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Factors Associated with Cold Chain Performance for Health Products in Health Facilities in Southern Benin in 2025

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Abstract

Introduction: The conservation of health products is critical, as they are sensitive to environmental conditions such as temperature, light, and freezing. Their storage and transport therefore require strict temperature controls [1]. Benin, like most West African countries, faces major challenges in managing the cold chain for health products, an issue that is critical to ensuring the quality and availability of vital medicines, particularly in low-income countries. Our study aimed to identify the factors associated with cold chain performance for health products in health facilities in southern Benin in 2025. **Methods:** We conducted an analytical cross-sectional study in 120 health facilities drawn from 17 health zones across 6 departments in southern Benin. A proportional random probability sampling method was used to select these health facilities. The association between good cold chain performance and its potential determinants was analyzed using multiple logistic regression, after adjustment for the variables included in the model. The significance threshold was set at 0.05, with a 95% confidence interval (95% CI), using Epi Info software version 7.2.2. **Results:** The mean performance score was 21.98 ± 4.10, with values ranging from 11 to 32, and a mode of 23. Staff training on cold chain management (aOR [95% CI] = 4.06 [1.01 - 16.35], p = 0.0485), refrigerator age ≤ 5 years (aOR [95% CI] = 4.10 [1.33 - 12.63], p = 0.0168), availability of a preventive maintenance schedule (aOR [95% CI] = 7.72 [1.78 - 33.47], p = 0.0084), and availability of a dedicated budget line (aOR [95% CI] = 5.98 [1.97 - 18.12], p = 0.0014) were statistically associated with good cold chain performance for health products. **Conclusion:** The results show that cold chain performance relies on a balance between human competencies, equipment quality, structured maintenance organization, and sustainable financing. The coordinated implementation of continuous staff capacity building, the progressive renewal of aging equipment, the institutionalization of preventive maintenance, and the securing of dedicated financial resources will help sustainably improve the performance of health facilities and strengthen the safety of vaccination and public health programs.

Keywords

Cold Chain, Vaccines, Maintenance, Africa, Health Facilities

1. Introduction

The cold chain for health products is an essential process for ensuring the efficacy and safety of vaccines, thermosensitive medicines, and other biological products [2]. Its interruption can lead to a loss of therapeutic potential, increased health risks, and substantial economic losses. Effective cold chain management is therefore a fundamental pillar of quality healthcare delivery, ensuring that appropriate temperature conditions are maintained throughout the storage and distribution of health products [3].

However, maintaining an optimal cold chain remains a major challenge, particularly in resource-limited countries, where infrastructure and human capacity are often insufficient [4]. In developed countries, cold chain management is generally well controlled thanks to modern infrastructure, high-performance equipment, and rigorous procedures, thereby ensuring the quality and availability of health products (WHO, 2020) [1]. In contrast, in many developing countries, this management is hindered by multiple constraints, including economic difficulties, inadequate infrastructure, and a shortage of qualified human resources [5].

In these contexts, health facilities and pharmacies frequently face problems such as inadequate refrigeration equipment, recurrent power outages, and a lack of staff training. These shortcomings compromise the quality of health products and expose populations to increased health risks [6].

Furthermore, cold chain failures are not merely a logistical challenge but represent a genuine threat to public health, population well-being, and socioeconomic development [7]. In Benin, the southern zone concentrates approximately 70% of health infrastructure, placing it at the heart of issues related to health system performance. The resulting wastage of health products generates substantial economic losses estimated at several billion CFA francs each year, representing resources that could otherwise be reallocated to other development priorities.

Consequently, improving cold chain management appears to be a strategic opportunity to strengthen Benin's health system. It would not only reduce losses but also improve the quality of care and strengthen public trust. The issue thus extends beyond the health sector alone, as it also contributes to safeguarding population health and the country's sustainable development [8] [9].

