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Capture-Recapture Methods in Surveillance of Fake Drug Syndicates in Nigeria: Decriptive Research

Nijerya'da Sahte İlaç Şebekelerinin İzlenmesinde Yakala-Tekrar Yakala Yöntemleri: Tanımlayıcı Araştırma

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ABSTRACT Objective: National Agency for Food and Drug Administration and Control (NAFDAC)-agency responsible for checkmating illicit and counterfeit drugs in Nigeria has raised alarm over the years the menace caused by fake and adulterated drugs in Nigeria. The Agency reported that fake drugs have claimed the life of many Nigerians especially children and old people. We believe this is only part of the story, because the syndicates of these drugs are also integral part of the problem. Yet no effort was made to examine the population size of these syndicates. This gap in the literature is what informed our study. **Material and Methods:** In this study, we estimate the population size of fake drug syndicates (FDS) by capture-recapture methods. Information on FDSs was obtained from the NAFDAC newsmagazines. Four candidate estimators namely; Maximum Likelihood, Turing, Chao and Zelterman of zero-truncated Poisson models were used. **Results:** The weighted estimator constructed estimated the population size of FDSs to be 11,469. Since 2,038 syndicates were arrested January to December, 2022, suggests that only 18% of the FDSs have been observed with 95% confidence interval of (9564-13374), leaving 82% of them still in the distribution chain. The study also shows that among the offense committed falsification of genuine drugs was the most rampant, followed by selling of expired drugs. **Conclusion:** Aside the population size of FDSs, this study will also form the basis for resource allocation to NAFDAC, because it may not be possible to fight war against fake drugs without investing in novel technologies.

Keywords: Poisson distribution; likelihood functions; counterfeit drugs; treatment failure; death

ÖZET Amaç: Nijerya'da yasa dışı ve sahte ilaçlarla mücadeleden sorumlu olan Ulusal Gıda ve İlaç İdaresi ve Kontrol Ajansı [National Agency for Food and Drug Administration and Control (NAFDAC)], yıllardır sahte ve bozulmuş ilaçların neden olduğu tehdide karşı alarm verdi. Ajans, sahte ilaçların özellikle çocuklar ve yaşlılar başta olmak üzere birçok Nijeryalı'nın hayatına mal olduğunu bildirmiştir. Ancak bunun hikâyenin sadece bir kısmını oluşturduğuna inanıyoruz; sahte ilaç örgütleri (SİÖ) de problemin ayrılmaz bir parçasıdır. Buna rağmen bu örgütlerin popülasyon büyüklüğünü incelemek için hiçbir çalışma yapılmamıştır. Literatürdeki bu boşluk, çalışmamızın temelini oluşturmuştur. **Gereç ve Yöntemler:** Bu çalışmada, SİÖ'lerin popülasyon büyüklüğü, yakala-tekrar yakala yöntemleri ile tahmin edilmiştir. SİÖ hakkında bilgiler, NAFDAC haber dergilerinden elde edilmiştir. Çalışmada, sıfır-kesikli Poisson modellerinin Maksimum Olabilirlik, Turing, Chao ve Zelterman olmak üzere dört aday tahmin edicisi kullanılmıştır. **Bulgular:** Ağırlıklı tahmin edici, SİÖ'nün popülasyon büyüklüğünü 11.469 olarak tahmin etmiştir. Ocak-Aralık 2022 arasında 2.038 örgütün yakalanmış olması, %95 güven aralığında (9.564-13.374) SİÖ'lerin yalnızca %18'inin gözlemlendiğini ve kalan %82'sinin hâlâ dağıtım zincirinde yer aldığını göstermektedir. Çalışmada ayrıca, tespit edilen suçlar arasında en yaygın olanının orijinal ilaçlarda sahteciliğin olduğu ve bunu son kullanma tarihi geçmiş ilaçların satışının izlediği belirlenmiştir. **Sonuç:** SİÖ'lerin popülasyon büyüklüğünün yanı sıra bu çalışma NAFDAC'a kaynak tahsisi için de bir temel oluşturacaktır; çünkü sahte ilaçlarla mücadelede yeni teknolojilere yatırım yapılmadan bu savaşın kazanılması mümkün olmayabilir.

