorption. Regarding the overall knowledge performance of the study participants, less than half of the participants, 101 (44.9%), were rated as having good knowledge.

Association between sociodemographic variables and overall knowledge performance

Table 3 presents results on the association between overall knowledge performance and sociodemographic characteristics of the participants. Chi-square analysis revealed there were significant associations between overall knowledge performance and educational level (X^2=40.849, p< 0.001), as well as gestational stage (X^2 = 9.764, p=0.008).

However, there was no significant association found between marital status, occupation, and gravida with overall knowledge performance.

Table 2: Knowledge of study participants regarding iron deficiency anaemia (IDA)

Question	Frequency (n)	Percentage (%)
Have you heard about IDA?		
Yes	177	78.7
No	21	9.3
Don't know	23	10.2
Signs and symptoms of IDA		
Knows	130	57.8
Don't know	95	42.2
Consequences of IDA for infants and young children		
Knows	50	22.2
Don't know	173	76.9
Consequences of IDA for pregnant women		
Knows	68	30.2
Don't know	157	69.8
Causes of IDA		
Knows	119	52.9
Don't know	106	47.1
Prevention of IDA		
Knows	124	55.1
Don't know	101	44.9
Iron-rich foods		
Knows	158	70.2
Don't know	67	29.8
Foods that increase iron absorption		
Knows	29	12.9
Foods that decrease iron absorption		
Knows	19	8.4
Don't know	206	91.6
Overall knowledge performance		
Good	101	44.9
Poor	124	55.1
N=225; Note. IDA represents iron deficiency anaemia		

Attitudes of study participants regarding iron deficiency anaemia (IDA)

Results of the attitudes of the pregnant women regarding IDA are presented in Table 4. It highlights results from the perceived susceptibility, severity, benefit and barriers to anaemia. A significant proportion of the participants (42.2%) reported that they were likely to be anemic. Majority of the participants (82.2%) reported that anaemia was a serious condition. Out of the 225 participants, majority (78.2%) reported that it was good to prepare meals with iron rich foods. Overall, a greater proportion of the study participants (90.3%) had a positive attitude towards anaemia.

Practices of study participants regarding IDA

Results of the practices of pregnant women are present in Table 5. Regarding consumption of vitamin C rich foods, majority (96.4%) of the participants reported to have been consuming vitamin C rich foods.

Association between overall knowledge performance and attitude of study participants

The association between the overall knowledge performance and attitude of the study participants was investigated. Chi-square analysis revealed there was significant association between the overall knowledge and attitudes of the pregnant women regarding anaemia (X^2 =11.791,p=0.003). Table 6 presents the results of the association between knowledge and attitude of pregnant women.

Discussion

Anaemia in pregnancy remains a public health problem in developing countries. Our research study assessed the knowledge, attitudes, and practices of pregnant women towards iron deficiency anaemia (IDA). Regarding the overall knowledge performance of the study participants, a greater proportion (55.1%) had poor knowledge on iron deficiency anaemia. Results from our study agree with a similar study in Saudi Arabia, where a greater proportion (66.7%) of pregnant women involved were found to have poor knowledge regarding iron deficiency anaemia (Aboud et al., 2019). Also, findings in our study support those of Ahamed et al. (2018), who found that a majority (60%) of participants in Egypt had poor knowledge regarding iron deficiency anaemia. Our study's results are also in agreement with those reported by Jayanthigopal and Demisie (2018) in Ethiopia. Furthermore, a study in Iraq also reported insufficient knowledge among pregnant women (Alabedi et al., 2020).

In our study, with respect to participants' awareness of IDA, most of them had heard about IDA (78.7%). The participants' awareness level towards IDA in our study is, however, lower compared to a similar study done in Ethiopia (Oumer & Hussein, 2019). The level of IDA awareness in our study is higher than what was recorded in a similar study in India. The awareness of IDA in that study was 39.9% (Nivedita & Shanthini, 2015). The awareness of pregnant women about IDA can influence their attitude and practices towards IDA (Adznam et al., 2018).

Our study found that the educational status and gestational features of the participants were significantly associated with their overall knowledge performance. This may be a contributing factor to anaemia in pregnancy based on the assumption that sociodemographic factors of pregnant women make them more vulnerable to anaemia than the general population. A similar study that examined the association between the knowledge of pregnant women and anaemia found that the knowledge score was positively correlated with blood hemoglobin (R = 0.23, p<0.05) (Zhang & Rojhani, 2018). The knowledge score was also a predictor of blood hemoglobin levels (R = 0.364, P = 0.02) (Zhang & Rojhani, 2018). Sociodemographic characteristics of pregnant women were also significantly associated with knowledge and practice regarding anaemia in another similar study done in Ethiopia (Jayanthigopal and Demisie, 2018). A statistically significant association between knowledge score and marital status, educational level, and occupation of participants was also observed in Baghdad,

Table 3: Association between sociodemographic variables and overall knowledge performance regarding anaemia of study participants.

Sociodemographic variable	Overall knowledge performance			
	Good, n (%)	Poor, n (%)	X^2	p-value
Marital status				
Single	17 (16.8)	29 (23.4)	1.615	0.446
Married	79 (78.2)	88 (71)		
Cohabiting	5 (5)	7 (5.6)		
Occupation				
Working	86 (85.1)	102 (82.3)	0.338	0.561
Housewife	15 (14.9)	22 (17.7)		
Gestational stage				
First trimester	8 (7.9)	25 (20.2)	9.764	0.008
Second trimester	29 (28.7)	43 (34.7)		
Third trimester	64 (63.4)	56 (45.2)		
Educational level				
No formal education	1 (1)	1 (0.8)	40.849	0
Primary	3 (3)	15 (12.1)		
Secondary	25 (24.8)	72 (58.1)		
Tertiary	72 (71.3)	36 (29)		
Gravida				
First pregnancy	36 (35.6)	47 (37.9)	1.275	0.529
Second pregnancy	32 (31.7)	31 (25)		
Third pregnancy or above	33 (32.7)	46 (37.1)		

Table 4: Attitudes of study participants towards iron deficiency anaemia, N=225

Question	Frequency (n)	Percentage (%)
Perceived susceptibility		
Likely	95	42.2
Not likely	81	36.0
Not sure	49	21.8
Perceived severity		
Serious	185	82.2
Not serious	3	1.3
Not sure	37	16.4
Perceived benefits		
Good	176	78.2
Not good	11	4.9
Not sure	38	16.9
Perceived barriers		
Difficult	10	4.4
Not difficult	194	86.2
Not sure	21	9.3

Table 5: Practices of study participants towards iron deficiency anaemia, N=225

Question	Frequency (n)	Percentage (%)
Consumption of Vitamin C rich foods		
Yes	217	96.4
No	8	3.6
Frequency of consumption of Vitamin C rich foods		
Daily	111	49.3
Twice weekly	91	40.4
Monthly	9	4
Twice monthly	6	2.7
Consumption of Coffee/Tea		
Yes	78	34.7
No	146	64.9
Timing of Coffee/Tea intake		
2hrs or more before meal	19	8.4
Right after meal	44	19.6
Right before meal	16	7.1
2hrs or more after meal	1	0.4
Intake of locally made drinks to prevent/manage anaemia		
Yes	111	49.3
No	114	50.7
Consumption of Pica		
Yes	41	18.2
No	184	81.8
Frequency of Pica consumption		
Daily	9	4
Twice weekly	16	7.1
Monthly	13	5.8
Twice Monthly	1	0.4

Iraq (Al-Sattam et al., 2022). The sociodemographic characteristics of pregnant women may influence their knowledge regarding anaemia.

The overall attitude of the pregnant women in this present study was good and satisfactory. However, their attitudes did not reflect their knowledge as 44.9% of the participants had good knowledge on iron deficiency anaemia. This is however in contrast to a similar study reporting there was a negative attitude and practices among pregnant women in Lahore (Habib et al., 2018). The attitude of the pregnant women in this present study agrees with a positive attitude to IDA found in Saudi Arabia and Egypt (Aboud et al., 2019; Ahamed et al., 2018). Less than 43% of the participants perceived that they were likely to become anemic. This

Table 6: Association between knowledge and attitude of study participants

	Attitude performance			X^2	P-value
	Positive	Neutral	Negative		
Overall knowledge performance					
Good , n (%)	99 (98)	2 (2)	0 (0)	11.791	0.003
Poor, n (%)	105 (84.7)	17 (13.7)	2 (1.6)		

compares lower to 53.8% of participants perceiving that they were more vulnerable to anaemia in a study conducted in India (Nivedita & Shanthini, 2015). Their perception of susceptibility to IDA was based on religious reasons in that the condition was not a good condition and hence they would not wish to say they are susceptible to it. Others were also of the view that they consumed healthy meals and hence cannot become anemic. This is in contrast to the scientific fact that dietary intake of iron is not sufficient to prevent anaemia in pregnancy because of the significant increase in demand. Hence the use of iron supplements (Skolmowska et al., 2022).

Regarding the study participants' practices, nearly 96% of them consumed vitamin C-rich foods. Vitamin C has been well established to enhance the absorption of nonheme iron (Wallace, 2016). However, about half (49.4%) of those who reported consuming vitamin C-rich foods consumed them daily. About half (49.3%) of the pregnant women in this present study reported the practice of using locally made drinks such as turkey berry juice in combination with milk to manage and prevent anaemia. This practice is contrary to the scientific principle of iron absorption. Milk is a poor source of iron and also contains substances such as calcium and casein that can inhibit iron absorption (Milman, 2020). This study has the drawback of not being an exploratory study but a descriptive cross-sectional study. It also employs a single-study design. We recommend conducting exploratory studies and employing triangulation to examine the factors that influence expectant mothers' knowledge, attitudes, and practices regarding anaemia in this region.

Recommendations

Results from our study suggest that knowledge level is below the FAO reference recommendation of 70%, and therefore a nutrition strategy may be necessary. In the propagation of educational messages, effort should be made to improve knowledge regarding iron deficiency anaemia. As part of an integrative health care delivery, a Registered Dietitian /Nutritionist should be involved in the antenatal care delivery to enable appropriate communication of nutrition-related issues related to iron deficiency anaemia (IDA).

Conclusion

The findings from this study suggest there is a knowledge deficit among pregnant women. The positive attitudes of the study participants regarding anaemia may not translate into their knowledge concerning a health situation.

Abbreviations

SSA: Sub-Saharan African; CDC: Centers for Disease Control and Prevention; WHO: World Health Organization; GDHS: Ghana Demographic Health and Survey; Hb: Hemoglobin; LBW: Low-Birth Weight; IUGR: Intrauterine Growth Retardation; UNFPA: United Nations Population Fund; UNICEF; United Nations Children's Fund; IFAS: Iron and Folic Acid Supplementation; KAP: Knowledge, Attitudes and Practices; IDA: Iron Deficiency Anaemia; FAO: Food and Agriculture Organization.

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REVIEW ARTICLE

Safety Culture and Patient Safety Outcomes in Developing Countries: A Narrative Review

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Abstract

Background: The effects of medical errors on patients are increasingly becoming a public concern. It is estimated that 10% and 20% of persons receiving healthcare in developed and developing economies, respectively, are harmed, but a majority of these errors are preventable.

Objective: The purpose of this paper is to summarise the current literature on the level of patient safety culture awareness and practice, predictors of patient safety culture, and the link between patient safety culture and patient outcomes in developing countries.

Materials and methods: A systematic search for literature from the following data bases, ScienceDirect, PubMed, JSTOR, ProQuest, Taylor & Francis Online, and Emerald Insight was carried out. Consistent with the inclusion criteria and study objectives, 23 published articles were included in this review.

Results: We found that patient safety culture awareness and practice in developing countries is low and still evolving. High predictors of patient safety culture include teamwork, communication, work environment and provider job satisfaction. Low predictors include a non-punitive response to errors, handoffs, transitions and transfers, staffing, and blameless reporting systems. We found that improved patient safety culture results in better patient outcomes. However, there is limited evidence on patient safety culture and patient outcomes in African countries, which hinder evidence-based practice aimed at promoting better health outcomes of patients.

Conclusion: Stakeholders must ensure enhanced medical data collection and preservation of comprehensive incidence reporting systems and strategies to improve patient safety and health outcomes.

Keywords: Safety Culture, Patient Safety Outcomes, Developing Countries, Narrative Review

Introduction

The motivation to improve the healthcare systems is because of the unnecessary patient injury and deaths resulting from preventable medical errors (Sameera et al., 2021; Slawomirski et al., 2017). Evidence suggests that medical errors are increasingly becoming an issue of global public health concern as they account for significant deaths. The World Health Organization (WHO, 2019) reported medical errors as the 14th cause of morbidity and mortality globally. Statistics show that at least one out of every 10 persons receiving healthcare is harmed in the developed world, but the figure is double in the developing countries (WHO, 2019). For instance, medical errors account for about 440,000 deaths annually in the United States of America (USA) alone (James, 2013;

Mohajan & Mohajan, 2018). Again, estimate indicates that medical errors account for 2.6 million deaths annually in low-and middle-income countries (LMICs) alone (WHO, 2019). Similarly, a study by Wilson et al. (2012) in eight developing countries revealed that 8.2% of patients receiving healthcare experienced at least one adverse effect. With a range of 2.5% to 18.4% per country, 83% of these adverse effects are preventable, with 30% resulting in patient death (Wilson et al., 2012). Notably, all these errors occur at various stages of healthcare delivery.

Ensuring the highest level of patient safety remains a priority for every healthcare system. However, despite considerable investments in enhancing client safety, patients still suffer preventable harms while receiving healthcare (Slawomirski et al., 2017). Studies show that to achieve a safe healthcare climate, healthcare organisations must establish and

practice a patient safety culture that views medical errors as challenging (Kohn et al., 2000; Rodziewicz et al., 2021). Moreover, every health professional should understand this culture well, that should be characterised by mutual trust and shared values among the professionals (Groves, 2014; O'Donovan et al., 2019). Patient safety culture refers to how patient safety is perceived, planned, and executed in a healthcare facility (Wilson et al., 2012). Thus, positive patient safety culture permits clinical or medical staff to reduce medical errors, learn from past mistakes and devote themselves to safer care delivery (Wu et al., 2022). It is evident that healthcare staff with positive attitudes toward patient safety culture contribute greatly to creating a safe atmosphere that is devoid of errors and promote patient-oriented services (O'Donovan et al., 2019).

Although uncovering medical errors can be challenging (Rodziewicz et al., 2021), it is believed that the opinions of individuals and societies are changing from accepting and normalising medical errors to demanding healthcare safety and accuracy of care. This change requires improving the understanding of patient safety culture and its effects on patient outcomes at all stages of healthcare delivery and among all cadres of care providers (Dicuccio, 2015). For instance, evidence suggests that it is critical for health professionals and patient safety researchers to collaborate with their counterparts in developing countries to share expertise and experiences to enhance their understanding of patient safety and healthcare quality (Harrison et al., 2015). A systematic review conducted in the United Kingdom concluded that "there is work to be done concerning the study of patient safety culture and its connection to patient outcomes" (Dicuccio, 2015, pp 142). Therefore, the current narrative review summarises literature between 2005 to 2022 to evaluate the state of research in developing countries on patient safety culture and patient outcomes. Narrative reviews are helpful in understanding and describing complex issues of interest (Greenhalgh & Papoutsi, 2018).

Therefore, the purpose of this paper is to summarise the current literature regarding the level of patient safety culture awareness and practice, the predictors of patient safety culture, and the relationships between patient safety culture and patient outcomes. The evidence gathered in this review contributes to a better understanding of patient safety culture in healthcare, with practical implications for enhancing the quality of care to improving patient outcomes.

Methods

Search strategy

This An initial literature search was carried out in Science Direct, PubMed, Emerald Insight, and JSTOR using phrases such as 'patient safety culture' OR 'patient safety' OR 'safety culture', patient outcomes' OR 'patient safety outcomes' OR 'medical errors.' We searched reference lists for systematic reviews conducted in developing countries to find relevant studies. Studies related to patient safety culture or patient outcomes, conducted within the healthcare settings in any developing country from January 2005 to May 2022 and published in English, were included. However, studies conducted in developed countries and in languages other than English before 2005 or outside the healthcare setting were excluded. Again, studies that did not focus on patient safety, safety culture, and patient outcomes were excluded from this study. Based on the above criteria, 23 studies were included in this study. See Table 1 for a detailed search strategy.

Narrative Review Approach

In this study, a systematic approach was undertaken for data extraction and analysis, employing the narrative synthesis method as outlined by Popay and colleagues (2006). To begin, papers of interest were meticulously identified, focusing on those directly aligned with the study's objectives related to patient safety culture awareness, practice, predictors, and outcomes. Subsequently, a thoughtful categorisation of these selected papers was conducted, systematically organising them into coherent and meaningful themes or groups. This categorisation not only streamlined the data but also served as a foundation

Table 1: Search strategy

Search strategy item	Search strategy
Databases	PubMed; JSTOR; ScienceDirect; ProQuest; NBCI; Emerald Insight; Taylor & Francis Online; Google scholar; and Google
Language filter	English
Time filter	2005-2022
Spatial filter	Developing Countries
Keywords	"patient culture" OR "patient safety culture" OR "safety culture" "patient outcomes" OR "patient safety outcomes" OR "patient satisfaction" OR "patient safety" "adverse effects" OR "medical errors" OR "patient harm" "impact" OR "fatalities" OR "deaths" OR "effects" "low-middle income countries" OR "developing countries"
Inclusion criteria	1. Published literature on developing countries; 2. grey literature on developing countries; publications between 2005 – 2022 in developing countries; and 3. literature must provide methodology, population, study setting (health setting), be on patient safety culture and or patient outcomes.
Exclusion criteria	1. News reports; 2. studies before 2005; 3. Conduct on developed countries; 4. either methodology, population, study setting not provided or conducted outside the health setting.

for in-depth analysis. The analysis phase involved a comprehensive exploration of the findings within each category, delving into the interconnections within the data, and identifying potential sources of variation among the studies. This iterative process culminated in the organisation of the data into overarching themes, contributing to a holistic understanding of patient safety culture in healthcare contexts.