2. Methods

The primary assessment "Assessment of cold chain performance for health products in health facilities in southern Benin in 2025” was based on standardized criteria, organized by cold chain components (Inputs, Implementation, and Results), to which binary scores (0 or 1) were assigned. The scores obtained, after review of each of these components, were used to determine both component-level performance and overall performance.

Scoring principle: Each criterion was scored from 0 - 1.

- One (1) if the criterion met the standards and zero (0) if it did not;
- Sub-component score = Total of all criterion scores;
- Component score = Total of all sub-component scores;
- Main component score = Total of all independent component scores.

Overall cold chain performance was based on an expected total score of 4200 points, of which 2558 points were obtained, corresponding to 60.90%. The Inputs component reached 61.98%, the Implementation component achieved 68.23%, and the results component recorded 47.36%. Given these results, overall cold chain performance in health facilities in southern Benin was judged poor, as performance is considered good if the score obtained is greater than or equal to 75%, and poor if the score obtained is below 75%.

The sampling method and technique, as well as the sample size calculation for the primary assessment, are the same as those used in the study of associated factors described in the manuscript.

In each selected health facility, a single healthcare provider was retained for the survey. This was the staff member directly responsible for cold chain management of health products or, failing that, the agent performing this role at the time of the survey. Thus, a single respondent was included per health facility.

Study setting: We conducted an analytical cross-sectional study in 120 health facilities drawn from 17 health zones across 6 departments in southern Benin.

Southern Benin comprises seven departments, among the most populous and dynamic in the country: Atlantique, Littoral, Ouémé, Plateau, Mono, Couffo, and Zou. Characterized by a high level of urbanization, it is the country’s most populous and most developed region. It includes several major cities, notably Cotonou, Porto-Novo, Ouidah, Abomey, Allada, and Lokossa, and concentrates significant economic, political, and cultural infrastructure. As a result, southern Benin represents the country’s economic and administrative core, with a high concentration of population and infrastructure.

The health system in this area is organized to meet the needs of a dense and diverse population. It is structured into several health zones, each responsible for coordinating health services. In February 2025, more than 150 managers were trained and deployed across the country’s 34 health zones to strengthen patient safety and improve quality of care [10]. In addition, the region hosts referral health facilities, notably the Hubert Koutoukou Maga National Teaching Hospital Center (CNHU-HKM), the country’s leading hospital institution, offering a wide range of medical services and serving as a training center for health professionals.

Study type and period: This was an analytical cross-sectional study conducted in 2025.

Study population: The study population comprised two categories: a primary population and a secondary population.

Primary population

This consisted of functional public health facilities in the six (6) departments of southern Benin included in the study.

Secondary population

This consisted of stakeholders involved in cold chain management within public health facilities in southern Benin.

Study criteria

Inclusion criteria: Health facilities and stakeholders involved in the study had to meet the following criteria:

For health facilities (primary population)

- Be a public health facility located in southern Benin;
- Have a cold chain system for the storage of vaccines and other thermosensitive products;
- Have usable data on cold chain management (temperature logs, supervision reports, etc.) covering a period of at least six (6) months prior to the survey.

For stakeholders involved in the cold chain (secondary population)

- Be involved in the management, supervision, or maintenance of the cold chain (pharmacists, logisticians, nurses, maintenance technicians);
- Have at least three (3) years of experience at the selected health facility;
- Have provided informed consent to participate in the study.

Non-inclusion criteria

The following were not included in the study:

For health facilities (primary population)

Health facilities without usable data on cold chain management.

For stakeholders involved in the cold chain (secondary population)

- Staff absent during the data collection period;
- Staff who declined to participate in the study.

2.1. Sampling Methods and Techniques

Primary targets were selected using proportional random probability sampling. Secondary targets were selected using a non-probability, purposive sampling method.

Sample size

The sample size was calculated using Cochran's formula [11]:

$$n = (Z^2 \times p \times q \times N)/(e^2 \times (N - 1) + Z^2 \times p \times q)$$

where

- N = Total number of health facilities in the study area;
- Z = Confidence level (1.96% for 95%);
- p = Expected proportion (often 0.5 if unknown = maximum variability);
- q = 1 − p;
- e = accepted margin of error (often 5% = 0.05).