Anahtar Kelimeler: Poisson dağılımı; olabilirlik fonksiyonları; sahte ilaçlar; tedavi başarısızlığı; ölüm

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Circulation of fake, adulterated and substandard drugs in the Nigerian markets, especially in the open markets and rural communities of the country has for many years now become a big health issue not alone to the National Agency for Food and Drug Administration and Control (NAFDAC)-the agency responsible for checkmating illicit and counterfeit drugs in Nigeria, but to Nigerian Health sector in particular. Health problem associated with the intake of fake, counterfeit or adulterated drugs cannot be over emphasized. Administering fake or counterfeit drugs to patients can lead to drug resistance, abuse or even death. According to, the intake of fake or counterfeit drugs has led to treatment failures, organ dysfunctions and deaths of many Nigerians. And even if patients were treated with genuine drugs, but because of the previous intake of fake drugs, that genuine drugs will not response to the treatment.[1,2]

In a film entitled "Preaching to the Uncovered" noted that Harry Lime, the greedy American capitalist, came to Vienna in 1949 to enrich himself at the expense of vulnerable European children by engaging in the sale of diluted penicillin, a lucrative business that freed him from the shackles of income tax; but in Nigeria, fake drugs were first noticed in 1968, when the crown agents was made the sole distributors of pharmaceutical products in Nigeria.[1,3] However, the problem of fake drugs assumed a dangerous dimension in 1980s during the time when the import license was eased followed by worsened adverse effect of Structural Adjustment Program that was introduced in the middle of 1980s.[1] The evil effects of fake drugs progressively became worsened until 2001 when NAFDAC started serious war against the scourge. A survey conducted in Nigeria in 2004 by WHO, EU, Department for International Development and Health Action International showed that about 90.2% Nigerians cannot afford good quality medicine due to low income level of about US₴2.0 a day; adding that patients pay between 2 to 64 times the international price for medicines in various facilities in both the private and public sectors of Nigeria.[4] Due to low income level, many Nigerians suffering from different ailments therefore resorted to cheap medicines which most often were substandard or faked.

EFFORTS OF NAFDAC IN COMBATING FAKE DRUGS IN NIGERIA

The death of many Nigerians due to fake or counterfeit drugs was responsible for the establishment of NAFDAC in 1994 to help in creating a fake-drug-free environment.[5] The intention was to make sure that only good quality drugs with NAFDAC registration numbers are in supply. The new NAFDAC led by Professor Dora Akunyili, as Director General, has since its inception in April, 2001, worked very hard in stopping the sale of fake drugs and in creating consumer awareness that any drug without NAFDAC number is a fake.

The consistent raids by NAFDAC on pharmacy stores, streets and commercial buses in search of vendors of fake drugs enabled the Agency to apprehend syndicates of these drugs. However, as things begin to ease, these illegal drug sellers surfaced from their hideouts to start the illicit business again. Fake drugs have been classified as counterfeit, falsified, substandard and unregistered drugs.[6]

FAKE DRUG A GLOBAL PUBLIC PROBLEM

Faking of drug is a global public health problem, because its effect can be felt by both the manufacturing countries and the recipient ones. The cause of fake drug is as a result of the neglect of good manufacturing practices (both accidental and deliberate), erratic supply and constant demand for medicines and weaknesses in the regulatory system, and inaccurate and inadequate undertaking of the problem among health workers and the public.[7] "Regulating drug quality requires political will, scientific expertise and solid data, all of which are scarce in countries ravaged by poverty and infectious disease", quoting Professor Paul Newton as saying.[8] Professor Newton was a doctor of infectious disease from Oxford University, working in Vientiane, Laos. Professor Newton, however, noted that the most formidable barrier for tracking fake drugs has been the lack of consensus on how to classify counterfeit drugs. According to him, efforts to establish a universal definition of fake drugs have been caught in a tug-of-war between safeguarding public health and protecting intellectual property.

