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Original Research Article

Assessment of cryogenic safety practices, exposure and occupational hazards in embryology laboratories of IVF clinics in Abuja, Nigeria

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ABSTRACT

Background: Assisted reproductive technology (ART) laboratories have cryogenic storage, which allows the long-term storage of gametes and embryos using liquid nitrogen in place of short-term storage. Although it is essential, cryogenic operations are known to create serious occupational hazards to the laboratory staff where there are no adequate safety measures. The study evaluated cryogenic safety practices, pattern of exposure, occupational hazards and compliance pattern among embryology laboratory staff in Abuja, Nigeria *in vitro* fertilizations (IVF) clinics.
Methods: A cross-sectional study of embryology lab staff in Abuja in selected IVF clinics was done in a descriptive study. The respondents filled a self-administered, structured questionnaire, which included data on cryogenic safety practices, exposure to cryogenic hazards and history of accidents. Frequencies and percentages were summarised using descriptive statistics. Principal component analysis (PCA) was used to identify underlying dimensions of cryogenic safety compliance across measured safety practices.
Results: The majority (90.24%) of respondents were directly involved in cryogenic storage, handling or supervision. 58.54% reported direct exposure to cryogenic liquids and 34.15% reported cryogenic related laboratory accidents. Principal component analysis identified two distinct dimensions of cryogenic safety compliance, reflecting procedural-behavioral practices and equipment monitoring activities.
Conclusions: High levels of staff exposure to cryogenic systems coexist with inconsistent engineering controls and uneven adherence to safety practices. The multidimensional compliance structure identified highlights the need for cryogenic safety management strategies that address both behavioral–procedural compliance and equipment monitoring practices in ART laboratories.

Keywords: Assisted reproductive technology, Cryogenic safety, Embryology laboratory, Occupational hazards, Safety compliance

INTRODUCTION

The process of assisted reproductive technology (ART) is inseparable from cryogenic storage, which allows frozen storing gametes and embryos in liquids with the help of liquid nitrogen. The safety of these systems is core to clinical success and confidence of patients, whereas safe functionality is the key to safety of embryology laboratory workers who regularly work with cryogenic devices.[1] The special occupational health and safety risks of liquid nitrogen are cold-burns, frostbites, splashed injury, and displacement of oxygen.[2] The hypoxia that is brought about by nitrogen is especially dangerous since it is fast and colorless and, in most cases, without specialized

monitoring equipment, it is not noticed.[3] According to the recent laboratory safety analysis, engineering controls, including oxygen deficiency warning systems and sufficient ventilation are necessary in reducing these risks.[4]

In addition to cryogenic-related risks, the embryology lab staff can experience cumulative occupational risks associated with long-term work with microscopes or repetitive manual work, monotonous work, and burnout due to cognitive and emotional loads.[5] Research studies in laboratory staff members and healthcare workers have shown that such exposures are related to musculoskeletal disorders, fatigue, and work-related stress.[5,6] Regulatory and professional organizations in various countries have developed new guidelines on safety and risk management in laboratories working in ARTs.[7,8] These suggestions focus on regular checking of the cryogenic equipment, written standard operating procedures, staff training, and the use of personal protective equipment on a regular basis.[1,9] Nonetheless, there are recent indications that the standards are not implemented consistently across geographic areas and institutions, especially in low and middle-income nations, in which the enforcement of these regulations might be uneven.[10]

In Nigeria, IVF services are rapidly growing and this has augmented the volume of embryology labs functioning under dissimilar infrastructures and regulations. Although some studies conducted in the past have mainly concentrated on clinical outcomes and service provision, the amount of empirical evidence about cryogenic safety practices, occupational exposure, and experiences of hazards in the embryology laboratory staff is limited.

The main purpose of the study was hence to evaluate the safety practice related to cryogenics, exposure patterns as well as occupational hazard on the embryology laboratory workers operating in IVF clinics in Abuja, Nigeria. Through creating context-specific evidence, the study added to the better management of laboratory safety and occupational health practices in ARTs.