$N = 414$;

$n = (3.84 \times 0.25 \times 414)/(0.0025 \times 413 + 0.96)$;

$n = 397.44/(1.0325 + 0.96)$;

$n = 397.44/1.9925$;

$n \approx 199$ health facilities.

The minimum sample size was estimated at approximately 199 health facilities. After adjusting for non-response (+10%), this was increased to 219 health facilities to be selected.

However, due to budgetary constraints, the margin of error was revised to 7%, resulting in a sample size of approximately 109 health facilities, rounded to 120 after accounting for non-response.

The 120 health facilities included in the study were distributed proportionally across the 17 health zones in the departments concerned in southern Benin, based on the total number of health facilities in each zone.

2.2. Study Variables

Dependent variable

The dependent variable is cold chain performance.

Independent variable

The independent variables are structured according to the key dimensions of the cold chain: thermal stability, infrastructure, equipment, practices, management, and outcomes. These include:

- **Institutional variables:** Department, health zone, type of health facility, level of the health facility, number of cold chain technicians, number of vaccinators.
- **Sociodemographic variables:** Sex, age, professional seniority, training in cold chain management, most recent training received.
- **Equipment and infrastructure variables:** Presence of a refrigerator dedicated to vaccines, number of functional refrigerators, main power source, presence of a generator, occurrence of a recent refrigerator breakdown, average breakdown duration, availability of a backup power source (solar, generator, batteries), existence of an equipment maintenance plan, presence of functional thermometers, type of temperature monitoring device, availability of financial resources, equipment reliability index.
- **Vaccine thermal stability variables:** Mean refrigerator temperature, number of days with a thermal excursion (>8˚C or <2˚C), amplitude of temperature variations, presence of sub-zero temperatures in refrigerators, presence of a functional thermometer in each storage unit, type of temperature monitoring device, thermal compliance rate.
- **Management and supervision variables:** Existence of a designated cold chain manager, recent external supervision, frequency of staff training, availability of a maintenance budget, availability of spare parts on site, occurrence of vaccine stock-outs due to a cold chain breakdown.
- **User perception variables:** Staff perception of cold chain quality, user satisfac-

tion level.

2.3. Data Processing and Analysis

Data were entered, checked, and cleaned to ensure quality prior to analysis.

Descriptive statistics were performed and presented as frequency tables for qualitative variables, and as means ± standard deviation (δ) for quantitative variables, using Epi Info software version 7.2.6.0.

A bivariate analysis using simple logistic regression was performed to estimate crude odds ratios (OR) for each variable, with their 95% confidence intervals (95% CI) and p-values. Subsequently, variables associated with good cold chain performance with a p-value < 0.05 in the bivariate analysis were entered into a multiple logistic regression model.

A statistical significance threshold of $p < 0.05$ was retained for the multivariate analysis.

Variables that showed a statistically significant association with cold chain performance in the bivariate analysis ($p < 0.05$) were entered into a multivariate logistic regression model to identify factors independently associated with cold chain performance. Results are expressed as adjusted odds ratios (aOR) with their 95% confidence intervals. The statistical significance threshold was set at 5%. No missing data were observed for the variables included in the analyses; all observations were therefore accounted for in the logistic regression model.

3. Results

General characteristics of health facilities

The study covered 120 health facilities distributed across six departments in southern Benin (see Table A1). The most represented departments were Zou (24.17%), followed by Atlantique (20.83%) and Ouémé (19.17%). The health facilities came from 17 health zones, with the DAA health zone being the most represented (10%), followed by CBGH, PAK, and ZoBoZa (9.17% each).

Characteristics of respondents (see Table A2)

Regarding respondents' position within the cold chain, the majority were cold chain managers (91.15%). About 70% of these staff had more than three (3) years of experience in cold chain management.