AIM AND OBJECTIVES

At issue here is both the number of fake drug syndicates (FDSs) that have been arrested and those that escaped arrest. The former is straightforward-we just count the number of arrested cases, but the latter is complicated: How do we know the large number of FDSs that could have been arrested, but were not? This is important because it will help NAFDAC know the number of FDSs still in the distribution chain. Otherwise, the fight against the scourge and effort by NAFDAC to secure drug supply chain from fake drugs and FDSs could be an effort in futility. This of course could portend a serious threat to good quality healthcare service delivery, especially in the rural areas where patent medicine dealers, chemist shops and drug vendors administer these drugs to patients without knowing that the drugs are faked. This study, therefore, seeks to use zero truncated Poisson models of capture-recapture methods in estimating the non-negligible proportion of FDSs that escaped arrest to enable us have a reliable estimate of the population size of FDSs in Nigeria, while the objective is to construct a weighted estimator for the four candidate estimators namely; Maximum Likelihood, Turing, Chao's Lower Bound and Zelterman under the zero-truncated Poisson model of capture-recapture methods for the estimate of FDSs in Nigeria.

MATERIAL AND METHODS

STUDY SAMPLE

NAFDAC is a regulatory agency responsible for checkmating illicit and counterfeit drugs in Nigeria. The Agency has offices in the thirty-six States of Nigeria with the Federal Capital Tertiary, Abuja, as its headquarters. The Agency publishes two newsmagazines namely, NAFDAC News and NAFDAC Consumer Safety. While the former is published monthly, the latter is quarterly. The magazines contain official reports on fake drug possession and the syndicates across different parts of the country. Thus the study sample is non-random, because our sources of information on FDSs are publicly available in the two magazines which ran into 100s of pages. But for the sake of this study, the study sample covers only January to December, 2022; and any syndicate found in the two magazines around that period is a potential participant in the study.

We note that the main aim of this study is to estimate N, the true population size of the syndicates. But since FDSs is a hidden population whose sample size cannot be determined by any sampling techniques we rely on the secondary data obtained from the NAFDAC newsmagazines. Going through the pages of the magazines one by one, we were able to extract relevant information about FDSs which we present in tables (Table 1, Table 2). In these newsmagazines, we identify FDSs by their surnames, homes and shop addresses, phone numbers and National Identity Number. If the identities of a syndicate that appeared two or more times in the magazines are the same or similar it is recapture (Table 1).

But the question is: Are the figures in Table 1 only the number of FDSs in Nigeria? The answer is definitely no! There may be a lot of them that escape NAFDAC arrest. These numbers that have not been arrested need to be estimated to enable us have a reliable number that are still in the distribution chain.

TABLE 1: Frequency distribution (per count) of FDSs, figures extracted from the NAFDAC newsmagazines covering January-December, 2022 by capture-capture methods.

	Number of arrest per month												
Place of arrest	f_1	f_2	f_3	f_4	f_5	f_6	f_7	f_8	f_9	f_{10}	f_{11}	f_{12}	**N**
Onitsha	1250	94	25	18	16	11	8	6	3	2	1	0	1434
Lagos	430	10	3	3	1	1	0	0	1	1	0	1	451
Kano	140	4	4	3	1	0	0	0	0	0	1	0	153
Total counts of FDSs	1820	108	32	24	18	12	8	6	4	3	2	1	2038

f_1, f_2, -----, f_{12} are the number of FDSs arrested in the months of January, February, ---, December, 2022 respectively by the NAFDAC taskforces; FDS: Fake drug syndicates; NAFDAC: National Agency for Food and Drug Administration and Control.

TABLE 2: Frequency distribution (per count) of FDSs and offense committed, figures extracted from the NAFDAC newsmagazines covering January-December, 2022 by capture-capture methods.

		Number of arrest per month												
Location	Offense	f_1	f_2	f_3	f_4	f_5	f_6	f_7	f_8	f_9	f_{10}	f_{11}	f_{12}	n
Onitsha	Falsified drug	565	54	15	9	8	5	5	3	3	1	1	0	669
	Expired drug	288	20	6	9	3	2	1	1	0	1	0	0	325
	Unregistered drug	210	14	3	4	3	2	1	1	0	0	0	0	238
	Banned drug	187	6	1	2	2	2	1	1	0	0	0	0	202
Lagos	Falsified drug	250	5	3	2	0	1	0	0	1	1	0	1	264
	Expired drug	90	1	0	1	0	0	0	0	0	0	0	0	92
	Unregistered drug	75	3	0	0	1	0	0	0	0	0	0	0	79
	Banned drug	15	1	0	0	0	0	0	0	0	0	0	0	16
Kano	Falsified drug	40	1	2	0	0	0	0	0	0	0	1	0	44
	Expired drug	30	0	0	3	0	0	0	0	0	0	0	0	33
	Unregistered drug	70	3	2	0	1	0	0	0	0	0	0	0	76
	Banned drug	0	0	0	0	0	0	0	0	0	0	0	0	0
Total count of FDSs		1820	108	32	24	18	12	8	6	4	3	2	1	2038

f_1, f_2,-----, f_{12} are the number of FDSs arrested in the months of January, February, ---, December, 2022 respectively by the NAFDAC taskforces; FDS: Fake drug syndicates; NAFDAC: National Agency for Food and Drug Administration and Control.