Findings

Twenty-three published articles are included in this review (see Figure 1). The majority of the studies used a cross-sectional descriptive design. Predominantly, primary data was collected using the Hospital Survey on Patient Safety Culture (HSOPSC) or other similar forms of questionnaires. The studies were conducted in healthcare settings, and participants were mostly healthcare workers, clinical or administrative or both. See Table 2 for the details (At the end .

The findings indicate that the majority of the studies focused on the determinants of patient safety culture, with only three studies investigating relationships between patient culture and patient outcomes. We presented the findings under level of patience safety culture awareness and practice, predictors of patient safety culture and patient health outcomes.

Level of Patience safety culture awareness/practice

Some studies reported a high level of patient safety culture awareness with corresponding levels of practice (Hellings et al., 2010; Öhrn et al., 2011; Webair et al., 2015). However, most studies recorded low levels of awareness and low practice of patient safety culture (Ammouri et al., 2015; Elsheikh et al., 2017; Garuma et al., 2020; Hellings et al., 2007; Nourmoradi et al., 2015; Prates et al., 2021). Other studies, however, did not assess or report the level of patient safety culture awareness or practice (Abdallah et al., 2019; Dirik, 2017; El-Jardali et al., 2012; Lee et al., 2015).

Predictors of Patient Safety Culture

Hospital Survey on Patient Safety Culture (used for most of the studies in this review) is used to design, implement, and evaluate patient safety programmes (Palmieri et al., 2020; Sorra, 2004). The tool highlights patient safety, error and error reporting rate. It has 42 items grouped into 12 composite measures. This survey requires respondents to provide an overall grade on patient safety for their work area and to indicate the number of incidents they reported over the previous 12 months (Sorra et al., 2018). See Table 3 below for the 12 patient safety culture composites and their definitions.

The overall rating of patient safety culture is classified as positive and negative, based on the participants' average percentage of positive responses in each study. High predictors in the current review are the composite factors that significantly enhance patient safety culture in the organisation. In contrast, the low predictors are those factors that got a lower percentage of positive ratings from participants. Thus, these factors need to be improved to ensure a positive culture in the healthcare facilities. Some high predictors identified across studies were teamwork
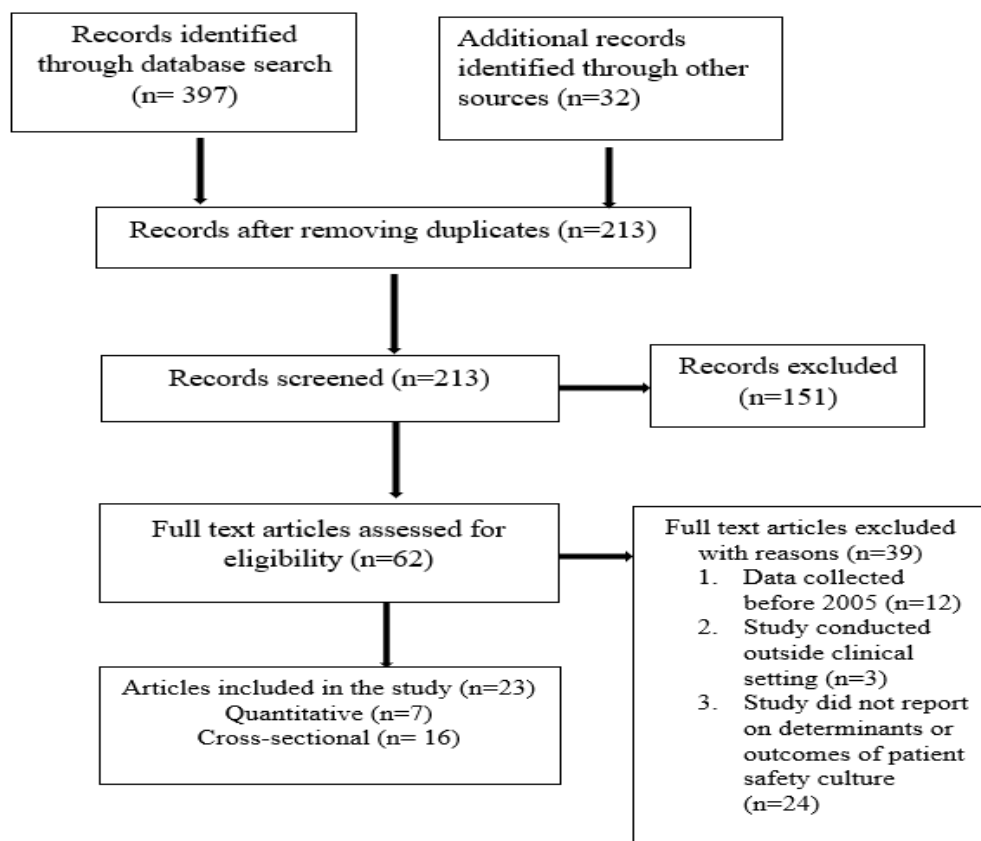
Figure 1: Flow chart of the record screening process

Table 2: Summary of Studies Included (n = 23)

Author/year/ Country	Purpose	Methodology/ Design	Population/sample	Level of PSC awareness/ practice	Predictors (Highest contributors)	Predictors (Lowest contributors)	Patient Safety outcomes
(Webair et al., 2015)/ Yemen	To provide a baseline assessment of patient safety culture in primary care settings in Al-Mukala, Yemen as a first published study from a least developed country.	Quantitative/ Survey	Staff of primary healthcare centres and units in Al-Mukala District. 71 physicians, nurses, medical assistants, midwives, and non-clinical staff (non-care providers)	Positive (High)	'Communication openness', 'Work pressure and pace' and 'Patient care tracking/follow-up';	Under reporting errors, non-punitive response to error	positive rating on quality and patient safety were low
(Nourmoradi et al., 2015)/Iran	To assess Patient safety culture in four educational hospitals in Ilam city, Iran.	Cross-sectional study.	Four educational hospitals (Imam Khomeini, Mustafa Khomeini, Taleghani and Kowsar hospitals) in Ilam city. A total of 104 persons in different wards of the hospitals including physicians, nurses, midwives, and paramedics (radiology and laboratory staff) participated	Negative (low)	Teamwork within units	non-punitive response to error	
(Ammouri, Tailakh, Muliira, Geethakrishnan, & Al Kindi, 2015)/ Oman	To investigate nurses' perceptions about patient safety culture and to identify the factors that need to be emphasised to develop and maintain the culture of safety among nurses in Oman	Cross-sectional design	All nurses were working full time in four major governmental hospitals in Muscat. (Responses were received from 414 participants)	Negative (low)	teamwork within units, organisational learning and continuous improvement, feedback and communications about error	non-punitive response to error, hospital management support and staffing	
(El-Jardali et al., 2012)/Lebanon	To assess hospitals' readiness to integrate patient safety standards into routine practice	Cross-sectional study	6807 respondents from 68 hospitals in Lebanon		Staff education and training		
(Garuma et al., 2020)/Ethiopia	To assess the patient-safety culture and associated factors among healthcare workers in public hospitals of East Wollega Zone, western Ethiopia	Cross-sectional study	421 healthcare workers selected from public hospitals of East Wollega Zone, western Ethiopia using simple random sampling	Negative (low)	Teamwork within hospital units	Non-punitive responses to error. blameless event-reporting systems, appropriate staffing, and management support to patient-safety initiatives. risk free hospital handoffs and transitions	

(Hellings et al., 2007)/Belgium	To measure patient safety culture in five Belgian general hospitals.	Quantitative	3,940 individuals responded: 2,813 nurses and assistants, 462 physicians, 397 physiotherapists, laboratory and radiology assistants, social workers and 64 pharmacists and pharmacy assistants.	Negative (low)	teamwork within hospital units,	hospital management support for patient safety, non-punitive response to error, hospital transfers and transitions, staffing,	
(Prates et al., 2021)/ Brazil	To assess the patient safety culture perceived by healthcare and administrative staff in a Brazilian hospital and examine whether education and experience are related to positive perceptions	A descriptive-analytical case study	618 participants, of whom 315 worked in healthcare assistance and 303 in administrative services	Negative (low)	Hospital management support for patient safety	Non-punitive response to error	
(Abedi et al., 2019)/ Iran	To investigate the relationship between patients' safety, medical errors and patients' safety rights with patients' security feeling in selected hospitals of Mazandaran Province, Iran	descriptive cross-sectional study	1,083 patients were randomly selected for the study				patients' safety, medical errors and patients' rights have significant effects on patients' security feeling simultaneously. patients' safety leads to the avoidance of error and a feeling of peace and security for them
(Abdallah et al., 2019)/Kuwait	To explore the relationship between organisational learning and patient safety culture in hospital pharmacy settings and to explore how dimensions of organisational learning relate to dimensions of pharmacy patient safety culture.	Cross-sectional study	from three public hospital pharmacies and three private hospital pharmacies in Kuwait. 272 different categories of pharmacy staff completed surveys		Training (TRN), management that reinforces learning (MRL) and supportive learning environment (SLE)		

(Hellings et al., 2010)/Belgium	To describe a patient safety culture improvement approach in five Belgian hospitals.	Quantitative	3,940 and 3,626 individuals responded respectively to the first and second surveys	Positive (high)	teamwork within hospital units, supervisor expectations and actions promoting safety	hospital transfers and transitions, non-punitive response to error, and staffing	
(Elsheikh et al., 2017)/Saudi Arabia	To measure patient safety culture to improve its perception, reaction, and implementation, leading to improvement in care delivery.	Quantitative survey	The total population surveyed was 623: 336 nurses, 174 physicians, 9 pharmacists, and 104 technicians	Negative (low)		Staffing and Non-Punitive response to error"	
(Öhrn et al., 2011)/Sweden	To evaluate the results and changes after 5 years of the Patient Safety Dialogue in 50 departments (37 medical and 13 psychiatric) in 3 hospitals	Quantitative		Positive (high)			improved their patient safety culture maturity in the areas of hospital-acquired infections, outcome measurements, and general patient safety.
(Lee et al.,2015)/Taiwan	To improve and develop better strategies regarding patient safety in healthcare organisations.	Quantitative			teamwork climate, safety climate, job satisfaction, stress recognition and working conditions	perceptions of management and hospital handoffs and transitions	
(Dirik, 2017)/Turkey	To investigate further the relationships between these three variables.	cross-sectional descriptive	274 nurse participants working in a university hospital located in Izmir (Turkey).		work environment, Support for optimal patient care, 'nurse/physician relationships' and 'staff involvement in organisational affairs		

Table 3: Organization of Themes: Predictors of Patient Safety Culture

Major Themes	Sub-Themes	Authors
High Predictors	Teamwork	Ammouri et al., 2015; Garuma et al., 2020; Hellings et al., 2007, 2010; Lee et al., 2015; Nourmoradi et al., 2015
	Communication	Ammouri et al., 2015; El-jardali et al., 2011; Webair et al., 2015
	Work environment/job satisfaction	Abdallah et al., 2019; Dirik, 2017; Lee et al., 2015; Webair et al., 2015
	Training/Learning	Abdallah et al., 2019; Ammouri et al., 2015; El-Jardali et al., 2012
	Management Support	Abdallah et al., 2019; El-jardali et al., 2011; Prates et al., 2021
Low Predictors	Handoffs/Transitions/Transfers	Garuma et al., 2020; Hellings et al., 2007, 2010; Lee et al., 2015
	Non-punitive response to error	Ammouri et al., 2015; Elsheikh et al., 2017; Hellings et al., 2010; Nourmoradi et al., 2015; Prates et al., 2021; Webair et al., 2015
	Poor leadership	
	Poor Management support	Ammouri et al., 2015; Garuma et al., 2020; Hellings et al., 2007; Lee et al., 2015
	Staffing	Ammouri et al., 2015; Elsheikh et al., 2017; Garuma et al., 2020; Hellings et al., 2007, 2010
	Event reporting systems	El-Jardali et al., 2012; Garuma et al., 2020; Webair et al., 2015

(Ammouri et al., 2015; Garuma et al., 2020; Hellings et al., 2007, 2010; Lee et al., 2015; Nourmoradi et al., 2015), communication (Ammouri et al., 2015; El-jardali et al., 2011; Webair et al., 2015) work environment and provider job satisfaction (Abdallah et al., 2019; Dirik, 2017; Lee et al., 2015; Webair et al., 2015), staff training, information sharing and learning (Abdallah et al., 2019; Ammouri et al., 2015; El-Jardali et al., 2012) and management support for safety culture (Abdallah et al., 2019; El-jardali et al., 2011; Prates et al., 2021).

We also identified low predictors of safety culture, which include a non-punitive response to errors (Ammouri et al., 2015; Elsheikh et al., 2017; Hellings et al., 2010; Nourmoradi et al., 2015; Prates et al., 2021; Webair et al., 2015), handoffs, transitions and transfers (Garuma et al., 2020; Hellings et al., 2007, 2010; Lee et al., 2015), and staffing (Ammouri et al., 2015; Elsheikh et al., 2017; Garuma et al., 2020; Hellings et al., 2007, 2010).

Patient Safety Outcomes

Evidence suggests that improved patient safety culture reduces hospital-acquired infections, the occurrence of medical errors and improves general patient safety (Öhrn et al., 2011). It was further evident that positive patient safety culture increases patients' feeling of peace and security while preserving patients' rights (Abedi et al., 2019), culminating into overall patient health outcomes.

Table 3 presents results on the association between overall knowledge performance and sociodemographic characteristics of the participants. Chi-square analysis revealed there were significant associations between overall knowledge performance and educational level (X^2=40.849, p< 0.001), as well as gestational stage (X^2 = 9.764, p=0.008). However, there was no significant association found between marital status, occupation, and gravida with overall knowledge performance.

Discussion

An The strength of the patient safety culture of any healthcare organisation does not only affect patient outcomes, its equally affects the professionals working within the organisation and the overall image of the organisation (Sorra & Nieva, 2004). The findings from the current review indicate that patient safety culture is grey and evolving (even in research) in developing nations. This confirms that healthcare systems in developing countries are far from achieving effective patient safety culture (Farokhzadian et al., 2018). Although there has been an increased interest in patient safety culture research over the past few years (Dicuccio, 2015), most of the articles included in this study were baseline studies from developing countries. Some of the studies were baseline assessments of safety culture (Nourmoradi et al., 2015; Webair et al., 2015), and others explored the perceptions of various cadre of healthcare professionals about patient safety culture (Ammouri et al., 2015; Elsheikh et al., 2017; Garuma et al., 2020; Prates et al., 2021). Contrary to this, research from developed countries have moved from baseline to evaluation of improvement strategies and interventions that aimed at improving patients' safety and associated health outcomes (Garuma et al., 2020; Webair et al., 2015).

Level of patients' safety culture awareness and practice in developing countries

The review reveals a consistent pattern across the studies, indicating that the reported level of awareness of patient safety culture and corresponding practice among healthcare professionals tends to be relatively low. This finding underscores the complexity of implementing strategies to enhance patient safety culture within the healthcare system. Several critical challenges surface, including inadequate administrative infrastructure, ineffective leadership, and a lack of concerted efforts to align healthcare practices with national and international standards. Furthermore, the prevalence of deeply ingrained values that may not prioritize team participation poses significant obstacles to developing an effective culture of patient safety (Farokhzadian et al., 2018). Moreover, it is evident that many developing countries face additional challenge of not having comprehensive national standards and policies specifically tailored to patient safety culture (Prates et al., 2021). The absence of such foundational guidelines can hinder proactive actions to enhance patient safety.

On the other hand, the review highlights a contrasting situation in high-income countries, where healthcare professionals generally exhibit a higher level of awareness, understanding, and practice when it comes to patient safety culture (Farokhzadian et al., 2018). However, it is essential to note that these countries also report higher levels of medical errors or adverse events. This paradox can be attributed to the presence of more robust incidence reporting systems and a greater motivation among healthcare professionals to accurately report incidents when they occur. In essence, these reporting systems serve not only to provide accurate data but also to serve as valuable tools for training and developing interventions that address the challenges posed by medical errors within the healthcare system (Garuma et al., 2020). Consequently, the review underscores the pressing need for developing countries to establish similar incident reporting systems and prioritise patient safety culture within their healthcare systems. By doing so, they do not only generate accurate data but also enhance training and intervention strategies to mitigate medical errors, ultimately improving patient safety and promoting better health outcomes.

Predictors of patient safety culture in developing countries

Numerous studies have identified a range of predictors that influence patient safety culture within healthcare settings. These include critical factors such as teamwork, management support for patient safety culture, leadership, communication, staffing levels, job satisfaction, training and learning opportunities, effectiveness of handoffs, transitions, and transfers, the presence of robust reporting systems, and a non-punitive response to errors (El-jardali et al., 2011; Garuma et al., 2020; Hellings et al., 2007, 2010; Nourmoradi et al., 2015; Prates et al., 2021; Webair et al., 2015). However, it is essential to recognise that the influence of these predictors can vary significantly across different healthcare settings. Consequently, measurement and assessment of patient safety culture must be conducted at the unit level, consistently using a common standardized measurement. For instance, findings reveal that units dealing with a higher volume of active cases and elderly patients may exhibit lower patient safety culture scores (Huang et al., 2010). Similarly, larger units with lower staff turnovers may experience more medical errors (Dodek et al., 2012). Furthermore, the dynamics of teamwork can differ between individual units within the same healthcare facility, indicating that patient safety culture comprises distinct subcultures (El-jardali et al., 2011). Therefore, improving patient safety culture requires a multifaceted approach that considers the unique dynamics within each unit.