Women accounted for 55.83% of respondents, versus 44.17% men. The mean age of respondents was 43.8 ± 6.3 years, ranging from 27 to 56 years. The most represented age group was 42 years and older (72.5%).

Factors associated with cold chain performance

After adjustment for the variables included in the model, the multivariate analysis identified the following factors independently associated with cold chain performance:

- Staff training on cold chain management (aOR [95% CI] = 4.06 [1.01 - 16.35], p = 0.0485);
- Refrigerator age ≤ 5 years (aOR [95% CI] = 4.10 [1.33 - 12.63], p = 0.0168).

- Availability of a preventive maintenance schedule (aOR [95% CI] = 7.72 [1.78 - 33.47], p = 0.0084);
- Availability of a dedicated budget line (aOR [95% CI] = 5.98 [1.97 - 18.12], p = 0.0014).

4. Discussion

Achievement of study objectives

The main objective of this study was to identify the factors associated with cold chain performance for health products in health facilities in southern Benin in 2025.

The multivariate analysis identified four factors independently associated with performance:

- Staff training on cold chain management;
- Refrigerator age less than or equal to five (5) years;
- Availability of a preventive maintenance schedule;
- The existence of a dedicated budget line or annual plan.

The identification of these factors confirms that the study's objective was achieved and highlights concrete intervention levers, both technical, organizational, and financial.

Quality and validity of the results

The robustness of the results rests on several methodological elements.

First, data collection was carried out using a structured, standardized questionnaire, ensuring the homogeneity of the information gathered. Second, the statistical analysis was conducted using Epi Info software, combining descriptive, bivariate, and multivariate analyses.

The use of multivariate logistic regression is a major strength of the study. It allowed the associations observed in the bivariate analysis to be adjusted and the factors independently associated with performance to be isolated, while controlling for confounding effects.

However, certain limitations must be acknowledged. This was a cross-sectional study, which does not allow a strict causal relationship to be established between the factors studied and the observed performance. In addition, some variables relied on self-reports from health facility managers, which exposes the study to a potential risk of reporting bias or social desirability bias.

Despite these limitations, the internal consistency of the results, their organizational plausibility, and their concordance with the international literature give the study satisfactory internal validity.

Factors independently associated and comparison with the literature

Among the variables significant in the bivariate analysis (see Table A3), only four retained a statistically significant association after adjustment in the multivariate model (see Table A4). These independent factors reflect the essential dimensions of a high-performing system, namely human competencies, equipment quality, structured maintenance, and dedicated financing.

Staff training on the cold chain

Staff training emerged as a major independent factor (aOR = 4.06; $p = 0.0485$). Health facilities with trained staff had an approximately four-fold higher probability of showing good performance.

Training strengthens technical skills related to temperature monitoring, interpretation of temperature logs, management of temperature excursions, and basic equipment maintenance. It also improves organizational capacity and responsiveness to incidents. These results are consistent with those of Yakum *et al.* (2015) in Cameroon, who showed that insufficient staff training was associated with poor compliance with vaccine storage practices [12]. Similarly, WHO [1] [13] emphasizes that continuing education is one of the fundamental pillars of a high-performing cold chain. Recent studies conducted in Sub-Saharan Africa confirm that strengthening human capacity significantly improves the quality of thermal monitoring and reduces vaccine wastage (Zipursky *et al.*, 2014) [14].

Refrigerator age ≤ 5 years

Refrigerator age of five (5) years or less was significantly associated with better performance (aOR = 4.10; $p = 0.0168$). Newer equipment is generally more reliable, compliant with WHO PQS (Performance, Quality and Safety) standards, and less prone to technical breakdowns.

Equipment obsolescence is recognized as a major risk factor for cold chain disruption, particularly in resource-limited settings. Ashok *et al.* (2017) [15] showed that equipment modernization is a key intervention for improving the reliability of storage systems. Similarly, initiatives supported by GAVI through the Cold Chain Equipment Optimization Platform (CCEOP) have demonstrated that targeted equipment renewal significantly improves logistical performance [16].