And since FDSs is a hidden population we resort to the use of capture-recapture methods to estimate its population size.

Despite the fact that authors of this article have no physical contacts with the syndicates, they still carried out their study in accordance with the Helsinki Declaration principle by obtaining an approval from the State Health Research Ethics Committee of the Anambra State Ministry of Health Nigeria on first November, 2023 with the approval number MH/PRSD/1401/26 (date: November 1, 2023).

CAPTURE-RECAPTURE

Aside being used to estimate animal abundance, capture-recapture has been proven to provide a reliable estimate of hidden populations such as mobile male sex workers, female commercial sex workers and lesbian, or the size of illicit methamphetamine users and many others.[9] The method relied on the pattern found in the observed part of the population to make inference in an unobserved part.

ZERO-TRUNCATED MODEL

Let n denotes the size of observed zero-truncated counts with f_k being the frequency of observing exactly k counts. We use similar description by, that an arrest which occurs only once are called singleton, twice are called doubletons, thrice are called tripletons, and so forth.[10] In Table 1, there are 1,820 singletons, only 108 doubletons and 32 tripletons. This huge numbers of singletons are the FDSs caught once, doubletons are the ones caught twice by NAFDAC taskforce and so on. While Table 2 shows the kind of offense each of the syndicates committed.

Frequency counts of observed cases in a single or multiple registers to estimate unobserved cases give rise to zero truncated models. This method has been used to estimate the hidden populations of illicit drug users and homeless persons.[11] Consider a population size N and count variable Y taking values from the set of integers {0, 1, 2, 3…}. In this study, Y might represent the number of times a syndicate is arrested and f_0, f_1, f_2, ——-, the frequency with which a 0, 1, 2, ——, occurs in this population. Again consider a list where every syndicate arrested is included except Y=0, the syndicates that escaped arrest. This list reflects a count variable truncated at zero which we denote by Y_0. Accordingly, the list will have the observed frequencies f_1, f_2, f_3, —-. Since the frequency f_0 of zeros in the population is unknown, the cell f_0 is therefore empty. This empty cell shall be filled by estimating the number of syndicates that have escaped arrest, but still in the supply chain.

ZERO TRUNCATED POISSON MODEL

A typical capture-recapture method is interested in finding the appropriate models for count variables. In the study of animal abundance, for instance, the probability of capturing an animal usually followed a binomial distribution. However, if there are many trapping occasions with little catch, binomial distribution will be approximated by Poisson distribution. We notice that NAFDAC conducts series of surveillance to arrest FDSs, but arrests were few. So instead of using binomial distribution to describe FDSs observed in the NAFDAC records we use Poisson distribution. The zero-truncated Poisson distribution is defined as a probability function conditional on y >0, such that:

$$P(Y_+ = k) = P_{0+}(k|\lambda) = \frac{\exp(-\lambda)\lambda^k}{1-\exp(-\lambda)k!};\ k=1, 2, \text{---------}$$

Applying Taylor's approximation series λ can be approximated as:

$$\hat{\lambda} = 2\left(\frac{\bar{v}-1}{\bar{v}}\right), \text{ where } \bar{v} = \frac{1}{m}(f_1 + f_2 + - - - + f_m)$$

If we let *n* to be the number of FDSs arrested and f_0 the frequencies of FDSs that have not been arrested, then the true population of FDSs in the supply chain shall be:

$$N = n + \hat{f}_0, \text{ where } \hat{f}_0 = \frac{n\exp(-\hat{\lambda})}{1-\exp(-\hat{\lambda})}$$

CANDIDATE ESTIMATORS

Under zero truncated Poisson model, we have four candidate estimators namely; Maximum likelihood (N_{MLE}), Turing (N_T), Chao's lower bound (N_C) and Zelterman (N_Z).