While acknowledging the significance of unit-level assessment, it is essential for healthcare systems to recognise broader factors that influence the quality of healthcare delivery in their unique contexts. For instance, a study conducted in Nigeria by Okafor and colleagues (2018) found that patient satisfaction, while excellent, exhibited no significant relationship with patient safety culture. Other factors, such as the patient-provider relationship and the cost-effectiveness of services, appeared to be more influential in this regard. Additionally, within some

healthcare systems, a culture of blame persists, making healthcare professionals reluctant to report medical errors or adverse events (Mohajan & Mohajan, 2018; Singer & Vogus, 2013). In contrast, research in developed countries has increasingly focused on enhancing individual predictors to align with desired health outcomes. Therefore, healthcare systems in developing countries must intensify their efforts to elevate patient safety culture into action-driven practices that ultimately lead to improved patient outcomes.

Patient safety outcomes

In the context of developing countries, there is a notable scarcity of literature examining the correlation between patient safety culture and patient outcomes. Specifically, research in these regions has been limited in exploring correlations such as patient experience, medication errors, and patient mortality (Chang & Mark, 2011; Gearhart, 2010; Hofmann & Mark, 2006; Mark et al., 2008; Sorra et al., 2012). This paucity of studies may be attributed to the challenges associated with reporting medical errors within developing healthcare systems, where healthcare professionals and institutions may be inclined to conceal adverse incidents (Elmontsri et al., 2017). The reluctance to report errors often stems from fears of blame and potential legal repercussions, as highlighted in a systematic review on the status of safety culture in Arab countries (Elmontsri et al., 2017). This culture of underreporting poses significant barriers to understanding the relationship between patient safety culture incidents and their impact on patient health outcomes. Nonetheless, it remains crucial to establish these links to inform the development of effective organisational interventions tailored to the unique challenges faced in developing healthcare systems.

Limitations

While a narrative review approach allows for subjectivity in selecting articles, it does introduce the potential for selection bias. To mitigate this bias, we established clear inclusion and exclusion criteria at the outset of the review process. However, it is worth noting that by focusing solely on published literature, we may have inadvertently overlooked relevant unpublished and non-empirical perspectives. Additionally, the use of varying terminology across different databases may have limited the comprehensiveness of our search results. Therefore, standardising terminologies in the field is essential to ensure uniformity in future research. Furthermore, the assessment of data related to patient safety culture and patient outcomes presents challenges, often stemming from inadequate or incomplete medical data. For instance, healthcare professionals' reluctance to report adverse incidents due to fear of blame can result in inaccurate prevalence data in the literature (El-Jardali et al., 2012; Garuma et al., 2020; Webair et al., 2015).

Policy and Research Implications

The findings underscore the need for healthcare organisations to take a comprehensive approach to patient safety culture. This involves recognising that patient safety culture is not a one-size-fits-all concept but comprises diverse subcultures at the unit level. Healthcare leaders

must prioritise initiatives that promote teamwork, effective leadership, open communication, and robust reporting systems tailored to the specific needs of individual units. Additionally, fostering a culture of blame-free reporting and accountability is essential to encourage healthcare professionals to report errors and adverse events transparently. Moreover, healthcare systems in developing countries should consider the broader factors influencing patient safety, such as the patient-provider relationship and cost-effectiveness, and develop strategies that align with their unique contexts. Ultimately, the goal is to transform patient safety culture into tangible improvements in healthcare quality for patient outcomes.

Furthermore, our findings hold significant implications for developing countries where patient safety culture is in its infancy. While these nations have much to learn from developed countries, there is an opportunity for collaborative knowledge-sharing to bridge the existing gap. Extensive research has been instrumental in enhancing healthcare quality and safety globally, motivating governments in developed nations to invest in interventions that reduce medical errors and improve patient satisfaction. Therefore, it is imperative for policymakers and governments in developing countries to recognise the potential risks within their healthcare systems and invest in systematic research to identify unique patient safety challenges. To facilitate this, they should prioritise the establishment of efficient patient data collection systems, empower healthcare professionals to utilize incident reporting systems, and foster a positive patient safety culture. Moreover, collaborative efforts between healthcare researchers in developing and developed countries can help explore the intricate relationship between safety culture and patient outcomes, leading to the development of context-specific evidence-based interventions and the assessment of their long-term effectiveness.

Conclusion

Research on patient safety culture and patient outcomes in developing countries is still a grey area with a huge gap. This review observed that understanding of patient safety culture is low among healthcare professionals, and issues of adverse effects from medical errors are still a challenge in developing countries. Therefore, stakeholders must ensure that enhanced medical data collection and preservation, comprehensive incidence reporting systems are created, and strategies to improve patient safety culture are implemented and measured regularly to ensure efficiency. Finally, sharing knowledge and best practices through collaborative research between healthcare professionals and healthcare researchers across and within countries will help bridge the knowledge/practice gap and improve patient outcomes and satisfaction.

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REVIEW ARTICLE

The Dilemma of Chronic Kidney Disease of Unknown Origin

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Abstract

Background: Over the past two decades, cumulative increases in the prevalence of chronic kidney disease (CKD) have been observed in selected geographic areas in several countries. The etiology of this CKD cannot be attributed to known or traditional causes or risk factors, and the term chronic kidney disease of unknown etiology (CKDu) has been used to describe this entity. These regional endemic nephropathies are commonly known as CKD of unidentified cause (CKDu) or CKD of nontraditional etiology (CKDnt) and, more recently, Chronic interstitial nephritis of agricultural communities (CINAC). Unlike the traditional causes of CKD (i.e., Hypertension, Diabetes, chronic glomerulonephritis, etc), CKDu has been associated with agricultural and arid regions. Also, the socioeconomic state of those regions is key.

Objective: This review addresses the present status of the knowledge for different aspects of this regional health problem as well as summarizes available evidence on the risk factors, epidemiology, clinical features, diagnosis, treatment, and prevention of CKDu. It will also highlight the reasons why Africa should be concerned about this condition.

Materials and Methods: Using the keywords "Africa, CKD of unknown origin," a literature search was conducted on PubMed, Scopus, and Google Scholar, focusing on the research published between 2000 and 2022.

Results: Results from the literature show that predisposition to heat stress and dehydration, subclinical rhabdomyolysis, toxins from alcoholic beverages, agrochemicals, and heavy metals all result in acute kidney injury, and repeated exposures to these factors can then cause CKDu. Earlier studies in Sri Lanka nephropathy by Nanayakkara and his team in 2014 identified that a genetic variant of SLC13A3 (sodium-dependent dicarboxylate transporter member 3) is associated with CKDu. Later research conducted in 2015 discovered KCNA10 (a voltage-gated potassium channel) also as a gene implicated in CKDu; these genetic variances were discovered to be common among the populace suffering from kidney diseases, hence suggesting that, people with these genes have a high risk of developing kidney disease.

Conclusion: Predisposition to heat stress and dehydration, subclinical rhabdomyolysis, and toxins from alcoholic beverages, agrochemicals, and heavy metals all result in acute kidney injury, and repeated exposures to these factors can then cause CKDu. Also, certain genes have been found to be associated with CKDu.

Keywords: CKD of unknown origin, heat stress, rhabdomyolysis

Introduction

Chronic kidney disease (CKD) is a growing global health problem.[1,2] CKD affects between 8% and 16% of the world's population and is often underestimated by patients and physicians.[3] CKD is a clinical syndrome that results from a definitive change in the function and/or structure of the kidney and is characterized by its irreversibility and slow and progressive development.[4] The definition of CKD is essential to understanding its pathology. CKD is generally characterized by a glomerular filtration rate (GFR) of less than 60 ml/min / 1.73 m², albuminuria of at least 30

mg every 24 hours, or markers of kidney damage (eg, Hematuria or structural abnormalities such as dysplastic kidneys) that last more than 13 weeks.[5] The pathology presents a higher risk of complications and mortality.[4]

People with CKD are at increased risk for cardiovascular disease and can develop ESRD.[4,6] Other effects of CKD can include anemia due to the underproduction of erythropoietin (EPO). Once a CKD diagnosis is made, the next step is to determine the staging based on GFR, albuminuria, and the cause of CKD.[5] CKD, as defined above, is classified into five (5) stages. The early stages of CKD (stages 1 and 2) are manifested by kidney damage and are generally asymptomatic; kidney function is normal, but the risk of disease progression is significant. As kidney disease worsens, kidney function begins to deteriorate (stages 3 and 4 of CKD). Renal failure or ESRD (stage 5 CKD) develops over time and renal replacement therapy is required.[7] The main causes of CKD include diabetes, high blood pressure, chronic glomerulonephritis, chronic pyelonephritis, chronic use of anti-inflammatories, autoimmune diseases, polycystic kidney disease, Alport's disease, congenital malformations, and persistent acute kidney disease.[4] Several sociodemographic factors contribute to an increased risk of CKD, including non-white race, low education, low income, and food insecurity. Compared to whites, African Americans and Pacific Islanders have a significantly higher risk of ESRD.[5] This is due to the higher prevalence of diabetes, high blood pressure, old age[7], and obesity[5]. However, there is an aspect of genetic factors.

Recently, due to its idiopathic nature, a conclusive diagnosis of CKD problems has not been made. Over the past two decades, cumulative increases in the prevalence of CKD have been observed in selected geographic areas in several countries.[8] The etiology of this CKD cannot be attributed to known or traditional causes or risk factors, and the term chronic kidney disease of unknown etiology (CKDu) has been used to describe this entity.[9] These regional endemic nephropathies are commonly known as CKD of unidentified cause (CKDu) or CKD of non-traditional etiology (CKDnt) and, more recently, chronic interstitial nephritis of agricultural communities (CINAC).[10] However, it is more locally identified by its geographic location, for example; Sri Lankan nephropathy, Uddanam nephropathy, and endemic Mesoamerican nephropathy (MeN).[11] The pathology is asymptomatic and therefore does not correspond to known risk factors such as diabetes, arterial hypertension, or chronic glomerulonephritis and mainly affects young and medium-sized people from low socioeconomic groups who live in agricultural communities.[12] The condition is said to have occurred in arid regions, as demonstrated by several studies in Sri Lanka.[13] Many of the CKDu-plagued regions lack the scalable medical infrastructure and equipment, such as dialysis systems, necessary to treat kidney dysfunction associated with generalized kidney disease.[14]

Pathologically, the disease appears to primarily affect the proximal tubules and the interstitium, resulting in distinctive and recognizable histopathologic and clinical features. Clinically, the disease is characterized by tubular proteinuria, mainly ß2-microglobulinuria, and the absence of hypertension and edema. The histological appearance shows tubulointerstitial nephropathy, which indicates a possible cause of toxin. CKDu can be found more and more frequently in the agricultural regions of the world.[15,16] In general, CKDu is more common (3: 1 ratio) in men who are typically around 40 to 60 years old and who work in agriculture.[17] The cause of this form of CKD is currently unknown. Heavy metals, agrochemicals, excessive use of non-steroidal anti-inflammatory drugs as analgesics, and illegal alcohol consumption have been suggested as risk factors.[15] Heavy metal toxicity, pesticide exposure, snake bites, and genetics have also been suggested as risk factors9. Given that the disease has a specific geographic distribution, it is highly likely that environmental and/ or genetic factors are strongly linked to the etiology and progression of the disease[17]. In this regard, heavy metals (cadmium [Cd], arsenic [As], and various nucleotides, including uracil [U]), increased levels of fluoride (F) in groundwater, the specific composition of groundwater, aluminium (Al), and aflatoxins.[17] It is important to note that this CKD problem is not limited to a single region. It has been investigated in Sri Lanka and there are reports in the literature describing similar clinical etiologies in India, Nicaragua, Costa Rica, and other Central American countries.[17] In Latin America, heat stress and dehydration are the most researched topics related to CKD risk factors. Several comprehensive reviews of the literature on MeN in Latin America have examined various routes of exposure and have found that correlations of gender, family history of CKD, water intake, and latitude with the prevalence of MeN have a high odds ratio.[18]

Methods

literature Using the keywords "Africa, CKD of unknown origin," a literature search was conducted on PubMed, Scopus, and Google Scholar, focusing on the research published between 2000 and 2022.

In this review, we have incorporated 52 original studies, 2 systematic reviews, 6 narrative reviews/editorials, and 2 documents.

Historical Perspectives and Theoritical Framework

Epidemiology and Global Implications

The prevalence of CKD varies widely throughout the world, as does its evidence; and treatment varies.[19] It is prevalent in low-income rural societies in the tropics.[20,21,22] CKDu's geographic access points include El Salvador, Bulgaria, Guatemala, Mexico, Nicaragua, Croatia, Egypt, Serbia, India, and Sri Lanka.[8,19] as shown in Figure 1. In Central America, it is one of the main causes of hospitalizations and deaths, mainly among young male sugarcane workers.[19,23] The true burden of this disease is not well documented due to surveillance limitations and a lack of consensus on diagnostic criteria or case definitions.[24] Less is known about the epidemiology of CKD in sub-Saharan Africa in general due to the rarity of kidney biopsies and insufficient general reporting.[8,25] However, increasing global warming, agricultural activity, and the young population pose a threat to the African community.
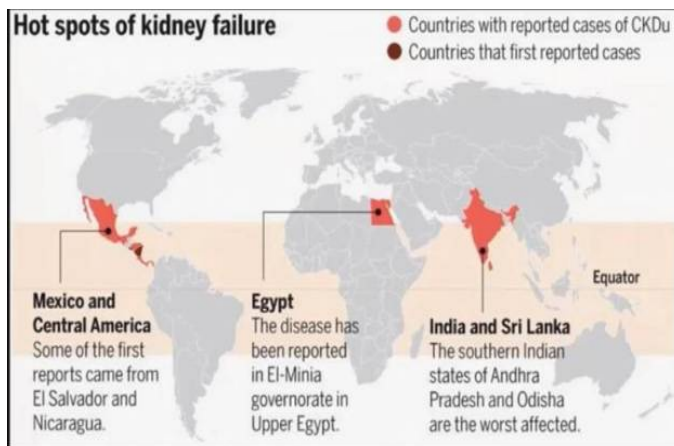
Figure 1: CKDu regional hotspots ("Home", 2021)

Causes of CKDu and Why Africa Should Be Concerned

Heat Stress and Dehydration

Recently, Central America (Mesoamerican nephropathy) has identified recurrent dehydration and heat stress as the main cause of CKD of unknown etiology epidemic.[15] Rajapurkar and his team in a study conducted in India suggested that people living around hot, coastal/subcoastal, low-altitude, tropical/subtropical geographical areas are commonly affected by CKDu.[26] Glaser and his team in a recent study also revealed that tropical lowlands on the Pacific Coast are hot spots for Mesoamerican neuropathy. They further added that global warming in such areas has further exacerbated the condition among sugarcane farmers and has increased the prevalence of the disease.[27]

In India, a high CKD burden has been recognized in areas where Indigenes are engaged in manual hard work under hot and humid ambient conditions.[27] Glaser and his colleagues also discovered that escalating levels of CKD is predominantly reported in the hottest regions in various countries [27]; in line with this, some authors also discovered that CKD is more common among people working at sea level (high temperate areas) than sugarcane fields at higher altitudes (cooler areas).[28,29,30,31]

Many scientists in Africa studying climate change have predicted that Africa is likely to experience higher temperatures, rising sea levels, changing rainfall patterns, and increased climate variability, all of which could affect much of its population.[32] One of the serious but less researched effects of climate change is CKD.

Some scientists suggested that recurrent heat exposure with physical exertion and inadequate hydration causes recurrent AKI which then progresses over time to CKD (heat stress nephropathy). Garcia-Tobranino et al., [29] in a study suggested that decreased plasma volume as a result of dehydration causes increased reabsorption of urea and other toxic waste which together with the dehydration initiates chronic kidney damage.

In addition, some authors reported that dehydration among sugarcane workers results in a decrease in their renal perfusion without structural injury. However, other authors think that an increase in creatinine levels during work shifts may signify injury to the kidneys, and if repetitive could predispose them to develop CKD.[33,34] Kupferman and his team estimated this to represent one-third of all cases of CKD (eGFR <60 ml per minute per 1.73m^2 of body surface area).[35]

Carl-Gustaf Elinder and his colleagues in a study suggested that the reason for the high rate of dehydration observed in these sugar cane workers could possibly be because, sugar cane harvest is a work paid by piece, not by hours in Central American countries. Hence, these employees purposefully defer taking breaks and ensuring adequate hydration with the explicit objective of maximizing their earnings.[36] Wesselling and his team proposed that recurrent heat stress with subsequent dehydration can cause subclinical ischemic kidney injury which can later cause CKD.[24]

The reason for higher numbers of sugarcane workers having CKD is that they often work with limited shade at environmental heat levels generally exceeding recommended limits for physical activity resulting in heat stress and dehydration which then culminates into kidney damage.[19,24] Research in Sri Lanka revealed that prolonged sun exposure and low fluid intake were risk factors for a person developing CKD.[37]

Heat stress and dehydration have been suggested to potentiate toxin-mediated kidney injury by enhancing the reabsorption of toxins in a state of decreased plasma volume10; other effects of heat stress, physical exertion, and dehydration that may be mechanisms of acute or chronic kidney injury include clinical or subclinical rhabdomyolysis[28,38,] elevation in serum urate levels and urate crystalluria[39], release of vasopressin, and activation of aldose reductase in the kidney, with aldose reductase generating oxidative stress.[40,41]

Dehydration which increases plasma osmolality will result in the activation of the aldose reductase pathway, converting glucose to fructose. The fructokinase in the proximal convoluted tubules of the nephron converts fructose into urates, oxidant species, and inflammatory mediators which later results in chronic kidney damage.[19]

Sugar cane workers laboring under the sweltering sun will further exacerbate their condition if they continuously chew the sugarcane or even hydrate with any sugary drink.[41] In fact, a study on laboratory rats conducted in Mexico by Garcia and his team to investigate the effect of heat-associated dehydration on the kidneys revealed that rehydration with sugary drinks as opposed to water is associated with worse kidney damage.[29]

Also, heat stress accompanied by severe dehydration can cause hypovolemia which will result in a decreased perfusion of the kidney and hence eventually elicit renal tubular injury ultimately leading to CKD.[27] Recurrent and prolonged dehydration resulting from strenuous work in tropical climates is believed to lead to subclinical acute kidney injuries that develop into chronic damage over time. Furthermore, it has been identified as a causative factor that could lead to glomerular hypertension, interstitial fibrosis, and tubular injury due to the oxidative stress exerted onto the kidneys which could be a probable pathway leading to CKDu.[21,27]

The limitation of the heat stress hypothesis is that there are many hot regions in the world where this type of kidney disease is uncommon or has not been reported.[42] For instance, few cases have been reported in the northern tip of Sri Lanka, even though this area is as hot as the regions with the highest frequency of disease; this might also be the lack of research in these regions. To help mitigate these problems, implementations should focus more on properly managing people at risk including screening, enhancing early detection to ensure proper treatments, minimizing exposure to nephrotoxins, etc.