Preventive maintenance schedule available

The availability of a preventive maintenance schedule emerged as the factor most strongly associated with performance (aOR = 7.72; $p = 0.0084$). Health facilities with such a system in place were nearly eight times more likely to show good performance.

Preventive maintenance makes it possible to anticipate failures, reduce service interruptions, and extend equipment lifespan. According to WHO recommendations, a structured maintenance program is essential to ensure continuity of the cold chain [13]. Lydon *et al.* (2014) also emphasize that optimizing maintenance generates substantial economic benefits by reducing vaccine losses [17].

This result highlights the importance of proactive rather than reactive equipment management.

Dedicated budget line/annual plan available

The availability of a dedicated budget line was also independently associated with performance (aOR = 5.98; $p = 0.0014$). This factor reflects the structural and institutional dimension of the system.

Financial planning ensures the availability of resources needed for maintenance, replacement of defective parts, equipment acquisition, and staff training. The absence of dedicated funding compromises the sustainability of technical interventions [18].

These results are consistent with analyses by GAVI and WHO, which identify sustainable financing as an essential condition for the performance of vaccine logistics systems [1] [19].

Thus, the four independent determinants identified—staff training, refrigerator age, preventive maintenance, and dedicated financing—constitute the pillars of a high-performing cold chain management system. They reflect the interaction between human resources, technical infrastructure, organization, and financial governance.

5. Conclusions

The evaluation of cold chain management in health facilities in southern Benin provided a precise overview of logistical performance and identified the independent factors influencing this performance.

The multivariate analysis identified four independent determinants:

- Staff training on cold chain management;
- Refrigerator age of five (5) years or less;
- Availability of a preventive maintenance schedule;
- The existence of a dedicated budget line or annual plan.

These results show that cold chain performance relies on a balance between human competencies, equipment quality, structured maintenance organization, and sustainable financing.

Accordingly, priority interventions should aim to:

- Continuously strengthen staff capacity;
- Progressively renew aging equipment;
- Institutionalize preventive maintenance;
- Secure dedicated financial resources.

The coordinated implementation of these actions will help sustainably improve the performance of health facilities and strengthen the safety of vaccination and public health programs.

Ethical Statements

This study was conducted in accordance with applicable ethical principles. Authorization for data collection was granted by Benin's Ministry of Health: No. 3988/MS/DC/SGM/DFRS/SA dated August 4, 2025.

Participants gave their informed consent prior to inclusion. No specific funding likely to influence the results was received for this research.

What is known about this topic

- The performance of the cold chain for health products in health facilities.

What this study adds

- This study provided the general characteristics of health facilities;
- The factors associated with cold chain performance for health products in health facilities;

- Our results could serve as a reference for other studies.

Author Contributions

Mr. Rigobert Missikpodé: Conceptualization and study design; development of the methodology; supervision of data collection; analysis and interpretation of results; drafting of the manuscript (initial version); overall coordination of the research project.

Pr. Patrick Makoutodé: Co-conceptualization of the study; field data collection; contribution to statistical analysis; critical revision of the manuscript.

Pr. Charles Jérôme Sossa: Scientific supervision; validation of results; critical revision of intellectual content; approval of the final version submitted for publication.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Appendix

Table A1. General characteristics of health facilities.

Departments	n	Percentage (%)
Atlantique	25	20.83
Littoral	8	6.67
Mono	17	14.17
Ouémé	23	19.17
Plateau	18	15.00
Zou	29	24.17
Health zones		
3A	7	5.83
ABD	9	7.50
AB-SO	7	5.83
ATZ	9	7.50
CBGH	11	9.17
COTONOU 1 AND 4	2	1.67
COTONOU 2 AND 3	2	1.67
COTONOU 5	2	1.67
COTONOU 6	2	1.67
COZO	6	5.00
DAA	12	10.00
LA	6	5.00
OKT	9	7.50
PAK	11	9.17
PAS	7	5.83
SAKIF	7	5.83
ZOBOZA	11	9.17

Table A2. General characteristics of respondents.