• *Maximum Likelihood estimator*

We obtain the maximum likelihood estimator (MLE) for unknown parameter θ by maximizing the function L (θ), i.e., taking the log-likelihood of the distribution, differentiating it with respect to θ and equating it to zero. MLE given by is:[12]

$$\hat{\lambda}_{MLE} = \frac{1}{n+f_0}(0f_0 + 1f_1 + 2f_2 + - - + mf_m)$$

If, for instance, we let Y_i be the number of times the syndicate is arrested over the surveillance period say *i*=1, 2, ———, k. Under zero-truncated Poisson model, the MLE shall be:

$$\hat{N}_{MLE-p} = \frac{n}{1-\exp(\hat{\lambda}_{MLE})}, \text{ with variance given as:}$$

$$\widehat{Var}(\hat{N}_{MLE-P}) = \frac{\hat{N}_{MLE-P}}{\left(exp\left(\frac{\sum kf_k}{\hat{N}_{MLE-P}}\right)-\frac{\sum kf_k}{\hat{N}_{MLE-P}}\right)-1}$$ See authors.[12-15]

• *Turing estimator*

Turing estimator was formulated to estimate the number of classes or species of animals, using the sum of probabilities of observed classes.[13] Let f_k be the frequency distribution of FDSs apprehended exactly k times, k=0, 1, 2, —-, m where m is the largest observe cases. The total number of captured FDSs can be defined as:

$$S = 1f_1 + 2f_2 + \cdots + mf_m$$

Under zero-truncated Poisson model, the Turing estimator is given as:

$$\hat{N}_{T\_P} = \frac{n}{1-f_1/S}, \text{ with variance derived as:}$$

$$\widehat{var}(\hat{N}_{T\_P}) = \frac{nf_1/S}{(1-f_1/S)^2} + \frac{n^2}{(1-f_1/S)^4}\left(\frac{f_1(1-\frac{f_1}{n})}{S^2} + \frac{f_1^2}{S^3}\right)$$

See author.[16]

• *Chao's lower bound estimator*

Estimators we have so far discussed are developed under homogenous Poisson model, but in practice it is rarely met. Therefore, it is more suitable to incorporate heterogeneity.[17] provided a lower bound estimator for the population size N under the heterogeneous Poisson population. Under Poisson zero-truncated of capture-recapture methods, Chao's lower bound estimator is given as:

$$\hat{N}_{C\_P} = n + \frac{f_1^2}{2f_2}, \text{ with variance provided byas,}$$

$$\widehat{var}(\hat{N}_{C\_P}) = \left(\frac{1}{4}\right)\frac{f_1^4}{f_2^3} + \frac{f_1^3}{f_2^2} + \left(\frac{1}{2}\right)\frac{f_1^2}{f_2}.$$ [17]

• ***Zelterman estimator***

Because Poisson assumption is frequently violated, argued that homogeneity Poisson probability may be valid for small range of Y from k to k+1. For example, singleton f_1 and doubleton f_2 follows a homogeneous Poisson distribution, whereas other counts may arbitrarily be distributed.[16,18] Thus, the neighbouring frequencies f_k and f_{k+1} can be used to estimate a parameter by considering Poisson distributions of truncated and un-truncated with estimator as:

$$\hat{\lambda}_k = \frac{(k+1)f_{k+1}}{f_k}.$$

If k=1, we find that $\lambda_1=2f_2/f_1$. Zelterman estimator under zero-truncated Poisson model therefore shall be:

$\hat{N}_{Z\_P} = \frac{n}{1-exp(-\lambda)} = \frac{n}{1-\exp(-\frac{2f_2}{f_1})}$, with variance worked out as:

$\widehat{var}(\hat{N}_{Z_P}) = nG(\hat{\lambda})\left[1 + nG(\hat{\lambda})\hat{\lambda}^2\left(\frac{1}{f_1}+\frac{1}{f_2}\right)\right]$; where

$nG(\hat{\lambda}) = \frac{\exp(-\hat{\lambda})}{1-\exp(-\hat{\lambda})}$ and $\hat{\lambda} = \frac{2f_2}{f_1}$ See.[19]