In Central America, policies made focused on reducing exposures to excessive heat and improved hydration in at-risk groups.[28,43] Many people are exposed to excessive sun rays and also engage in hard labor. This, therefore, implies that Africans are at a higher risk of CKD than non-Africans. Hence, more studies are required to investigate this crucial issue. But currently, no research shows that shows that hydration can slow the development of CKD, therefore more research should be done to evaluate this hypothesis. Africans should be concerned because dehydration is a common condition since we are exposed to excessive amounts of sunshine thereby putting us all at risk of developing CKD.

Role of rhabdomyolysis

Rhabdomyolysis is a condition characterized by injury to skeletal muscle fibers with disruption and release of their contents into the circulation. Clarkson and his team revealed in a study among marathon runners that exertional rhabdomyolysis is one of the factors responsible for the increased rate of AKI and repeated exposures to these factors can result in CKD observed in this category of people.[44]

Aside from the Mesoamerican nephropathy observed among sugarcane workers, it has also been observed in farmers of other crops (eg, cotton, corn, and beans), miners, and fishermen, as well as construction workers.[31] After they presented with symptoms of kidney damage (raised creatinine and urea levels, proteinuria, etc.), a kidney biopsy showed marked tubulointerstitial disease, often with glomerulosclerosis and evidence of kidney ischemia.[45] This condition will later progress to end-stage kidney damage.

Correa and Colleagues in research conducted in Central America revealed that CKDu mostly affects low-income, rural, and middle-aged men in agriculture or other fieldworkers requiring strenuous work.[46] Roncal-Jimenez and his team revealed that strenuous work in hot climates causes subclinical rhabdomyolysis, exacerbating hyperuricemia and urinary urate can exceed its solubility and form microcrystals.[39]

Vanholder and his team in a paper suggested that extreme temperature is one of the major causes of rhabdomyolysis in recent times.[47] It has been well established by Glaser and his team that rhabdomyolysis can lead to AKI, and repeated exposures can result in CKDu.[27] Africa as a poor continent is not fully mechanized in the working space. Most of the jobs in Africa involve manual hard work. The escalation of the cost of living has precipitated a situation wherein individuals find themselves compelled to undertake more than two employment positions concurrently as a means to address their financial needs. All these factors can therefore position Africa as a hotspot for an outbreak of CKD with time.

Toxins in Alcoholic Beverages

All metabolic wastes are excreted by the kidneys. The content of ethanol and its metabolites in urine is higher than that of blood and the liver. Chronic alcohol consumption causes decreased renal function.[48] Some studies suggest that, since the kidneys are made up of long-chain polyunsaturated fatty acids, it makes them highly sensitive to oxidative stress.[49]

Research conducted by Ozbek and his team to review the induction of oxidative stress on the kidneys revealed that ethanol administration caused a significant decrease in levels of some antioxidant enzymes like catalase (CAT) and glutathione peroxidase (GSHPx) e.tc. in the kidneys of rats. Shanker and his team in a study showed that renal metabolism of ethanol via Cytochrome P450 2E1 and ADH-1(Antidiuretic hormone-1) leads to the production of oxygen species. In summary, alcohol intake results in excessive production of free radicals and a decrease in the levels of antioxidants (which confer protection against oxidative stress) in the kidneys. This can cause intrinsic kidney damage and with time can cause CKD.

Other authors suggested that the possible mechanisms alcohol can cause CKD are as follows: i. it can increase the chance of developing high blood pressure, which is the second leading cause of kidney disease, ii. Interfere with medicines making it harder to control high blood pressure. Uncontrolled high blood pressure is more likely to damage kidneys, iii. Cause more frequent urination, which can lead to dehydration prevent the kidneys from maintaining a proper balance of body fluids and minerals iv. damage kidney cells changing the structure and function of the kidneys.[50]

In 1979 the World Health Organization reported in Health News that alcoholism was becoming a major problem in developing countries. Alcoholism is becoming a serious problem in Africa. According to some studies, no amount of alcohol intake is beneficial; whereas, other studies argue otherwise.[50,51] Alcohol intake has contributed massively to disabilities, ill health conditions and death. It has been rated as the sixth most common cause of mortality and disability-adjusted life years (DALYs) among individuals globally.[51]

According to the WHO, drinkers in African countries consume 13% more alcohol per capita than the average among drinkers globally.[52] With the increased rate of alcoholism among Africans, we are therefore at a high risk of developing CKD and other conditions

Agrochemicals, Heavy Metals, and Nephrotoxic Exposure

The pollution of water bodies by industrial waste and agrochemical runoff is becoming a serious threat to human lives. Due to the subsidy made by governments on all fertilizers for farmers, they sometimes overuse them way

more than what is prescribed by the Ministry of Agriculture (MOA), which later is washed off by the rains into water bodies. Chemical fertilizers are the key suppliers of heavy metals and other compounds like fluoride, nitrogen, and phosphorus to soils and water bodies. Excessive amounts of these compounds in soil will lead to bioaccumulation of them in plants and animals which indirectly affects the health of humans.[50]

The consumption of water contaminated with heavy metals, fluoride, agrochemicals, and other toxins causes insidious illnesses that lead to protracted, non-communicable diseases and death[22]; CKDu is one such disease that is likely to manifest. The breakout CKDu in Sri Lanka was postulated to be potentiated by many factors, including heavy metals, fluoride, cyanobacterial, algae toxins, and agrochemicals. But no specific cause has been identified for CKDu; hence the name CKD of multifactorial origin (CKDmfo) was also proposed by other scientist.[22]

This therefore indicates that no single factor has been identified to be the main cause of CKDu, but the synergistic effects of a combination of factors and components, even exposure to lower amounts with yet other unidentified factors can be a cause of this (CKDu) epidemic in Sri Lanka.[53] Heavy metals as well as some minerals have been discovered to cause kidney injuries. Most notable among them are Cadmium and lead.[54]

In addition to testing for turbidity, total dissolved substances (TDS), and total suspended particles, sophisticated water purification plants routinely test for between 40 and 90 different water contaminants. Such extensive monitoring is not considered to be practical or necessary for small-scale, community-based water purification plants, especially in developing countries.[22]

In many African countries, only urban dwellers have assessed to quality water. Most of the rural communities still drink water from streams, rivers, etc. Many of these African countries are battling with the issue of illegal mining (known as Galamsey). These activities seriously contaminate our water bodies and no extensive water purifications are performed in most African countries. It, therefore, places Africa as a hot spot for the occurrence of CKDu. Hence, Africans should be concerned and should therefore allocate resources to help avert this epidemic waiting to unfold.

Genetic factors

With regards to Mesoamerican nephropathy, some authors suggested that genetic factors could account for the reason why some people develop kidney disease and others do not even though they are all exposed to the same risk factors. They further added that genetic factors could be the reason accounting for the improved conditions observed in some groups of people while others have the worst prognosis.[28] Nanayakkara and his team in a recent study conducted in Sri Lanka observed familial clustering in some families which suggests that CKDu could be caused by genetic factors.[21]

Earlier studies in Sri Lanka nephropathy by Nanayakkara and his team in 2014 identified that a genetic variant of SLC13A3 (sodium-dependent dicarboxylate transporter member 3) is associated with CKDu.[21] A later research conducted in 2015 discovered KCNA10 (a voltage-gated potassium channel) also as a gene implicated in CKDu; these genetic variances were discovered to be common among the populace suffering from kidney diseases, hence suggesting that, people with these genes have a high risk of developing kidney disease.[21] These findings still need validation by additional studies.

Some authors have identified SLC13A3 as one of the sensitive marker genes for prognosing the clinical outcomes in type 2 diabetes mellitus patients with End Stage Renal Disease (ESRD). They further added that people with this genetic variant are at a high risk of developing hypertension, in which case if not properly managed makes kidney damage inevitable.[55]

Ju and his team in a recent study using animal modules (mice) identified the SLC13A3 gene to be among other 43 genes that can be used in protein expression signatures to predict progressive renal fibrosis in mice, and hence was suggested to be a potentially useful molecular predictor for CKD progression in humans.[55] Some authors also suggested that the SLC13A3 gene plays a key role in Hg-thiol conjugates (mercury-thiol) accumulation in the renal tubules. The accumulation of inorganic mercury in the renal tubules was suggested to play a vital role in the development of CKD in humans.[56]

With these alarming facts, few studies in Africa have actually focused on CKDu. Recently, there has been an increase in research worldwide in identifying genetic factors which play a key role in the development of CKDu. So far, no studies in Africa have focused on elucidating the genetic factors responsible for this disease. One possible reason might be due to a lack of adequate resources. There is a need to therefore research more on this topic since CKDu is becoming a global challenge and hence needs to be tackled with alacrity in order to avert future outbreaks.

Socio-economic Determinants

Most of the outbreaks of CKDu occurred in low-income communities. This is because, these communities are more predisposed to most of the identified risk factors associated with this condition (heat stress and dehydration, exposure to heavy metals, excessive stress, and rhabdomyolysis).

Some authors reported that CKDu occurs mostly in poorer young and middle-aged individuals in agricultural communities. And because it is progressive and asymptomatic until the late stage, a lot of people who develop this condition hardly recover.[57] Kuruppuarachchi and his team in a recent paper revealed that Sri Lanka's North Central region, notably the Medawachchiya District Secretariat Division of the Anuradhapura District which recorded the highest prevalence of CKDu, 80% of that population are farmers who rely on groundwater for their daily water needs.[58]

Recent studies have demonstrated the association between CKDu and groundwater chemistry and the water quality in household wells[59,60] suggesting that the disease could be caused by hydrogeochemical factors such as high fluoride and water hardness and heavy metals. Extensive monitoring of water is not considered to be practical or necessary for

small-scale, community-based water purification plants, especially in developing countries.[22] This, therefore, puts these indigenes at a higher risk of developing CKDu.

Furthermore, most of these low-income communities are involved in strenuous work like farming sugarcane, rice, and a lot. Most of these farmers still rely on manual hard labor other than mechanized farming due to financial constraints. These activities mostly can cause subclinical rhabdomyolysis and if this persists may lead to the development of CKDu.

Within the African continent, the majority of the populace finds themselves positioned within the category of low-income earners. Consequently, individuals within this demographic often resort to engaging in multiple employments, surpassing the threshold of two occupations, to meet the exigencies of their daily needs. These jobs mostly involve hard labor, and they get little rest working under the scorching sun. This, therefore, predisposes them to heat stress and dehydration, subclinical rhabdomyolysis. Their risks are further compounded by the skipping of rehydration or drinking unsafe water since the prices of purified water are rising rapidly.

The aforementioned factors, therefore, point out how the poor socioeconomic status in Africa can negatively impact the health of its inhabitants. Significant but less researched in Africa is CKDu which is our main focus for this paper.
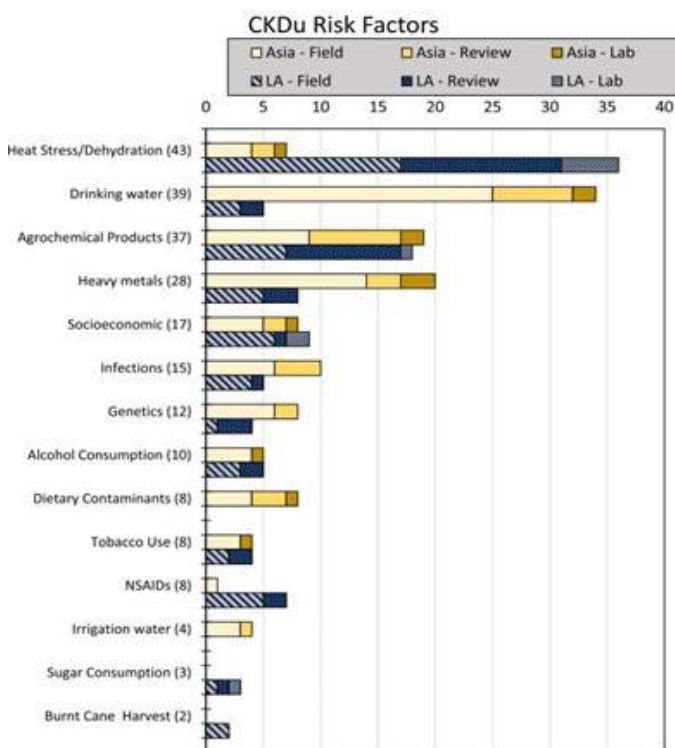

Figure. 2: Risk factors of CKDu[19]

Future Perspectives

CKD is a growing health burden globally with many known and unknown etiologies.[1] In high-income countries, it is most commonly associated with non-communicable diseases like diabetes and hypertension. However, in low- and middle-income countries, it has several additional potential etiologies, such as infectious diseases and environmental toxins, but many remain unknown.[1,61]

In this paper, the predisposition to heat stress and dehydration, subclinical rhabdomyolysis, toxins from alcoholic beverages, agrochemicals, and heavy metals all result in acute kidney injury and repeated exposures to these factors can then cause CKDu. These findings have been confirmed by several authors.[21,27,39,50]

Also, certain genes have been found to be associated with CKDu. A study conducted in Sri Lanka to unravel the outbreak of CKDu by Nanayakkara and his team observed a familial clustering pattern of this condition.[21] Other authors further added that genetic factors could account for the reason why some people develop kidney disease and others do not even though they are all exposed to the same risk factors.

Finally, countries with poor socioeconomic status have been discovered to record high cases of CKDu. The low-income countries are more predisposed to most of the identified risk factors associated with this condition (heat stress and dehydration, exposure to heavy metals, excessive stress, and rhabdomyolysis). Hence socioeconomic determinants have been implicated as one of the factors causing the outbreak of CKD of unknown origin worldwide.

CKDu is being reported with increasing frequency across the globe, and in many parts of Central America, Eastern Europe, and South Asia, it is being reported in epidemic proportions.[62,63,64] Despite the increased recognition of CKDu across the globe, no studies in Africa have focused on this crucial issue. Africans should be worried because most of the factors identified above are more prevalent here in Africa and to some extent with an even higher intensity. CKDu might be the cause of most of the kidney failure cases recorded here in Africa but due to the lack of its recognition and the implementation of preventive measures in our poor healthcare state, an outbreak of this condition might be closer than ever.

The goal is to incite more research to be done on this very crucial issue to create more awareness and to also push for the implementation of the necessary measures to help avert this awaiting doom.