METHODS

Study design and setting

The research design used in this study was a descriptive cross-sectional study which aimed at measuring the cryogenic safety practices, patterns of exposure, and occupational hazards in embryology labs of chosen *in-vitro* fertilization (IVF) clinics in Abuja, Nigeria. The choice of Abuja was made as it is experiencing an increase in the number of fertility clinics.

The study was conducted between February 2025 and August 2025. The study was conducted at Primecare Fertility Clinic Ltd, located in Garki, Abuja, Nigeria.

Study population and eligibility criteria

The population of the study was represented by the staff of embryology laboratories that consisted of clinical embryologists, embryologists, embryologist trainees, and laboratory technicians. The eligible participants included staff that had a minimum of six months working experience in the laboratory and who were actively engaged in the cryogenic storage, handling or other laboratory processes.

Sample size and sampling technique

At the time of this study, eligible embryology laboratory workers were put at about 70 to be working in registered IVF clinics in Abuja. Such a specialised nature and limited size of the target population led to adoption of non-probability purposive sampling method. There were 41 eligible respondents who agreed to participate and take part in the study. This was deemed suitable where the focus of the exploratory occupational health research was on specialised professional groups.

Data collection instrument

A structured, self-administered questionnaire adapted from internationally valid occupational health and safety measures was used as a template to design the questionnaire used to gather the data.[21,6] The questionnaire was designed based on the working environment of the embryology laboratories in Nigeria and it was divided into seven parts that encompassed aspects of the respondent, laboratory environment, cryogenic safety precautions, hazard exposures, history of accidents and control measures.

Validity and reliability

Expert review of the instrument provided content and face validity. The piloting activity was done on five embryology laboratory staff based in an IVF clinic in Abuja who qualified to be included in the study but were not included in the main study.

Data analysis

The Statistical Package of the Social Sciences (SPSS) version 26 was used to enter and analyse the data. The categorical variables were summarised using descriptive statistics in terms of frequencies and percentages. Principal component analysis (PCA) was carried to identify latent dimensions fundamental cryogenic safety compliance practices among embryology laboratory staff. Kaiser–Meyer-Olkin measure of sampling adequacy and Bartlett's test of sphericity was used to ascertain the suitability of the data for PCA.

RESULTS

The characteristics of the respondents are summarized in Table 1.

Table 1: Socio-demographic characteristics of the respondents.

Variable	Frequency	Percentage
Job role		
Clinical Embryologist	19	46.34
Embryologist	11	26.83
Embryologist Trainee	8	19.51
Laboratory Technician	3	7.32
Total	41	100
Sex		
Male	12	29.27
Female	29	70.73
Total	41	100
Age in years		
20-29	11	26.83
30-39	17	41.46
40-49	8	19.51
50-59	5	12.20
Total	41	100
Qualification attained		
Interns	9	21.95
B.Sc	15	36.59
M.Sc	8	19.51
MBBS	6	14.63
PhD	3	7.32
Total	41	100
Experience (years)		
<1	3	7.32
1-3	13	31.71
4-6	9	21.95
>6	16	39.02
Total	41	100
Working hours per week		
<40	13	31.71
40-50	17	41.46
51-60	6	14.63
>60	5	12.20
Total	41	100
Shift rotation		
Yes	13	31.71
No	21	51.22
Occasionally	7	17.07
Total	41	100

Source: Data Analysis, 2025

Among the respondents, the highest percentage was represented by clinical embryologists (46.34%), embryologists (26.83%), embryologist trainees (19.51%), and laboratory technicians (7.32). Majority (70.7) of the respondents were female with most aged between 30-39 years (41.5%). In terms of qualifications, the largest group held a B.Sc. degree (36.6%), followed by interns (21.9%) and M.Sc. holders (19.5%). Almost half (39.02%) of the respondents had over six years of professional experience. The majority (41.46%) of the participants worked 40-50 hours a week, with 12.20% of the participants reporting that they worked over 60 hours a week. Only (31.71%) of the participants reported shift rotation with 51.22% having no shift-based responsibilities (Table 1).

The result of cryogenic safety practices is presented in Table 2.

Table 2: Cryogenic safety practices and control measures.