RESULTS

Having reviewed the candidate estimators for the zero truncated Poisson model necessary of the capture-recapture methods we needed in our study, we now use them in application. We notice that in Table 3, both MLE and Turing estimators have small variances compared to Chao and Zelterman estimators. In such a situation, there is need to construct a weighted estimator as:[20]

$$N_W = (w_1\hat{N}_{MLE} + w_2\hat{N}_T + w_3\hat{N}_C + w_4\hat{N}_Z)/(w_1 + w_2 + w_3 + w_4)$$

where, $\hat{N}_{MLE}, \hat{N}_T, \hat{N}_C$, and $\hat{N}_Z$ are the candidate estimators already discussed. And since the true variances are unknown suggestes using equal weights as follows:[19]

$$N_W = \frac{1}{4}\left(w_1\hat{N}_{MLE} + w_2\hat{N}_T + w_3\hat{N}_C + w_4\hat{N}_Z\right).$$

TABLE 3: The estimated population size of FDSs in Nigeria by the candidate estimators and weighted estimator of zero-truncated model of Poisson distribution of capture-recapture methods.

Estimator	Obs.	Est.	SE	95% CI
MLE ($\hat{N}_{MLE\text{-}p}$)	2038	3184	37	(3111-3257)
Turning ($\hat{N}_{T\text{-}p}$)	2038	6793	372	(6064-7522)
Chao ($\hat{N}_{C\text{-}p}$)	2038	17373	1646	(14147-20599)
Zelterman ($\hat{N}_{Z\text{-}p}$)	2038	18527	1834	(14932-22122)
Weighted ($\hat{N}_{W\text{-}p}$)	2038	11469	972	(9564-13374)

Obs: Observed cases of FDS from the NAFDAC newsmagazines;
Est: Estimates of the population size of the FDS; SE: Standard error of the estimate;
CI: Confidence interval of the estimate; FDS: Fake drug syndicates.

• **Presentation of results**

In Table 1, we present the frequency distribution of FDSs per count of arrest made by the NAFDAC taskforces, and where the arrest took place as at January to December 2022. In this study, we also categorize FDSs according to the offense they committed. The offenses are falsification of genuine drugs, selling of expired drugs, unregistered drugs and banned drugs (Table 2, Table 4). In Table 3 we present the estimates of FDSs in Nigeria by the four candidate estimators and the weighted estimator of zero truncated model of Poisson distribution of capture-recapture methods. And in Table 4, we categorize the estimates by the offense of the syndicates.

DISCUSSIONS

We note that in Table 3, the population size of FDSs in the NAFDAC records was 2038. Using zero-truncated Poisson model, the four candidate estimators namely ML, Turing, Chao and Zelterman estimated the population to be 3184; 6793; 17373; 18527 respectively. But because the estimators have different results, we consider their weighted estimator. The weighted estimator for the four candidate estimators therefore gives the population size estimate of FDSs in Nigeria to be 11469. Since 2038 FDSs were arrested by the NAFDAC taskforce as at the time of this study, suggests that only about 18% of the population of FDSs have been observed with 95% CI (9564-13374), leaving about 82% FDSs still in the distribution chain.

We also look at the most widely committed offense of fake drug business. In Table 4, we see that

TABLE 4: The estimated population size of FDSs in Nigeria by the candidate estimators and weighted estimator of zero-truncated model of Poisson distribution of capture-recapture methods according to the offense of the syndicates (See Table 2).