Characteristics	n	Percentage (%)
Position held in the cold chain		
Manager	110	91.15
Technician	4	3.54
Maintenance agent	6	5.31
Sex		
Male	53	44.17
Female	67	55.83
Respondent age		
<27	2	1.67
27 - 31	12	10.00
32 - 36	5	4.17
37 - 41	14	11.67
42 and older	87	72.50
Seniority in cold chain management		
<3 years	37	30.83
≥3 years	83	69.17

Table A3. Bivariate analysis of factors associated with cold chain performance in health facilities.

Variables	Good n	Good %	Poor n	Poor %	PR [95% CI]	p
Staff training on the CDF						**0.0016**
Yes	58	81.69	13	18.31	1	
No	27	55.10	22	44.90	0.67 [0.51 - 0.88]	
Training suited to the position held						**0.0028**
Yes	61	80.26	15	19.74	1	
No	24	54.55	20	45.45	0.67 [0.10 - 0.50]	
Availability of a generator						0.3929
Yes	26	76.47	8	23.53	1	
No	59	68.60	27	31.40	0.89 [0.70 - 1.13]	
Availability of at least one motorcycle						0.5663
Yes	76	71.70	30	28.30	1	
No	9	64.29	5	35.71	0.89 [0.59 - 1.34]	
Refrigerator less than 5 years old						**0.0128**
Yes	55	79.71	14	20.29	1	
No	30	58.82	21	41.18	0.73 [0.56 - 0.95]	

Continued

Acquisition and maintenance cost analysis						**0.0284**
Yes	29	85.29	5	14.71	1	
No	56	65.12	30	34.88	0.76 [0.61 - 0.94]	
Existence of service contracts						0.1620
Yes	16	84.21	3	15.79	1	
No	69	68.32	32	31.68	0.81 [0.64 - 1.02]	
Availability of a preventive maintenance schedule						**0.0036**
Yes	78	75.73	25	24.27	1	
No	7	41.18	10	58.82	0.54 [0.30 - 0.96]	
Availability of an alert system						0.0618
Yes	59	76.62	18	23.38	1	
No	26	60.47	17	39.53	0.78 [0.60 - 1.03]	
Recent external supervision						0.7378
Yes	76	70.37	32	29.63	1	
No	9	75.00	3	25.00	1.06 [0.75 - 1.51]	
Speed of incident response						**0.0026**
Yes	59	80.82	14	19.18	1	
No	26	55.32	21	44.68	0.68 [0.51 - 0.90]	
Availability of a budget line for procurement						**0.0000**
Yes	67	84.81	12	15.19	1	
No	18	43.90	23	56.10	0.51 [0.36 - 0.74]	
Effective availability of financial resources						**0.0154**
Yes	61	78.21	17	21.79	1	
No	24	57.14	18	42.86	0.73 [0.54 - 0.97]	
Continuous staff training						**0.0002**
Yes	66	81.48	15	18.52	1	
No	19	48.72	20	51.28	0.59 [0.42 - 0.83]	

PR: prevalence ratio; CI: confidence interval. Bold p-values indicate statistical significance ($p < 0.05$).

Table A4. Multivariate analysis of factors associated with cold chain performance in health facilities (logistic regression).

Associated factors	aOR	95% CI	p
Staff training on cold chain management	4.06	[1.01 - 16.35]	0.0485
Refrigerator age ≤ 5 years	4.10	[1.33 - 12.63]	0.0168
Availability of a preventive maintenance schedule	7.72	[1.78 - 33.47]	0.0084
Availability of a dedicated budget line/annual plan	5.98	[1.97 - 18.12]	0.0014

aOR: adjusted odds ratio; CI: confidence interval.