Variable	Frequency	Percentage
Involvement in cryogenic storage, handling and supervision		
Yes	37	90.24
No	2	4.88
Occasionally	2	4.88
Availability of designated cryogenic storage areas		
Yes	40	97.56
No	1	2.44
Frequency of cryogenic equipment inspection		
Weekly	24	58.54
Monthly	9	21.95
Annually	5	12.20
Not sure	3	7.32
PPE use for handling cryogenic substances		
Always	7	17.07
Often	13	31.71
Sometimes	14	34.15
Never	7	17.07
Availability of SOPs		
Yes	34	82.93
No	3	7.32
Maybe	4	9.76
Oxygen monitors/depletion alarms installed near cryogenic storage		
Yes	10	24.39
No	29	70.73
Maybe	2	4.88
Safety measures	**Yes (%)**	**No (%)**
Fire extinguishers	31 (75.61)	10 (24.39)
Emergency exit signs	22 (53.66)	19 (46.34)
First aid kits	22 (53.66)	19 (46.34)
Eye wash stations	17 (41.46)	24 (58.54)
Alarm systems	13 (31.71)	28 (68.29)
Safety drills	12 (29.27)	29 (70.73)
Safety officer/safety committee	11 (26.83)	30 (73.17)
Spill kits	6 (14.63)	35 (85.37)

Source: Data Analysis, 2025

It showed that majority (90.24%) of the respondents indicated that they were directly engaged in cryogenic

storage, handling or supervision. Designated cryogenic storage areas were available in 97.56% of laboratories. Only 24.39% of the laboratories had oxygen monitors or oxygen depletion alarms near the cryogenic storage locations with 70.73% reporting none at all. Another 4.88% of the respondents were unsure about the availability of oxygen monitoring devices. Weekly inspection of cryogenic equipment was the most (58.54%) commonly reported practice, followed by monthly (21.95%) and annual inspections (12.20%). Use of personal protective equipment (PPE) during cryogenic handling varied considerably, with only 17.07% reporting consistent use and an equal proportion reporting no PPE use. Standard operating procedures (SOPs) were reported to be available in 82.93% of laboratories. Fire extinguishers were present in 75.61% of facilities, while emergency exit signage and first aid kits were each reported by 53.66%. Spill kits were available in 14.63% of laboratories (Table 2).

Table 3: Cryogenic exposure and related hazard among respondents.

Variable	Frequency	Percentage
Exposure to cryogenic liquid (LN_2)		
Yes	24	58.54
No	17	41.46
Total	41	100
Oxygen displacement exposure		
Yes	4	9.76
No	37	90.24
Total	41	100
Cryogenic-related laboratory accident		
Cryogenic-related laboratory accident experienced	14	34.15
Cryogenic-related laboratory accident not experienced	27	65.85
Total	41	100
Outcome of accident (n=14)		
Injury/property damage	8	55.56
No injury or damage	6	44.44
Total	14	100
Cryogenic related injuries		
Frostbite/cold burns	20	48.78
Cryogenic splash injuries	6	14.63
No cryogenic-related injuries reported	15	36.59
Total	41	100

Source: Data Analysis, 2025

Cryogenic exposure and hazard experiences are presented in Table 3. It showed that direct exposure to cryogenic liquids was reported by 58.54% of respondents, while 9.76% of them reported exposure to oxygen displacement. Laboratory accidents that are cryogenic related were reported by 34.15% of participants. Among those that had accident, 55.56% were injured or had their property damaged. Majority (48.78%) of the respondents had frostbite or cold burns with 14.63% having cryogenic splash injuries.

Principal component analysis as presented in Table 4 revealed two components with eigenvalues greater than 1.0. The first component (PC1) is explained by 39.01% of the variance and loaded strongly on PPE provision, SOP availability, and PPE use. The second component (PC2) explained 22.35% of the variance and loaded primarily on equipment inspection frequency and oxygen monitoring systems. The two components accounted for 61.36% of the total variance in cryogenic safety compliance variables.

Table 4: Principal component loadings for cryogenic safety compliance variables.