Offense	Estimator	Obs.	Est.	SE	95% CI
Falsifying of drug	MLE ($\hat{N}_{MLE\text{-}p}$)	977	1396	23	(1351-1441)
	Turning ($\hat{N}_{T\text{-}p}$)	977	2874	230	(2423-3325)
	Chao ($\hat{N}_{C\text{-}p}$)	977	7069	432	(6222-7916)
	Zelterman ($\hat{N}_{Z\text{-}p}$)	977	7515	973	(5608-9422)
	Weighted ($\hat{N}_{W\text{-}p}$)	977	4714	415	(3901-5526)
Selling of expired drug	MLE ($\hat{N}_{MLE\text{-}p}$)	450	692	17	(659-725)
	Turning ($\hat{N}_{T\text{-}p}$)	450	1731	248	(1245-2217)
	Chao ($\hat{N}_{C\text{-}p}$)	450	4413	952	(2547-6279)
	Zelterman ($\hat{N}_{Z\text{-}p}$)	450	4500	922	(2693- 6307)
	Weighted ($\hat{N}_{W\text{-}p}$)	450	2834	535	(1786-3882)
Selling of unregistered drug	MLE ($\hat{N}_{MLE\text{-}p}$)	393	605	16	(574-636)
	Turning ($\hat{N}_{T\text{-}p}$)	393	1512	229	(1064-1960)
	Chao ($\hat{N}_{C\text{-}p}$)	393	3544	782	(2011-5077)
	Zelterman ($\hat{N}_{Z\text{-}p}$)	393	3573	781	(2042-5104)
	Weighted ($\hat{N}_{W\text{-}p}$)	393	309	452	(1423-3194)
Selling of banned drug	MLE ($\hat{N}_{MLE\text{-}p}$)	218	341	12	(318-364)
	Turning ($\hat{N}_{T\text{-}p}$)	218	948	228	(720-1176)
	Chao ($\hat{N}_{C\text{-}p}$)	218	3133	1177	(1956-4310)
	Zelterman ($\hat{N}_{Z\text{-}p}$)	218	3114	1133	(893-5334)
	Weighted ($\hat{N}_{W\text{-}p}$)	218	1884	638	(972-2796)

Obs: Observed cases of FDSs in the NAFDAC records; Est: Estimates of the population size of the FDSs; SE: Standard error of the estimate; CI: Confidence interval of the estimate; FDS: Fake drug syndicates.

falsification of genuine drugs was the most widely committed offense of this illicit business, followed by selling of expired drugs. The four candidate estimators ML, Turing, Chao and Zelterman estimated the population size of FDSs involved in falsifying the genuine drugs to be 1396, 2874, 7069, and 7515 respectively, while their weighted estimator estimated it to be 4714 with 95% CI (3901-5526). Since 977 were number of FDSs caught in the business by the NAFDAC taskforce at the time of this study**,** suggests that only about 21% of FDSs committing this offense had been observed, leaving about 80% of them still in the distribution chain of this illicit business**.**

The National Primary Healthcare Development Agency (NPHDA) of Nigeria, the agency charged with the responsibility for the primary health welfare delivery under Federal Ministry of Health, reported in 2022 that about 70% of drugs distributed in Nigeria are substandard or counterfeits.[21] This report by NPHDA was countered by the NAFDAC in its statement which reads: "the country has 13% to 15% of fake and substandard medicines contrary to claims in some quarters that the country has 70 percent of fake medicines".[22] In this our study, the authors want to investigate both claims by estimating the population size of the syndicates who are distributing these drugs. Our study shows that only about 18% of FDSs have been apprehended by NAFDAC in 2022 supports the report of NPHDA. The claim by NAFDAC that only about 13 per cent or 15 per cent of medicine in circulation in Nigeria were fake drugs may therefore not necessarily be correct conflating with what is going underground.

CONCLUSION

The implication of this decriptive research is that NAFDAC chose to publicize fake drugs more than FDSs. Its choice was to reflect the immediate political context and routine practices **o**nly**.** But we say this

is only part of the story, because FDSs are also integral part of the problem**.** That only about 18% of FDSs had been apprehended by the NAFDAC taskforce while 82% of them were still in the distribution channel at the time of this research shall be a cause of worry for NAFDAC. It shows that NAFDAC is not winning the war against the scourge.

In other countries of the world they have databank to store information on illicit drugs and the syndicates. For instance, there is Office of the Narcotics Control Board in Bangkok where drug abuse cases were recorded.[20] In Amsterdam, there is Municipal Health Service that receive sample of opiate users arrested.[23] In Italy, there is single Data Ware House for monitoring the health of the people.[24] In England there are registered cases of Problem Drug Users.[25] Similar agencies abound in Nigeria, but unfortunately many of them including NAFDAC have no databank to store information. This unfortunate scenario placed NAFDAC to a mere guess work. That only about 13 per cent or 15 per cent of medicine in circulation in Nigeria was fake; as claimed by the Director General of NAFDAC in 2022, is one of such guess works, which may not necessarily be correct conflating with what is going underground as our research findings have attested.

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Conflict of Interest

No conflicts of interest between the authors and / or family members of the scientific and medical committee members or members of the potential conflicts of interest, counseling, expertise, working conditions, share holding and similar situations in any firm.

Authorship Contributions

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