List of Abbreviations

ADH-1- Antidiuretic Hormone-1

AKI - Acute Kidney Injury

CAT - Catalase

CINAC - Chronic interstitial nephritis of agricultural communities

CKD - Chronic Kidney Disease

CKDmfo - Chronic Kidney Disease of Multifactorial Origin

CKDnt - Chronic Kidney Disease of non-traditional etiology (CKDnt)

CKDu - Chronic Kidney Disease of Unknown Origin

ESRD - End Stage Renal Disease
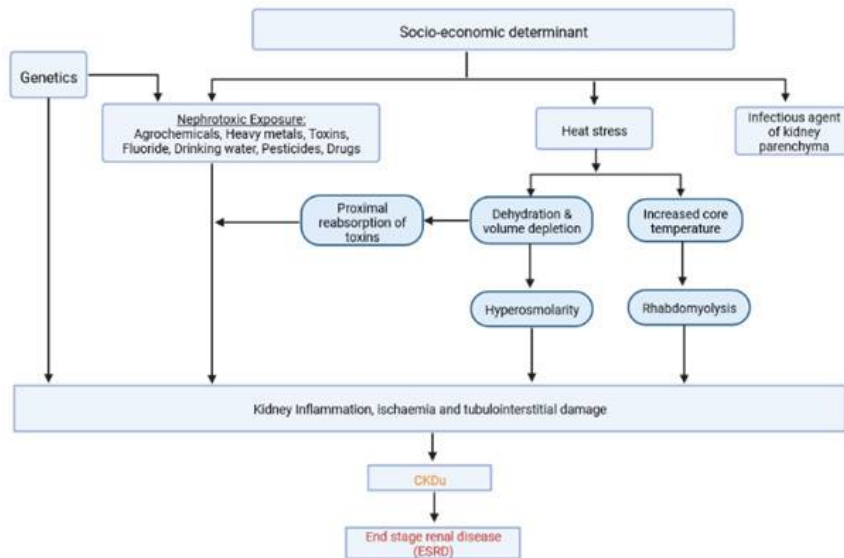
GFR - Glomerular Filtration Rate

Figure. 3: Pathogenesis of CKDu (Daba, 2020)

GSHPx- Glutathione peroxidase

MeN   - Mesoamerican Nephropathy

MOA   - Ministry of Agriculture

TDS   - Total Dissolved Substances

WHO - World Health Organization

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REVIEW ARTICLE

Plasmodium falciparum RIFINS: Role in malaria pathogenesis

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Abstract

Malaria kills an estimated 600,000 people each year, especially children under five years who reside in sub-Saharan Africa. Malaria fatalities are associated with severe forms such as cerebral malaria, acute respiratory failure, severe anaemia, renal failure, hypoglycaemia, and pulmonary oedema. Although the underlying pathogenic mechanisms in immune responses and parasite immune evasion, cytoadherence of parasitized red blood cells, and rosetting are enumerated, the mechanisms are not fully understood. P. falciparum parasite-derived surface protein, repetitive interspersed family (RIFIN) genes are involved in rosetting, blocking microcirculation, and playing a role in malaria pathogenesis; it is unclear which RIFIN family genes are involved in the various pathogenic mechanisms in malaria. RIFINs are the extensive malaria family genes expressed throughout the malaria parasite stages, indicating their diverse roles. Malaria pathogenesis occurs in erythrocyte-stage infection, and the expression of RIFINs at this phase could play a diverse role in the various pathogenic mechanisms. They are involved in major phenomena such as cytoadherence, merozoite evasion, and immune evasion. RIFINs aid in the immune evasion of P. falciparum through various molecular interactions by binding to the inhibitory receptors LAIR1, LILRB1, and LILRB2. RIFINs in severe forms of malaria (such as cerebral malaria and severe anaemia) require a considerable understanding to target and control malaria severity and mortality. RIFINs are implicated in severe malaria and are discussed together with other variant surface antigens such as STEVORS or PfEMP1 in the specific pathophysiology of malaria. This review details the role of RIFINs in the various malaria pathophysiological mechanisms underlying severe malaria and mortality.

Keywords: *Plasmodium falciparum*, Severe malaria, cerebral malaria, rosette formation, cytoadherence, malaria immunity, variant surface antigens.

Introduction

Malaria is one of the perilous infectious diseases that affect humans (World Health Organization, 2016). *Plasmodium falciparum, Plasmodium malariae, Plasmodium ovale, Plasmodium vivax*, and *Plasmodium knowlesi* are the causative organisms for human malaria. More than 200 million people are affected by malaria each year, with more than 600,000 deaths in 2021 (World Malaria Report, 2021). Most deaths are primarily caused by Plasmodium falciparum, largely affecting children below the age of five, pregnant women in Sub-Saharan Africa, and non-immune travellers as well (World Health Organization, 2017). The majority of fatalities are caused by severe malaria, which includes cerebral malaria and severe malarial anaemia (Lawton et al., 2022).

Severe malaria is linked to cytoadherence to cell surfaces and the sequestration of parasitized red blood cells (pRBCs). Although all human malaria species adhere to cell surfaces, P. falciparum is more likely to sequestrate. P. falciparum infection spans a wide spectrum of clinical manifestations, ranging from asymptomatic infection to severe disease (including cerebral malaria, acute respiratory failure, severe anaemia, renal failure, hypoglycaemia, and pulmonary oedema) (Marsh & Snow, 1999). Patients with cerebral malaria initially experience unconsciousness as a result of vascular constriction caused by rosettes and some fibrillose components (Ndam & Deloron, 2007). Malaria pathogens have developed techniques to live inside infected hosts, one

tactic is changing the surface antigen expression to evade the host immune system (Deitsch et al., 2009).

Plasmodium species express and export family genes called variable surface antigens (VSA genes), for which each individual parasite expresses only one protein product (Fernandez et al., 1999; Mkumbaye et al., 2017). P. falciparum parasite has ≥ 60 erythrocytes membrane protein 1 (PfEMP-1) different var genes whose binding domain cassettes DC8 or DC13 are implicated in severe disease (Almelli et al., 2014a; Ndam et al., 2017). The DC8 or DC13 has a superior binding phenotype for diverse human endothelium including intecelullar adhesion molecule 1 (ICAM-1) and Endothelial protein C receptor (EPCR), cluster of differentiation 36 receptor (CD36), and chondroitin sulfate A (CSA) and leads to sequestration of pRBCs within small vessels which obstruct organs (Angeletti, 2013).

The mechanical obstruction of microcirculation by pRBCs, or the formation of rosettes, contributes to microvascular disease. P. falciparum parasite-derived surface protein, repetitive interspersed family (RIFIN), has been implicated in rosetting and blocking microcirculation, leading to malaria pathogenesis (Goel et al., 2015). This review discusses the role and underlying mechanism of P. falciparum RIFINs in the pathogenesis of malaria.

The molecular characteristics of Plasmodium falciparum RIFINs

RIFINs form the largest family of surface proteins in Plasmodium falciparum, with 150–200 copies per haploid genome. They are two-exon genes with a conserved domain architecture that is tiny (1000 base pairs or less) (Cheng et al., 1998). The Plasmodium falciparum 3D7 strain RIFINs can be split into two main categories: A and B-RIFINs (Joannin et al., 2008). The difference is largely due to a 25-amino acid indel present only in the conserved N-terminal region of A-RIFINs (Joannin et al., 2008) (figure 1)

Protein domains are illustrated as signal peptide (SP), short hypervariable region (V1) and hypervariable domain (V2), transmembrane domains (TM), brown (pexel motif), purple (indel, a 25 amino acid sequence unique to RIFIN-A), conserved (C), and semi conserved (SC) domains. RIFIN proteins are carried by infected erythrocytes to the Maurer's clefts and then to the erythrocyte membrane. The RIFIN proteins' C-terminal and semi-conserved domains are inserted into the erythrocyte membrane. Consequently, RIFIN B proteins are inserted by two transmembrane domains and express only a few amino acids at the surface of pRBC. Immune cells are bound by the C-terminal of RIFIN B, which enhances immune evasion. RIFINs are exported across parasitophorous vacuoles into the host cell by Pexel and signal peptideS. The hypervariable region of RIFINs generates antigenic variability. RIFIN A proteins are inserted by one transmembrane domain. Surface-exposed loops of RIFINs bind to immune cells to trigger immune invasion by parasites.

Compared to A-RIFINs, B-RIFINs are more hydrophobic (Goel et al., 2015). RIFINs are trafficked to the pRBC membrane via the parasite Maurer's clefts (MCs).

Members of the two sub-families have two transmembrane domains: a Plasmodium export element (PEXEL) or vacuolar transport signal (VTS) motif with an N-terminal signal peptide which is required to export target proteins outside the parasite (Horrocks & Muhia, 2005). A signal peptide and just one transmembrane (TM) region are present in the majority of A-RIFINs, whereas two TM regions and a signal peptide are present in the majority of B-RIFINs. After multiple sequence alignments with known STEVOR and RIFIN proteins, the similarities between the RIFIN and STEVOR proteins are minimal, making it easy to spot differences between them (Joannin & Kallberg, 2011). RIFINs are comparatively more resistant to trypsin treatment and require a high dosage of trypsin to remove them from the surface of the pRBCs (Bachmann et al., 2015). The TM domain at the N-terminus of RIFIN
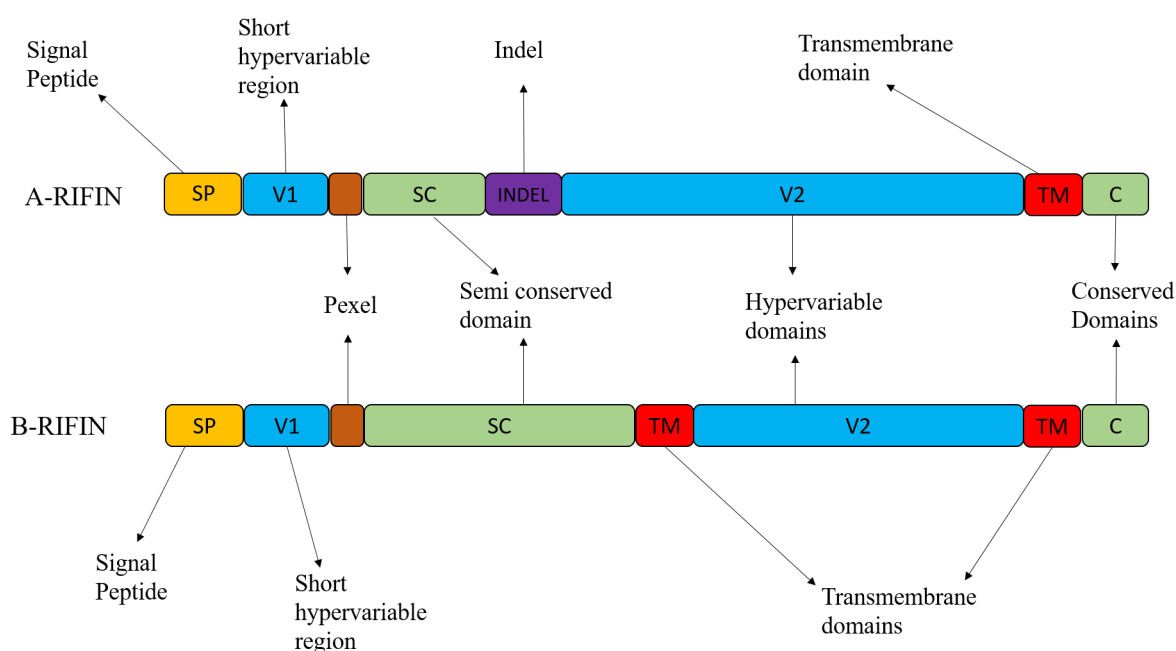

Figure 1 | General Structure of RIFIN A and B

contains a high concentration of alanine and glycine residues and conserved central proline residue, suggesting a connection with ion channel function (Schneider & Mercereau-Puijalon, 2005).

Interactions Between RIFINs and Other Virulence Factors

The expression of VSAs on the surface of pRBCs is a significant virulence factor of P. falciparum. These surface-derived antigens aid the adherence of parasites to the vasculature. They include PfeMP1 (Leech et al., 1984), STEVOR (Blythe et al., 2008; Kaviratne et al., 2002), RIFIN (Cheng et al., 1998; Fernandez et al., 1999; Kyes et al., 1999), and SURFIN (Winter et al., 2005). Several of these VSAs are exported by parasite-induced membrane structures called "Maurer's clefts" (MCs) that are found in the cytoplasm of pRBCs. MCs are distinct from the tubulovesicular network (TVN) that extends from the parasitophorous vacuole membrane (PVM) in that they serve as a sorting substrate for protein transport (Lanzer et al., 2006; Wickert & Krohne, 2007). Clonal diversity in the expression of PfEMP1 and RIFINS is thought to have evolved as a strategy for immune evasion, increasing the likelihood of extended parasite life, gametocyte maturation, and transmission to the subsequent host. PfEMP1 and RIFIN polypeptides initially emerge at the ring stage, 6–10 hours post-invasion (Haeggström et al., 2004). RIFIN proteins are thought to be concurrently expressed with PfeMP1 on the surface of pRBCs (Kyes et al., 2000). Haeggström and associates showed that RIFINs and PfEMP1 are transported across the cytoplasm of pRBCs via a shared trafficking route (Haeggström et al., 2004), in that would use lateral diffusion to traffic most or all of the gap between the erythrocyte plasma membrane and the parasite, once inserted into the cell membrane network. (Haeggström et al., 2004). PfEMP1, RIFIN, and STEVOR are believed to exhibit a mutually exclusive pattern of expression where one member at a time is expressed and others remain silent (Subudhi et al., 2016). The expression of RIFINs peaks at 12–27 hours (ring and trophozoite stages) after invasion, whereas STEVORs peak at 22–32 hours (trophozoite and schizont stages) after invasion of merozoites (Scherf et al., 2008).

STEVOR is expressed on the surface of pRBCs after the expression of both PfEMP1 and RIFIN, demonstrating its essential role in the development of late-stage parasites (Ferreira et al., 2004). It has been suggested that the enhanced rigidity of pRBCs due to STEVOR amplifies the sequestration mediated by PfEMP1 (Sanyal et al., 2012).

Expression of RIFINs at various stages of the parasite life cycle

Plasmodium has a complicated life cycle that necessitates the expression of certain proteins in both invertebrate and vertebrate hosts for both intracellular and extracellular survival, for invading various cell types, and for evading host immune responses. Targeting specific parasite life stages and/or specific proteins expressed at these phases will result in the most effective treatment methods, including antimalarial vaccines and medications. Proteomic and transcriptomic studies have shown that RIFINs are significantly expressed in the gametocytes, merozoites, and sporozoites stages of Plasmodium species (Bozdech et al., 2003; Florens et al., 2002; Le Roch et al., 2003).

Mosquitoes inject sporozoites after consuming a blood meal. Even though sporozoites spend only a few minutes in the bloodstream, sporozoites are the invasive stage that has the apical specialized machinery needed to invade host cells. RIFINs are mostly up-regulated in sporozoites (Florens et al., 2002; Le Roch et al., 2003), indicating that they play a major role in ensuring the survival of sporozoites against hostile environments in the blood and a successful hepatocyte invasion by sporozoites. The rif gene PF3D7_1300600 has been reported to dominate in the sporozoite stage (Mwakalinga et al., 2012; Wang et al., 2010).

Merozoites are released from pRBCs, and after a brief period in the plasma, they infiltrate new red blood cells (RBCs). RIFINs are highly co-expressed with other genes and are involved in merozoite invasion and remodelling of RBCs in the merozoite and the ring stage (Subudhi et al., 2016). A-type RIFINs are found at the apical tip of merozoites, whereas B-type RIFINs are found in the cytoplasm (Petter et al., 2007). Several RIFINs are co-expressed between 11 and 12 hours post-RBC invasion (Painter et al., 2018). P. falciparum 3D7 rif transcript PF3D7_1300600 has been discovered to be exported to the surface of invading merozoites, intimationtheir possible role in sensing or attachment to new RBCs (Mwakalinga et al., 2012). The rif gene PF3D7_1400400 has been implicated in merozoites and late ring stage in vitro, and PF3D7_0900600 has been implicated in merozoite, early ring, and late ring stage in vitro (Daily et al., 2005).

Transcriptome studies on developing gametocytes show persistent transcription of RIFINs with a distinct expression of variants (Wang et al., 2010). The expression of several RIFINs peaks at stages III and IV of the gametocytes and significantly decreases at stage V (Mwakalinga et al., 2012). The stage V gametocytes (mature) express high quantities of the type B rif gene, PF3D7_1300600, which likewise the predominates sporozoite rif transcript profile (Mwakalinga et al., 2012; Wang et al., 2010). The P. falciparum 3D7 rif transcript PF3D7_0900500 is most abundant during gametocyte stages II and III.

RIFINs are more expressed in vivo than in vitro throughout all stages of the parasite's life cycle (Daily et al., 2005). Types A and B RIFINs exhibit varying patterns of expression throughout the life cycle, and their localization to numerous subcellular sites indicates that they are involved in a variety of biological processes (Petter et al., 2008). In contrast to their cellular localization in asexual stages, the A-type RIFINs are expressed in gametocytes, whereas the B-type RIFINs do not appear to be exported to the erythrocyte in intra-erythrocytic sexual stage parasites (Petter et al., 2007).

Immunity against RIFINs

Exposure or repeated exposure to Plasmodium falciparum results in the gradual development of protective and

acquired clinical immunity against malaria (Doolan et al., 2009). For instance, the immunoglobulin G (IgG) antibody isotype repertoires against the cytophilic region of VSA have been shown to be involved in the opsonization of pRBCs (Yone et al., 2005). Similarly, antibodies against variant surface antigens such as RIFINs induce immune responses, which play a role in modulating the pathophysiology of malaria (Holder, 1999).

Anti-RIFIN antibodies are associated with protection against severe malaria through parasite clearance (Abdel-latif et al., 2003). Immune evasion techniques, including cytoadherence and rosetting of the parasite, may be blocked by antibodies against RIFINs (Gonzales et al., 2020). These antibodies may help natural killer (NK) cells kill pRBCs directly by inducing opsonic phagocytosis or antibody-dependent cellular cytotoxicity (Chan et al., 2019). Malaria patients develop receptor-containing antibodies, including a piece of the LAIR1 and LILRB1 exons (Chen et al., 2021; Tan et al., 2016). These antibodies are a class of widely neutralizing proteins that can simultaneously detect several LAIR1 and LILRB1-binding RIFINs (Tan et al., 2016), as well as block the interaction of LAIR1-binding RIFINs and LAIR1 on immune cells (Xie et al., 2021). Specific RIFIN family members have been identified as the target antigens of the LAIR1-containing antibodies (Tan et al., 2020). These antibodies are able to efficiently agglutinate and opsonize pRBCs for phagocytosis, suggesting that they might facilitate parasite clearance.

Additionally, IgGs with broad anti-RIFIN activity have been associated with protection against malaria and inhibit RIFIN's ability to bind to host leucocytes (Saito et al., 2017) to facilitate opsonization of P. falciparum-infected RBCs (Sakoguchi et al., 2021). In a particular study, children who had high levels of antibodies against four RIFIN variants had a significantly lower chance of contracting febrile malaria, indicating that RIFINs could be a significant target for protective immunity (Kanoi et al., 2020). Mwakalinga and colleagues also showed that there is a high prevalence of IgG antibodies to some specific RIFIN variants (Mwakalinga et al., 2012). Taken together, these findings illustrate a biologically relevant mechanism that may be suitable for vaccine development.