Safety practice	PC1: procedural and behavioral compliance	PC2: equipment monitoring and inspection
Presence of oxygen monitors near cryogenic storage	0.32	0.49
Weekly inspection of cryogenic equipment	0.15	0.76
Provision of PPE for handling cryogenic substances	0.61	-0.12
Consistent use of PPE during handling	-0.57	0.05
Availability of clearly defined SOPs	0.42	-0.41
Eigenvalue	1.95	1.12

Continued.

Safety practice	PC1: procedural and behavioral compliance	PC2: equipment monitoring and inspection
% Variance explained	39.01	22.35
Cumulative variance (%)	39.01	61.36

DISCUSSION

This study analysed the cryogenic safety practices, patterns of exposure and occupational hazards among embryology laboratory workers in IVF clinics in Abuja. The results showed that there is a large-scale staff participation in cryogenic handling activities, and there are significant engineering controls deficits and lack of uniformity in the protective practices. A large percentage of the respondents indicated they were directly involved in cryogenic storage, handling or supervising. This finding is consistent with the reports provided by assisted reproductive technology (ART) laboratories, where working with liquid nitrogen on a regular basis is still an inherent part of the laboratory processes.[11,12] Excessive exposure makes occupational hazard high especially where safety systems are not well applied or enforced regularly.[3,13]

Although the majority of laboratories had designated cryogenic storage spaces, only less than a quarter of them had oxygen monitors or depletion alarms. The same lapses were reported in the context of ART and laboratory conditions where oxygen deficiency monitoring is often not fully used even though it is one of the main engineering controls against nitrogen-induced hypoxia.[4,7] There is a special hazard of oxygen displacement events because they occur quickly and have no sensory warning, which is why it is important to have continuous monitoring systems.[3,14]

Cryogenic equipment inspection practices in the facilities were also not constant, with slightly more than half reporting to inspect its equipment weekly. Preventive maintenance and frequent check-up of cryogenic systems have been identified as the crucial elements of laboratory risk management and have also been linked to minimised chances of equipment failure and catastrophic storage overages.[1] Irregular inspection intervals can thus be a source of latent system weaknesses that are not noticed until the unfortunate incidents.[15] The respondents were inconsistent in their use of personal protective equipment (PPE) when handling cryogenics, with a very significant percentage of them reporting the use of their PPE intermittently or not at all. The same discrepancies between PPE availability and use have been noted in laboratory professionals, indicating that behavioural and organisational factors contribute to compliance and not access.[3] Poor use of PPEs has been linked to higher chances of frostbite, cold burns, and splashes-related injuries in the cryogenic areas.[16-18]

Over one-third of all respondents indicated that they had encounters with cryogenic-related laboratory accidents with more than half of them being associated with injury or damage to property. Similar levels of accidents were reported in laboratory safety research where cryogenic accidents are commonly associated with direct handling mistakes and inadequate safety procedures.[19] The prevalence of frostbite and cold burns in this study is also high and this is another indication of the occupational burden of cryogenic exposure.[20]

The cryogenic safety compliance has different dimensions which are complementary. The disengagement between procedural and behavioural practices and equipment monitoring procedures is consistent with previous occupational safety research that characterised discrepancies between formal safety practices and actual work practices.[5] The PPE use versus PPE availability is inversely loaded, which implies that institutional supply might not be adequate to establish stable protective behaviours, which is also observed in laboratory and industrial safety environments.[6,21] The equipment-oriented aspect emphasises the significance of the regular inspections and oxygen monitoring as the independent safety measures, especially in the areas with asphyxiation risk. These findings support a multidimensional method of cryogenic safety evaluation and specific intervention plan.[1]

The assessment of safety control measures was based on self-reported availability and use rather than direct observational verification. Despite this limitation, the study provides important baseline data on cryogenic safety practices and occupational hazards in embryology laboratories within a low-resource setting.

CONCLUSION

Cryogenic storage practices in embryology laboratories of IVF clinics in Abuja are associated with substantial occupational exposures and reported laboratory accidents. While standard operating procedures are widely reported, the analysis reveals persistent gaps in the availability and consistent implementation of critical cryogenic risk control measures, particularly engineering controls and personal protective equipment. The multidimensional compliance structure identified the need for targeted cryogenic safety management strategies that address both human and technical components of risk to mitigate latent hazards within IVF laboratory environments.

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