Immune evasion/immune suppression in humans

The survival, evasion, and development of malaria parasites require the ability of the merozoites to escape the host immune system and successfully invade the RBCs. Malaria-exposed individuals develop anti-parasitic immunity, such as antibodies and cellular immunity (T-cells), to clear invading malaria parasites. The anti-parasitic antibodies bind to pRBCs or mediate opsonization followed by phagocytosis by circulating macrophages (Gomes et al., 2016). However, Plasmodium parasites utilize multiple mechanisms, including the expression of variable surface, antigens to evade the human immune response (Kyes et al., 2001).

The presence of a hypervariable region and a huge repertoire of rif genes in the genome of a single parasite provides strong evidence that they are involved in antigenic variation during the pathogenic mechanisms of malaria parasites (Kaur & Hora, 2018). Some subsets of RIFINs are utilized by Plasmodium falciparum to evade the immune system of the host through the activation of inhibitory immune receptors, including leukocyte-associated immunoglobulin-like receptor 1 (LAIR1) and leukocyte immunoglobulin-like receptor B1 (LILRB1) (Harrison et al., 2020; Saito et al., 2017; Tan et al., 2016). The leukocyte immunoglobulin-like receptor (LILR) family is expressed on the surface of myeloid cells, B cells, certain NK cells, certain T-cell subsets, and major histocompatibility complex molecules (MHC) class 1 (Colonna et al., 1997). RIFIN variants PF3D7_1254800 and PF3D7_0223100 bind to LILRB1, while PF3D7_1101100 and PF3D7_1040300 bind to LAIR1 (Harrison et al., 2020; Saito et al., 2017; Xu et al., 2021) and prevents activation of immune cells
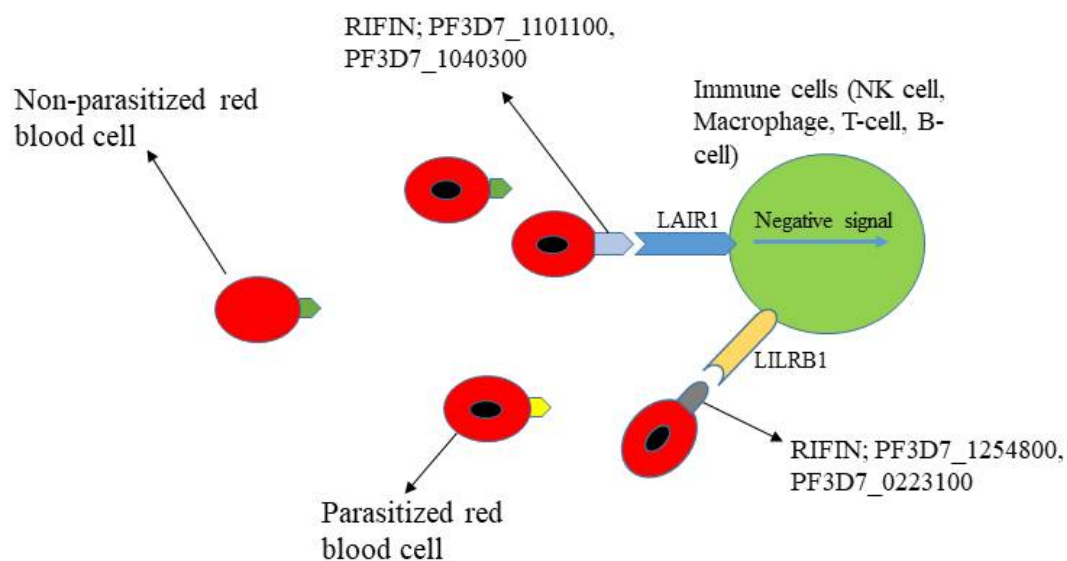

Figure 2 | Immune evasion mechanisms by P. falciparum RIFINs

expressing LILRB1 and LILR1(Saito et al., 2017) (Figure 2).

P. falciparum drives the expression of RIFINs on the exterior surface of pRBCs. Distinct RIFINs attack host inhibitory receptors LILRB1 and LAIR1 on the surface of immune cells (NK cells, Macrophages, T-cells and B-cells) to downregulate the innate and adaptive immune responses, enhancing parasites ability to evade the host immune system, which results in suboptimal immunity formation, which leads to severe malaria.

These interactions enable malaria parasites to escape immune clearance and offer survival advantages to the parasites. For example, the LILRB1-binding RIFIN, PF3D7_1254800, stimulates the reduction of NK cell cytotoxicity and the inhibition of B cells' generation of immunoglobulin M (IgM), which provides parasites with protection from macrophage phagocytosis and natural killer cell-mediated killing (Chew et al., 2020; Saito et al., 2017). Interactions between RIFINs and the leukocyte-associated immunoglobulin-like receptors are reported to be observed in more severe malaria cases than in mild instances, indicating that these interactions may be responsible for the disease's severity (Saito et al., 2017). Furthermore, some subsets of RIFINs bind to the inhibitory receptor LILRB2 to evade the host immune system during P. falciparum infection (Sakoguchi et al., 2021; Sakoguchi & Arase, 2022). Sakoguchi and associates demonstrated that the RIFIN PfKH02_070016000 binds to LILRB2, and domain 3 of LILRB2 is involved in RIFIN binding while domains 1 and 2 of LILRB2 are associated with binding to HLA class I molecules, indicating that, like LILRB1 and LAIR1, the inhibitory receptor LILRB2 is a target of RIFIN for P. falciparum immune evasion (Sakoguchi et al., 2021).

The importance of RIFIN proteins in immune defence is demonstrated by the association between the level of anti-RIFIN antibodies in infected patients' plasma and the removal of parasites from circulation (Abdel-latif et al., 2003). Therefore, the significance of RIFINs as immunological targets significantly promotes their prospects for vaccine development (Chan et al., 2014).

Rosette formation

Rosetting occurs when pRBCs attach to non-pRBCs, resulting in the activation of parasite ligands and RBC surface receptors (Miller et al., 2002; Udomsangpetch et al., 1989). It is a phenomenon of spontaneous binding between pRBCs and non-pRBCs (Barragan et al., 2000; Deans & Rowe, 2006; Udomsangpetch et al., 1989). Rosetting plays a part in the sequestration of RBCs and the development of severe malaria (Kaul et al., 1991). Rosettes are resistant to pulling forces but less so to shearing forces (Nash et al., 1992).

The pathophysiological effects of malaria parasites on hosts are aided through rosetting by: 1. circumventing the host immune system by protecting the freshly released merozoites and pRBCs from host invasion inhibitory antibodies; 2. ensuring parasite survival by creating an environment that will allow newly released merozoites to quickly infiltrate non-pRBCs (Deans & Rowe, 2006; Wahlgren et al., 2017). Receptor molecules such as blood group B and A sugars, glycophorin A (GYPA), complement receptor 1 (CR1), heparan sulfate (HS)-like molecules, and glycosaminoglycans play a part in rosetting (Barragan et al., 2000; Goel et al., 2015; Goerdeler et al., 2021).

The pathogenesis of severe malaria is aided by RIFINs, which facilitate RBC vascular binding and mediate aggregation and rosette formation (Goel et al., 2015; Sanyal et al., 2012; Tibúrcio et al., 2012). Small rosettes are formed when RIFINs bind glycophorin A on blood group O, while large rosettes are formed when RIFINs bind N-acetylgalactosamine on blood group A (Carlson & Wahlgren, 1992; Goel et al., 2015). Most rif genes have been associated with parasite-mediated rosetting (Rowe & Kyes, 2004). In a study to determine the functions of RIFINs, a semi-quantitative examination revealed that the percentage of PfEMP1 surface-positive pRBCs and RIFIN
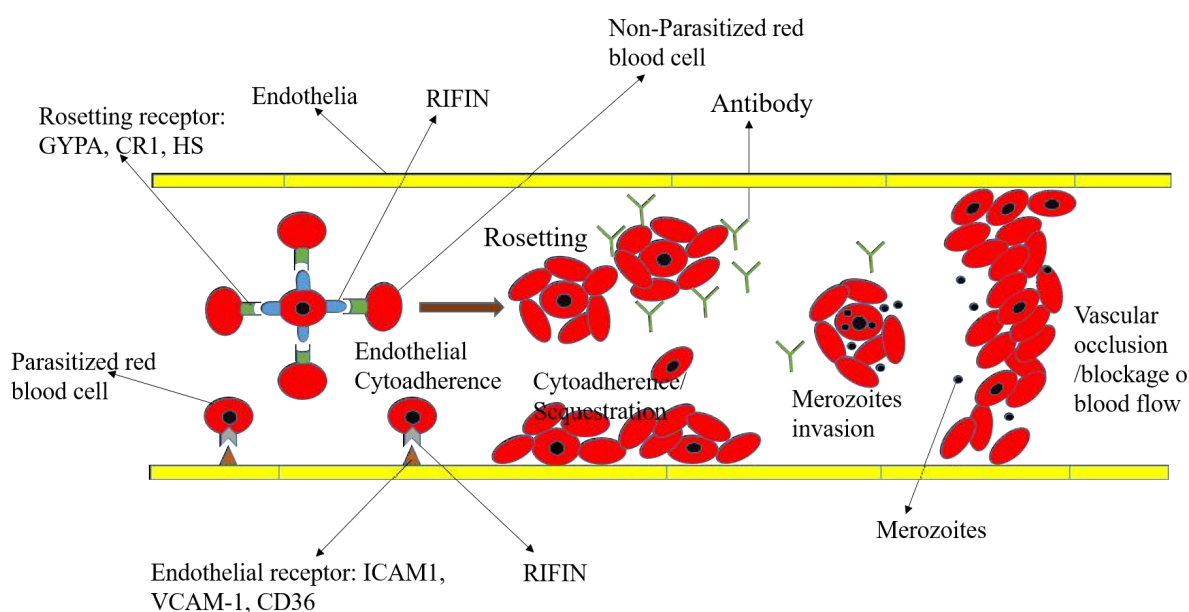

Figure 3 | Cytoadherence and rosetting phenomenon by P. falciparum RIFINs

correlated with the rates of rosetting, and upon selection for rosetting, both RIFINs and PfEMP1 were upregulated (Goel et al., 2015). These findings suggest that, likewise, PfEMP1 and RIFINs have a fundamental function in the development of severe malaria and therefore could be a potential target for therapy. Rosetting leads to the obstruction of the microvasculature and blood flow in various organs and tissues, such as in cerebral malaria (Kaul et al., 1991; Miller et al., 2002). This leads to an oxygen shortage in the tissues, excessive lactate generation, and a drop in blood and tissue pH, all of which can result in respiratory distress, coma, and severe anaemia (Pain et al., 2001). Immunoglobulin M, macroglobulin, albumin, and fibrinogen, which are host serum proteins, also aid in rosetting by either binding directly to the parasite adhesion molecules or by having non-specific effects on erythrocyte aggregation (Semblat et al., 2015).

Severe malaria

Severe malaria is characterized by pathophysiological abnormalities caused by inflammation, vascular endothelial failure, and sequestration of parasites due to high parasitaemia (Cunnington et al., 2013a; Cunnington et al., 2013b). RIFINs have been implicated in severe malaria due to their ability to mediate parasite sequestration through rosetting and cytoadherence (Cunnington et al., 2013b) (Figure 3).

The consecutive expressions of RIFINs found on the surface of pRBCs suggest a crucial role in the survival of the parasite. P. falciparum-pRBCs express RIFINs, which adhere to non-pRBCs and capillary endothelium. pRBCs employ specific RIFINs, which are expressed later in the parasite's lifecycle to adhere to receptors (ICAM1, VCAM-1, CD36) on endothelial cells to facilitate cytoadherence and sequestration to avoid splenic clearance. Rosettes are formed when pRBCs express distinct RIFINs to attach to surface receptors (GYPA, CR1, HS) on non-pRBCs. Rosetting helps with sequestration in vivo by utilizing RIFIN to adhere pRBCs to the endothelial and cause a vascular blockage, worsening of the condition, and pathogenesis of malaria. Cytoadherence and rosetting protect parasites from the host immune response and provide a convenient environment for the freshly released merozoites to enhance efficient and effective evasion.

Most malaria deaths in children are caused by three major syndromes; cerebral malaria, hyperlactatemia or acidosis, and severe anaemia (Cunnington al., 2013b; Phillips et al., 2017; Wassmer & Grau, 2017). RIFINs could interact with the host's immune cells and may cause the blood-brain barrier to break and activate endothelial cells (Pereira et al., 2020). Various rif genes are up-regulated in cerebral malaria, therefore, suggesting that they could play a major in the pathogenesis of cerebral malaria through promoting host cell invasion pathways and mediating immune system evasion in the host (Almelli, 2015; Almelli et al., 2014b).

Cytoadherence

Cytoadherence involves interactions between parasite ligands exported to the surface of pRBCs and the host endothelium receptors (Oquendo et al., 1989). The pRBCs cling to vascular endothelium and sequester in deep vasculature of different organs during the pathophysiology of severe malaria (Heddini et al., 2001; Ho et al., 1990).

The cytoadherence of Plasmodium falciparum pRBCs to host receptors is a major phenomenon in the pathological process of malaria which is linked with millions of deaths each year, especially among children in sub-Saharan Africa (Chen et al., 2000). Cytoadherence offers a survival benefit to the malaria parasites by evading host antibodies and the complement system to avoid the splenic clearance process (Barnwell et al., 1983; Cooke et al., 1995; Ho & White, 1999). The spleen filter and eliminates parasites that are unable to bind to vascular endothelium from the bloodstream (Rasti et al., 2004). Trophozoites and schizonts cytoadhere and sequestrate in deep organs' microvasculature to avoid passage through the spleen (Luse & Miller, 1971). RIFINs play a major role in the cytoadherence/microvascular binding of P. falciparum (Goel et al., 2015; Kyes et al., 1999). RIFINs enhance adherence to the capillary endothelial lining by binding to receptors such as ICAM-1, VCAM-1, CD36 (Fernandez et al., 1999; Rowe et al., 2009). RIFINs embedded in the RBCs' surface membrane mediate the adhesion of pRBCs in several microvascular beds, including the brain leading to cerebral malaria (Wahlgren et al., 2017). Malaria parasites achieve immunological protection by expressing variant RIFINs at different times to cytoadhere or form rosettes leading to microcirculatory blockage, localized hypoxia, metabolic problems and multiple organ failure (Yam et al., 2017a) (Figure 3, table 1).

Evolutionary dynamics and selection pressures

Significant variations in transcription occur during the adaptation of malaria parasites. These modifications are specific to genes implicated in the pathogenicity of malaria parasites. In particular, RIFINs demonstrate variable expression throughout the adaptation process (Chew et al., 2022). Unlike other genes, which exhibit a distinct maximum and minimum apex of expression, no such pattern is observed for RIFINs (Chew et al., 2022), which is consistent with earlier findings (Llinás et al., 2006). The variable region of RIFINs has been shown to be the main target of selection for positive diversification, and most mutation sites are found in the variable region due to high frequencies of amino acid changes in this region, and about 20 haplotypes have been identified in about 53 variable region sequences in RIFINs (Xu et al., 2023). This evolutionary adaptation could be a result of host immune pressures. RIFIN binds to immune receptors to evade the immune system by acting as a ligand for LILRB1, LILRB1, and LAIR1 or as a target for antibodies harboring anomalies. As a result, there are a large number of mutations in the variable region that evade host immune responses. McInerney and associates (2003) demonstrated that some subgroups of the RIFIN family are subject to a variety of selective pressures. Malaria-infected individuals usually develop an antibody response to RIFINs (Abdel-latif et al., 2003), and it is presumed that because they are detected by the host immune system, they are subjected to intense selective pressures. The logic for positive selection in some subgroups of RIFINs may be due to their location on the surface of the cell, their degree of expression, or possibly their marginally distinct role (McInerney et al.,

Table 1. Mechanisms and pathogenesis of *Plasmodium falciparum* RIFINs

RIFIN	Mechanisms	Pathogenesis	Reference
PF3D7_0401400	Immune evasion	Severe malaria	(Saito et al., 2017)
PF3D7_0937500	Immune evasion		(Saito et al., 2017)
PF3D7_0732200	Immune evasion		(Saito et al., 2017)
PF3D7_1479700	Immune evasion		(Saito et al., 2017)
PF3D7_1254400	Immune evasion		(Saito et al., 2017)
PF3D7_0632200	Immune evasion		(Saito et al., 2017)
PF3D7_1480000	Immune evasion		(Saito et al., 2017)
PF3D7_0700200	Immune evasion		(Saito et al., 2017)
PF3D7_0632700	Immune evasion		(Saito et al., 2017)
PF3D7_1100400	Immune evasion		(Saito et al., 2017)
PF3D7_1040700	Immune evasion		(Saito et al., 2017)
PfIT_060035900	Rosette formation		(Ch et al., 2016)
PF3D7_1254800	Immune evasion/rosetting	Severe malaria	(Harrison et al., 2020; Kassegne et al., 2020; Kaur & Hora, 2018; Saito et al., 2017)
PF3D7_0632400	Immunosuppression/evasion	Severe malaria	(Chen et al., 2021; Saito et al., 2017)
PF3D7_0324800	Immune evasion/cytoadherance	Severe malaria	(Almelli, 2015; Chen et al., 2021)
PF3D7_1041000	Immune evasion	Severe malaria	(Chen et al., 2021)
PF3D7_1300700	Immune evasion	Severe malaria	(Chen et al., 2021)
PF3D7_1300600	Transcript in gametocyte stage		(Florens et al., 2002; Mwakalinga et al., 2012; Wang et al., 2010)
PF3D7_0900500	Cytoadherence/transcript in gametocyte stage		(Florens et al., 2002)
PF3D7_0100400	Immune evasion/rosetting		(Goel et al., 2015; Saito et al., 2017)
PF3D7_0110100	Cytoadherence		(Goel et al., 2015)
PF3D7_0223100	Immune evasion	Severe malaria	(Kassegne et al., 2020; Saito et al., 2017)
PF3D7_1400600	Cytoadherence	Cerebral malaria	(Hebert et al., 2007; Kassegne et al., 2020; Xu et al., 2021)
PF3D7_1040300	Immunosuppression		(Xu et al., 2021)
PF3D7_0401200	Immunosuppression		(Xu et al., 2021)
PF3D7_1000600	Cytoadherence/rosetting		(Hebert et al., 2007; Kassegne et al., 2020)
PF3D7_0713000	Rosetting/cytoadherence		(Kassegne et al., 2020)
PF3D7_0632100	Rosetting/cytoadherence		(Kassegne et al., 2020)
PF3D7_1040900	Rosetting/cytoadherence		(Kassegne et al., 2020)
PF3D7_1300400	Immune evasion/rosetting/cytoadherence	Cerebral malaria, Severe malaria anaemia	(Almelli et al., 2014b; Kassegne et al., 2020; Lawton et al., 2022; Saito et al., 2017)
PF3D7_1254700	Rosetting/cytoadherence		(Kassegne et al., 2020)
PF3D7_1150300	Rosetting/cytoadherence	Cerebral malaria, severe malaria anaemia	(Almelli et al., 2014b; Kassegne et al., 2020; Lawton et al., 2022)
PF3D7_0808800	Rosetting/cytoadherence		(Kassegne et al., 2020)
PF3D7_0114700	Rosetting/cytoadherence	Severe malaria anaemia	(Kassegne et al., 2020; Lawton et al., 2022)
PF3D7_1101300	Rosetting/cytoadherence		(Kassegne et al., 2020)
PF3D7_1100300	Rosetting/cytoadherence	Cerebral malaria, severe malaria anaemia	(Almelli et al., 2014b; Kassegne et al., 2020)
PF3D7_0401300	Rosetting/cytoadherence		(Kassegne et al., 2020)
PF3D7_1101100	Immune evasion/cytoadherence		(Hebert et al., 2007; Saito et al., 2017)
PF3D7_0300200	Cytoadherence		(Hebert et al., 2007)
PF3D7_0631800	Cytoadherence		(Hebert et al., 2007)
PF3D7_1200500	Cytoadherence		(Hebert et al., 2007)
PF3D7_0500500	Cytoadherence		(Hebert et al., 2007)
PF3D7_0324800	Cytoadherence		(Hebert et al., 2007)
PF3D7_0114700	Cytoadherence		(Hebert et al., 2007)
PF3D7_0425700		Cerebral malaria	(Almelli et al., 2014b)
PF3D7_0401600		Cerebral malaria	(Almelli, 2015)
PF3D7_0101000	Immune evasion/Cytoadherence		(Hebert et al., 2007; Saito et al., 2017)
PF3D7_0100900		Cerebral malaria	(Almelli, 2015)
PF3D7_0324500		Cerebral malaria	(Almelli, 2015)
PF3D7_0900200	Immune evasion/Cytoadherence		(Hebert et al., 2007; Saito et al., 2017)
PF3D7_1400600	Cytoadherence		(Hebert et al., 2007)
PF3D7_0400300	Cytoadherence		(Hebert et al., 2007)
PF3D7_0400700	Cytoadherence		(Hebert et al., 2007)
PF3D7_0600300	Immune evasion		(Almelli, 2015; Saito et al., 2017)
PF3D7_0600800		Cerebral malaria	(Almelli, 2015)
PF3D7_0100200	Immune evasion		(Kassegne et al., 2020; Saito et al., 2017)
PF3D7_1000200	Immune evasion		(Saito et al., 2017)

2003). Positive selection will be evident only if the adaptive advantage offered by the mutation is adequate to overcome the random drift of genes (McInerney et al., 2003). Therefore, a protein will not be under the same selective pressure as one that is produced more frequently and/or has the ability to trigger a robust adaptive immunological response if it is only infrequently expressed or if it does not stimulate an intense antibody reaction. In a study to determine the natural selection and genetic diversity in the global populations of Plasmodium falciparum, Xu and colleagues showed that RIFINs from Ghana-imported cases had the highest level of genetic diversity among cases from Thailand, Cambodia, Myanmar, Vietnam, Mali, and Senegal (Xu et al., 2023), which indicates that climate affects RIFINs as well as the parasite life cycle and transmission. This identifies significant differences in RIFIN patterns that may have significant effects on the development of RIFIN-based vaccines.

Therapeutic Implications

RIFINs are a family of surface-exposed, antigenically varied proteins that play a role in rosetting and immune evasion. Immune evasion is a key survival mechanism for pRBCs, and it offers surface-exposed molecules involved in this process the potential to be targets for drugs or vaccines. Rosetting is a mechanism that plays a role in the pathophysiology of severe malaria (Carlson et al., 1990; Kaul et al., 1991; Rowe et al., 1995; Wahlgren et al., 1992), and molecules that prevent the occurrence of rosetting could be produced primarily for use in treating the disease. The ability of RIFINs to form rosettes independently of PfEMP1 (Yam et al., 2017b) makes them potential candidates for therapy. There may be a protective role for anti-RIFIN antibodies due to their correlation with both long-term persistence and quick parasite clearance in the sera of malaria-affected patients (Abdel-latif et al., 2003). These results collectively demonstrate the potential of RIFIN proteins as therapeutic targets and vaccination candidates.

Future Perspectives

A thorough understanding of the roles played by RIFINs is required to fully grasp the relationship between antigenic variation on the surface of pRBCs and parasite-induced diseases. Comprehensive transcriptome and proteomic analysis would be necessary for target identification since RIFINs exhibit variable expression, clonal variation, and antigenic switching. Furthermore, there is a dearth of structural and functional information on individual members of the RIFIN family. Members of the RIFIN family, along with PfEMP1, appear to be desirable additions to multistage and multisubunit vaccines due to their multistage transcription and roles in immune escape. To produce widely reactive antibodies against these RIFINs, it is critical to either find a highly immunogenic component expressed at all stages of parasite development or develop a common sequence that utilizes surface-exposed conserved epitomic sections of RIFINs.

Abbreviations

PfEMP1	Plasmodium falciparum erythrocyte membrane protein 1
RIFIN	Repetitive interspersed family proteins
STEVOR	Subtelomeric variable open reading frame proteins
PRBCs	Parasitized red blood cells
DC8	Domain cassette 8
DC13	Domain Cassette 13
CD36	Cluster of differentiation 36 receptor
ICAM-1	Intercelullar adhesion molecule 1
EPCR	Endothelial protein C receptor
CSA	Chondroitin sulfate A
MCs	Maurer's clefts
PEXEL	Plasmodium export element
VTS	Vacuolar transport signal
TM	Transmembrane
VSA	Variable surface antigen
GYPA	Glycophorin A
VCAM-1	Vascular cell adhesion molecule 1
CR1	Complement receptor 1
HS	Heparan sulfate
RBC	Red blood cell
SURFIN	Surface-associated interspersed gene family

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REVIEW ARTICLE

Electronic Health Record Impact on Data Quality: An Integrated Review

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Abstract

Background: Few studies have assessed the impact of Electronic Health Record (EHR) on data quality and how it has impacted timeliness, accuracy, availability, integrity, consistency and uniqueness of health data. Assessing the current gaps between electronic health record utilisation in relation to enhancing data quality can help to identify and recommend key measures to improve healthcare delivery.

Objective: This review examines the impact of electronic health record on data quality, and proposes recommendations desirable to improving healthcare delivery.

Materials and methods: Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) and Integrative Review Frameworks (IRF) were adapted as a sign post for the study. These frameworks guided literature search, data analysis and presentation of findings. Boolean AND/OR operators were combined with search terms to increase relevant search results. Six (6) electronic databases that were used for literature search are Scopus, Web of Science, Science Direct, PubMed, ProQuest and Google Scholar. Searched articles were between 2012 to 2022, with the exception of two articles on the Technology Acceptance Model (TAM) published in 1986 and 1975.

Results: EHR implementation impact key health outcomes and contribute to timely and complete data submission. Implementation of Electronic Health Systems (EHS) embellish consistency, completeness, accuracy and integrity of clinical data significantly through embedded interoperability solutions. By reducing the scope of manual reviews, integrating a technology that automates data integrity and quality checks into EHR may potentially lessen the strain of maintaining data quality.

Conclusion: Our findings depict that interoperability of clinical data sources will ensure consistent, timely and available health data when using EHR. The automated data integrity and consistency checks in the EHR improve data quality. The study contributes to advancing the theory of Technology Acceptance Model (TAM) in electronic health records and its impact on data quality in healthcare delivery.

Keywords: Electronic Health Record, Data Quality, eHealth, Health Data, Quality Healthcare

Introduction

Few studies have examined the impact of EHR on data quality (Kutney-Lee et al., 2019). There have been initiatives to mitigate data quality issues, yet, data quality issues remain unresolved due to data popularity and open data (Nikiforova, 2020). As postulated by Ali et al., (Ali et al., 2018), data that are relevant, accurate, valid, readable, trustworthy, complete, and available when needed by decision-makers for healthcare delivery and planning purposes are referred to as having high data quality. Health data use for decision-making in the health industry has been hampered by concerns about the quality of the information (Rumisha et al., 2020). Monitoring, analyzing, and optimizing the delivery of healthcare services and programs requires precise and reliable health information. (Mphatswe et al., 2012).

Paper-based record systems are prone to data quality defects, hence, the need to implement EHR to address these limitations (Adane et al., 2021). Low-and-medium-income countries (LMICs) are implementing EHR systems with the aim of enhancing quality of clinical data, which will improve health reporting and clinical practice (Ngugi et al., 2021). The implementation of these healthcare systems are mostly affirmed by the Technology Acceptance Model (TAM) proposed by Davis1 (Davis, 1986) as a well-known and well-accepted theory used to understand how new technologies and improvements in information and technology systems are accepted. Its elements are known to predict, explain, and govern acceptance in early TAM research (Fishbein and Ajzen, 1975). To support the idea of innovations, in healthcare systems researchers ultimately use the TAM model.

EHR adaption or adoption results in quality and safer care in hospitals (Kutney-Lee et al., 2019). Integrating data mining systems into electronic health records can ensure real-time access to relevant clinical information (Mohd Nor et al., 2019). Also, implementing electronic health record with standardised and structured recording of patient data may enhance data usability. It is essential to indicate that, standards set forth by the local government, such as data sharing protocols can affect data timeliness, which is a dimension of data quality (Tran et al., 2022). Electronic health record also has limitations that may influence the quality of health data (Makeleni & Cilliers, 2021). Lack of feedback from an electronic health record can lead to complacency at operational level, which may negatively affect data quality (Gumede-Moyo et al., 2019). Healthcare Professionals in high-income countries like United States of America find data entry and information retrieval using EHR as time consuming (Kutney-Lee et al., 2019). Funding gaps during implementation or post-implementation of electronic health record can result in data collection disparities, negatively affecting data completeness (Gumede-Moyo et al., 2019). Based on the above expeditions, this study seeks to examine the impact of electronic health record on data quality, and propose recommendations for improving healthcare delivery.

Methods

PRISMA and IRF were adopted to guide this study. These frameworks guided literature search, data analysis and presentation of findings. Boolean AND/OR operators were combined with search terms to increase relevant search results. Six (6) electronic databases that were used for literature search are Scopus, Web of Science, Science Direct, PubMed, ProQuest and Google Scholar. These databases were selected due to their reliability, the amount of data they keep, and the importance of the articles they contain with reference to data quality management and electronic health records. Several features of data collected in the healthcare sector are still obscure, and research expertise on its influence on data quality is still being developed. Quantitative, qualitative and mixed-method studies, which were published in peer-review journals that focused on the themes: electronic health record, health data, data quality, eHealth and healthcare were downloaded.

Text Selection

Searched articles were between 2012 to 2022, with the exception of two articles on the Technology Acceptance Model published in 1986 and 1975. After a meticulous search from six databases 1258 studies were identified. Mendeley reference management system was used to eliminate 563 duplicate papers. The inclusion criteria of the study were applied to screen the title, keywords and abstracts of the remaining 695studies. Post screening, 113 articles remained for full text evaluation. The inclusion criteria were that, literature must be:

- published between the periods of 2012 to 2022, except articles on TAM.
- relevant to study title, keywords and objectives.
- written in English Language.
- a peer-review journal paper.

Twenty-eight articles were selected, after 85 articles failed to meet the inclusion criteria. Table 1 shows the chosen databases, number of identified studies, number of included studies and the various percentages from the chosen databases. Figure 1 also shows the PRISMA flow for the process of selecting articles with the inclusion and exclusion criteria.

Table 1: Databases, Number of Identified and Included Studies, and Percentages of Included Studies

Electronic Databases	Number of Identified Studies	Number and Percentage of Included Studies
Scopus	304	9(32)
Web of Science	111	4(14)
Science Direct	102	3(11)
PubMed	191	5(18)
ProQuest	209	3(11)
Google Scholar	341	4(14)

Methodological Quality of Studies

To determine the quality of a selected study, five questions were posed requesting 'Yes' or 'No' response such as:

i. Has the objective of the study been clearly stipulated?

ii. Does the article address any thematic area of this study?

iii. Will inclusion of this article help attain the objective of this study?

iv. Were the findings of the study well elaborated?

v. Were data analysis adequately robust?

The quality assessment studies based on the criteria identified 28 studies as shown in table 2.

Results

In all, twenty-eight articles were included in this study. The included articles were categorised into four themes, excluding the two articles on TAM included in the introduction. Six articles representing 23% elaborated on
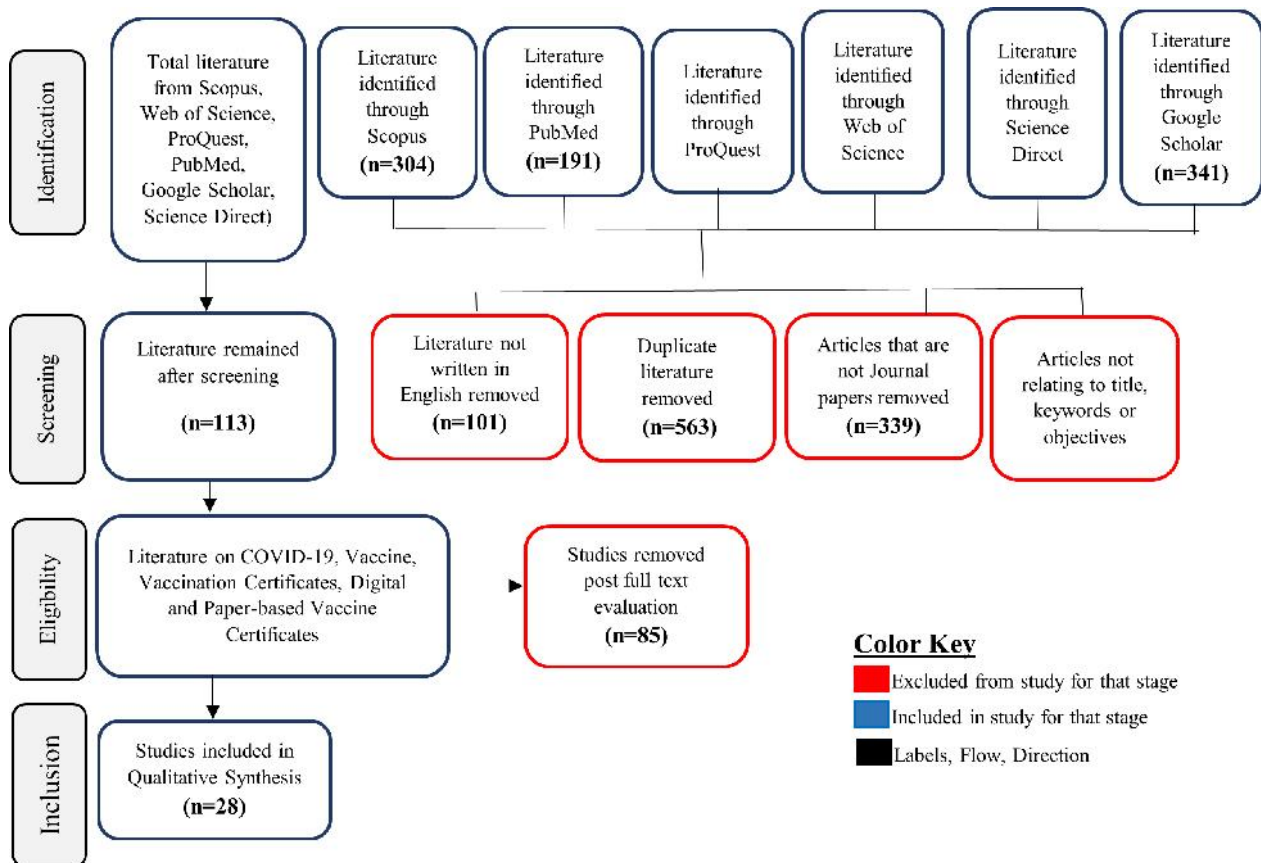
Figure 1: PRISMA Flow for Process of Article Inclusion and Exclusion

Table 2: Methodological Quality of Studies

	Studies	i	ii	iii	iv	v	Scores
1	(Nikiforova, 2020)	Yes	Yes	Yes	Yes	Yes	5/5
2	(Rumisha et al., 2020)	Yes	Yes	Yes	Yes	Yes	5/5
3	(Mphatswe et al., 2012)	Yes	Yes	Yes	Yes	Yes	5/5
4	(Adane et al., 2021)	Yes	Yes	Yes	Yes	Yes	5/5
5	(Ngugi et al., 2021)	Yes	Yes	Yes	Yes	Yes	5/5
6	(Kutney-Lee et al., 2019)	Yes	Yes	Yes	Yes	Yes	5/5
7	(Shiferaw et al., 2018)	Yes	Yes	Yes	Yes	Yes	5/5
8	(Ali et al., 2018)	Yes	Yes	Yes	Yes	Yes	5/5
9	(Atinga et al., 2020)	Yes	Yes	Yes	Yes	Yes	5/5
10	(Agniel et al., 2018)	Yes	Yes	Yes	Yes	Yes	5/5
11	(Tizifa et al., 2021)	Yes	Yes	Yes	Yes	Yes	5/5
12	(Tian et al., 2021)	Yes	Yes	Yes	Yes	Yes	5/5
13	(Makeleni & Cilliers, 2021)	Yes	Yes	Yes	Yes	Yes	5/5
14	(Kpobi et al., 2018)	Yes	Yes	Yes	Yes	Yes	5/5
15	(Artis et al., 2017)	Yes	Yes	Yes	Yes	Yes	5/5
16	(Gumede-Moyo et al., 2019)	Yes	Yes	Yes	Yes	Yes	5/5
17	(Tran et al., 2022)	Yes	Yes	Yes	Yes	Yes	5/5
18	(Roomaney et al., 2017)	Yes	Yes	Yes	Yes	Yes	5/5
19	(Hutchinson et al., 2021)	Yes	Yes	Yes	Yes	Yes	5/5
20	(Moukénet et al., 2021)	Yes	Yes	Yes	Yes	Yes	5/5
21	(Joukes et al., 2019)	Yes	Yes	Yes	Yes	Yes	5/5
22	(Monda et al., 2012)	Yes	Yes	Yes	Yes	Yes	5/5
23	(Mohd Nor et al., 2019)	Yes	Yes	Yes	Yes	Yes	5/5
24	(Walcott-Bryant et al., 2021)	Yes	Yes	Yes	Yes	Yes	5/5
25	(Thuraisingam et al., 2021)	Yes	Yes	Yes	Yes	Yes	5/5
26	(Bhattacharya et al., 2020)	Yes	Yes	Yes	Yes	Yes	5/5
27	(Davis, 1986)	Yes	Yes	Yes	Yes	Yes	5/5
28	(Fishbein and Ajzen, 1975)	Yes	Yes	Yes	Yes	Yes	5/5

the introduction and background of electronic health record and data quality. Articles that expounded on the positive impact of electronic health record on data quality were 6 (23%). Again, 7 (27%) of the total included papers scrutinised limitations of electronic health record with regards to data quality. Also, the remaining 7 (27%) of the papers proposed recommendations to mitigate the identified limitations of electronic health record with regards to data quality.

Included articles in the summary characteristics were from 19 different countries. Table 3 shows the distribution of countries with included studies.

All chosen articles for the study had similar characteristics, this has been summarized in Table 4 with the captions, year of publications, citation of authors, study location, title of the articles and some key findings identified in each article. The various articles have also been segmented based on a colour code system in the table.

Table 3: Distribution of Included Studies Based on Themes (Excluding Articles on TAM)

Colour Key	Description	Number of Included Studies (%)
	Introduction and Background to Electronic Health Record and Data Quality	6 (23)
	Positive impact of Electronic Health Record on Data Quality	6 (23)
	Identified Limitations of Electronic Health Record with regards to Data Quality	7 (27)
	Recommendations to mitigate the limitations of Electronic Health Record with regards to Data Quality	7 (27)

Table 4: Distribution of Countries of Included Studies in the Summary Characteristics

Countries	Included Articles	Countries	Included Articles
South Africa	4	Vietnam	1
United States of America	3	Zambia	1
Kenya	3	China	1
United Kingdom	2	Australia	1
The Netherlands	2	Malaysia	1
Ethiopia	2	Chad	1
Ghana	1	Pakistan	1
Tanzania	1	Latvia	1

Table 5: Summary Characteristics of Studies Included

Year of Publication	Author Name	Study Location	Title	Key Finding
2020	Nikiforova,	Faculty of Computing, University of Latvia, Latvia.	Definition and evaluation of data quality: user-oriented data object-driven approach to data quality assessment.	Data quality issues have existed since 1960's. Data Quality issues remain unresolved due to data popularity and open data.
2020	Rumisha et al.,	National Institute for Medical Research, Tanzania.	Data quality of the routine health management information system at the primary healthcare facility and district levels in Tanzania.	Data utilisation for decision-making in the health industry has been hindered by worries about the accuracy of health information.
2012	Mphatswe et al.,	Department of Paediatrics and Child Health, University of Kwazulu-Natal, South Africa.	Improving public health information: a data quality intervention in Kwazulu-Natal, South Africa.	For the purposes of monitoring, assessing, and improving healthcare service delivery and programmatic initiatives, accurate and reliable health information is crucial.
2021	Adane et al.,	Ethiopian Pharmaceutical Supply Agency, Addis Ababa, Ethiopia.	Exploring data quality and use of the routine health information system in Ethiopia: a mixed-methods study.	Paper-based record systems are faced with issues like availability of register books, variations in choice of denominators based on population estimates, hence, the need to implement EHR to address these limitations.
2021	Ngugi et al.,	Institute of Biomedical Informatics, Moi University, Kenya.	Development of standard indicators to assess use of electronic health record systems implementation in low-and medium-income countries.	Low-and-medium-income countries (LMICs) are implementing EHRs with the aim of enhancing quality of clinical data, which will improve health reporting and clinical practice.
2019	Kutney-Lee et al.,	Center for Health Outcomes and Policy Research, University of Pennsylvania, USA.	Electronic health record adoption and nurse reports of usability and quality of care: the role of work environment.	Few studies have examined the impact of EHR on data quality. EHR adoption results in safer and quality care in hospitals.

2018	Shiferaw et al.,	Addis Ababa University, Ethiopia.	Designing mHealth for maternal services in primary health facilities in low-income setting: lessons from a partially successful implementation.	Implementation of EHR can impact key health outcomes and contribute to timely and complete data submission.
2018	Ali et al.,	Mercy Corps, Pakistan.	Data quality: a negotiator between paper-based and digital records in Pakistan's TB control program.	Digital records have minimal data quality issues as opposed to paper-based records that have relatively higher data quality issues. More useful information for decision-making can be delivered by maximizing mobile data capture using continuous EHR data quality assessment.
2020	Atinga et al.,	University of Ghana, Ghana.	E-health usage and health workers' motivation and job satisfaction in Ghana.	Electronic health usage in Ghana has led to timely access to health information, such as patients' and administrative records, and diagnostic and treatment records.
2018	Agniel et al.,	Department of Biomedical Informatics, Harvard Medical School, USA.	Biases in electronic health record data due to processes within the healthcare system: retrospective observational study.	Electronic health record ensures real-time big data availability.
2021	Tizifa et al.,	Department of Infectious Diseases, University of Amsterdam, The Netherlands.	Leveraging phone-based mobile technology to improve data quality at health facilities in rural Malawi: a best practice project.	Electronic health system implementation improves consistency, completeness, and accuracy of data significantly.
2021	Tian et al.,	College of Biomedical Engineering and Instrument Science, Zhejiang University, China	Application of open EHR archetypes to automate data quality rules for electronic health records: a case study.	Some EHRs have integrated Data Quality Rules (DQRs), which measures data quality level of each indicator (accuracy, timeliness, consistency, completeness, integrity) and replaces the traditional time-consuming mode of assessing data quality.
2021	Makeleni & Cilliers,	Department of Information Systems, University of Fort Hare, South Africa.	Critical success factors to improve data quality of electronic medical records in public health institutions.	EHRs offer advantages to medical facilities that effectively deploy and use the system, but they may also introduce their own flaws that could impair the quality of the data.
2018	Kpobi et al.,	Alan J. Flisher Centre for Public Mental Health, Stellenbosch University, South Africa.	Challenges in the use of the mental health information system in a resource-limited setting: lessons from Ghana.	The success of a new system is not guaranteed by its setup. An electronic health record's usefulness depends on its appropriate setup and upkeep.
2017	Artis et al.,	Department of Medicine, Oregon Health and Science University, USA.	Accuracy of laboratory data communication on ICU daily rounds using an electronic health record.	Post EHR implementation, there can be inaccuracies and omissions in patient data, which highlights patient safety issues.
2019	Gumede-Moyo et al.,	School of Public Health., University of Zambia, Zambia.	A qualitative inquiry into implementing an electronic health record system (SmartCare) for prevention of mother-to-child transmission data in Zambia: a retrospective study.	The absence of feedback from an electronic health record might cause operational complacency, which can result in poor data quality.
2022	Tran et al.,	Oxford University Clinical Research Unit, Vietnam.	Digital Health Policy and Programs for Hospital Care in Vietnam: Scoping Review	Local governments' requirements and regulations such as data sharing protocols can affect data timeliness, which is a dimension of data quality.
2017	Roomaney et al.,	South African Medical Research Council, South Africa.	Availability and quality of routine morbidity data: review of studies in South Africa.	The elements that make up data quality are mainly shared across frameworks used to analyze health information systems.
2021	Hutchinson et al.,	London School of Hygiene & Tropical Medicine, United Kingdom.	Opening the 'black box' of collaborative improvement: a qualitative evaluation of a pilot intervention to improve quality of malaria surveillance data in public health centres in Uganda	It is important to address data quality issues associated with EHR because, incomplete, inaccurate, or delayed data restricts the data's reliability and usefulness.

2021	Moukénet et al.,	Malaria Consortium Chad Country Office, Chad.	Health management information system (HMIS) data quality and associated factors in Massaguet district, Chad.	Workload is linked to a higher likelihood of inaccuracy. Moreover, lesser inaccuracy was linked to the availability of dedicated workers and health technicians.
2019	Joukes et al.,	Department of Medical Informatics, University of Amsterdam, The Netherlands.	Impact of electronic versus paper-based recording before EHR implementation on health care professionals' perceptions of EHR use, data quality, and data reuse.	Organising pre-implementation data recording practice can positively influence quality of clinical data post EHR implementation.
2012	Monda et al.,	School of Medicine, Moi University, Kenya.	Data integrity module for data quality assurance within an e-Health system in Sub-Saharan Africa.	Integrating a tool that automates data integrity and quality checks into EHR will reduce potential burden of maintaining data quality by limiting the scale of manual reviews.
2019	Mohd Nor et al.,	Department of Surgery, University Malaya Medical Centre, Malaysia.	Development of electronic medical records for clinical and research purposes: the breast cancer module using an implementation framework in a middle-income country –Malaysia	Integrating multiple clinical visit data sources into Electronic Health Record may provide comprehensive, accurate and real-time update of patient record.
2021	Walcott-Bryant et al.,	IBM Research Africa, Kenya.	Addressing care continuity and quality challenges in management of hypertension: case study of the private health care sector in Kenya.	Digital health data interoperability solutions can enhance data consistency and maintain data integrity.
2021	Thuraisingam et al.,	Department of Surgery, University of Melbourne, Australia.	Assessing the suitability of general practice electronic health records for clinical prediction model development: a data quality assessment.	Data accuracy and completeness exceeds just EHR implementation. Health staff and clinicians must have the ability and competence to effectively use the EHR system.
2020	Bhattacharya et al.,	Department of Disease Control, London School of Hygiene & Tropical Medicine, United Kingdom.	Improving the quality of routine maternal and newborn data captured in primary health facilities in Gombe State, Northeastern Nigeria: a before-and-after study.	The correctness, completeness, and internal consistency of data can be improved after the deployment of an EHR by assuring regular self-assessments of data quality, peer-review and feedback, workshops, and work planning for improvement.

Discussion

This review examines the impact of electronic health record on data quality, scrutinises the limitations of electronic health record with regards to data quality, and proposes recommendations to the identified limitations.

Impact of Electronic Health Record on Data Quality

Electronic Health Record implementation can impact on the key health outcomes and contribute to timely and complete data submission (Shiferaw et al., 2018). Agniel et al., (2018) elaborates that, electronic health record ensures real-time big data availability as a result of easy filing and retrieval of clinical or patient record. As postulated by Ali et al., (2018), digital records have minimal data quality issues as opposed to paper-based records. Ali et al., (2018) further expounds that, electronic health record can deliver more meaningful information for decision making by maximising its mobile data capture and continued data quality assessment features. In Ghana, electronic health system usage has led to timely access to health information such as patients' and administrative records, and diagnostic and treatment records (Atinga et al., 2020). Implementation of electronic health systems

embellish consistency, completeness, accuracy and integrity of clinical data significantly through embedded interoperability solutions (Tizifa et al., 2021; Walcott-Bryant et al., 2021). Some electronic health record systems have integrated Data Quality Rules (DQRs), which applies automation to measure data quality level of each indicator (accuracy, timeliness, consistency, completeness, integrity) and replaces the traditional time-consuming mode of assessing data quality (Tian et al., 2021).

Although electronic health records provide benefits to health facilities that successfully implement and utilise these systems, it may also introduce its own limitations that may affect data quality (Makeleni & Cilliers, 2021). Patronising a new electronic system does not warrant its success (Kpobi et al., 2018). Even after implementation of electronic health record, there can be inaccuracies and omissions in patient data if clinicians and health staff are not well oriented on how to effectively use the system (Artis et al., 2017). Even in high-income country like the United States of America, nurses and other healthcare professionals find data entry and information retrieval as time consuming and expressed doubts in the ability of electronic health record to enhance patient care (Kutney-Lee et al., 2019). Accuracy and completeness of health data

can be negatively affected when there is no feedback from the EHR. This is because, lack of feedback from the system results in complacency at operational level (Gumede-Moyo et al., 2019). Frameworks that analyse health information systems mostly overlap, affecting integrity and consistency of data in electronic health records (Roomaney et al., 2017).

Recommendations to mitigate limitations of electronic health record with regards to data quality

According to Moukénet et al., (2021), a study with data sources from paper-based records and health management information systems (HMIS), there is a correlation between workload and increased probabilities of inaccurate data. From this, it can be inferred that, reducing workload of health staff may also reduce data inaccuracies. Also, lower inaccuracy was correlated with having a dedicated team and health technician. (Moukénet et al., 2021). Organising pre-implementation data documentation practice can positively influence post implementation data quality (Joukes et al., 2019). Integrating a tool that automates data integrity and quality checks into EHR system will reduce potential burden of maintaining data quality (Monda et al., 2012). Integrating multiple clinical data sources into a single electronic health record system may provide comprehensive, accurate and real-time update of patient record (Mohd Nor et al., 2019). Also, digital health data interoperability solutions can enhance data consistency and maintain data integrity (Walcott-Bryant et al., 2021). Orienting health staff and clinicians on how to properly document health data can enhance their ability and competence to effectively use the EHR system (Thuraisingam et al., 2021). In addition, the accuracy, completeness, and internal consistency of health data can be improved through routine self-evaluation of data quality, peer review, and feedback, supportive supervision, workshops, and work planning for improvement (Bhattacharya et al., 2020).

Conclusion

In two different ways, our investigation advances the theories (Technology Acceptance Model-TAM) in electronic health records and its impact on data quality in healthcare delivery. Firstly, our study contributes to the emerging field of technology acceptance theory of interoperability on clinical data sources to ensure consistent, timely and available health data when using electronic health record. In this regard, we assert that only adaptive EHR systems with the desired network and appropriate data managing tools that fits the healthcare industry should be introduced to healthcare professionals. The impact of the EHR system and data quality would facilitate working processes and help make rapid informed decision.

Secondly, our study contributes to TAM theory of automated data integrity and consistency checks in EHRs, which improves data integrity, accuracy and completeness. Electronic health record requires that stakeholders in the health industry develop strategies that go beyond mitigating damages when crises such as difficulty in obtaining patient data occurs. Healthcare facilities must include the development of a robust and continuous

information sensing system; that can constantly feed healthcare facilities with complete, timely, accurate, consistent and relevant updates that has the potential to predict threats to healthcare stability. These will be fruitless if there are no intense orientation and periodic training for operational level health staff before, during and after implementation of electronic health record. The study also contributes to advancing the frontiers of healthcare technologies.

Quintessential of academic studies, there were some limitations to this study. For instance, only six databases were used to gather the studies for the literature search. This might imply that all other research that weren't based on these sources were disregarded. The results of this research could be limited by the few papers (28) that were included. As a result, other articles with relevant material were ignored and devalued due to the strict inclusive and exclusive criteria used. The results of this study are severely constrained by the methodological shortcomings of the parent studies, namely the sampling methods used to choose reviewed materials in primary investigations. This is because the majority of these studies did not explicitly state how participants were chosen and recruited, which may restrict the generalizability of their findings.

This review largely contributes to the understanding of the overall effects of EHR on the quality of the data in particular databases. The proposed integration of electronic healthcare systems must be further investigated in order to determine whether it will have a positive impact on the future quality of healthcare data. In order to comprehend the many scenarios of EHR efficacy and efficiency on data quality based on historical records and future projections, this study needs more primary-based data that can be simulated.

Declarations

Author Contributions

Conceptualization, JK, and CA formal analysis, investigation, and data curation, JK, and CA,. formal data analysis and results interpretation, JK, and CA. writing, original draft preparation, JK and CA; writing, review and editing, JK,CA, TA and AAK. All authors have read and agreed to the published version of the manuscript.

Ethics approval and consent to participate:

Not applicable

Consent for publication

All authors have provided their consent for the manuscript to be submitted for review and publication

Availability of data and materials:

Pieces of Literature analysed during the current study are available online and can also be made available through the corresponding author upon request.

Conflicts of Interest:

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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