Detecting Data Falsification by Front-line Development Workers: A Case Study of Vaccination in Pakistan

Amna Batool
abatool@umich.edu
School of Information, UM
Ann Arbor, Michigan, USA

Kentaro Toyama
toyama@umich.edu
School of Information, UM
Ann Arbor, Michigan, USA

Tiffany Veinot
tveinot@umich.edu
School of Information, UM
Ann Arbor, Michigan, USA

Beenish Fatima
mscs13017@itu.edu.pk
Information Technology University
Lahore, Pakistan

Mustafa Naseem
mnaseem@umich.edu
School of Information, UM
Ann Arbor, Michigan, USA

ABSTRACT

Front-line workers in global development are often responsible for data collection and record-keeping about their own work. The authenticity of such data and the role of mid-level supervisors, however, remains understudied. We report on the case of immunization in Pakistan, where, through interviews with 30 mid-level vaccination managers in Punjab district, we find that data falsification by vaccinators is common, though not necessarily rampant. Because of an intricate protocol for record-keeping, supervisors can detect data falsification, and we find they have devised an array of methods, broadly classifiable into four types: triangulation, supplementary data collection, anomaly detection, and interrogation. We also find that the strategies that supervisors use to detect falsification seem linked to their style of management, with authoritarian supervisors preferring supplementary data collection and spot checks, while supportive supervisors use triangulation. Our findings lead to recommendations for designing technologies intended to monitor and manage front-line data.

CCS CONCEPTS

• **Human-centered computing → Field studies**.

KEYWORDS

Data Falsification, Mid-level Managers, Immunization, Supervisors, Healthcare, Front-line Workers, Supportive Supervision, Technology, Developing Countries

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1 INTRODUCTION

In a variety of global development contexts such as vaccination, healthcare, and agricultural extension, front-line workers are tasked not only with the delivery of services, but also with the collection of relevant data – which increasingly happens on digital devices [7, 14, 26]. Often, this data is used by workers' supervisors to monitor their work and to ensure compliance with protocols. But workers also have reasons to falsify records, whether to mask poor performance or to appear to meet unreasonable targets.

One context in which data falsification is known to occur is in child immunization in Pakistan, where there is high child mortality from vaccine-preventable diseases despite reports of high immunization coverage [36, 41]. According to one official we spoke with at the Expanded Program on Immunization (EPI) in Pakistan, the data collected by front-line health workers suggests immunization coverage of 90% in 2019. However, the Pakistan Social and Living Standards Measurement (PSLM) survey, independently conducted by the Ministry of Planning Development & Special Initiatives, showed only 81% coverage in 2019 [40], and the Pakistan Demographic and Health Survey (PDHS) survey (2017-2018) funded in part by the United States Agency for International Development (USAID) reported coverage of only 65.6% [39]. From these discrepancies between administrative data and independent surveys, it is evident that there is a problem with the reporting of vaccination status, and in all likelihood, the administrative data collected from the field is inflating immunization coverage. Partly as a result, Pakistan accounts for 40% of the 3.8 million infants who did not receive one or more vaccines in 2015 globally, and is ranked third among the list of countries with the most unvaccinated and under-vaccinated children [44].

Previous findings highlight paper-based, manual recording of immunization data to be a salient reason for data inconsistencies [36, 41], and subsequent work has focused on designing digital data collection tools [6, 7, 16, 31, 45]. This work has found that data errors result from accidental omissions, prioritization of quantity over quality, rough approximations, and deliberate fabrication in the data collected by front-line workers [25]. Of these, intentional falsification of data is reportedly the most common [7, 17, 25, 45] and the most difficult to detect [12]. Thus far, however, few studies either by technology or healthcare researchers have focused on understanding data falsification in depth.

In this paper, we focus on what the immediate supervisors of front-line vaccinators know about data falsification among the vaccinators they oversee. Past work has demonstrated that the attentive involvement of supervisors can ensure good performance by front-line health workers [15, 17, 18]. It therefore seems likely that supervisors have strategies for detecting data falsification and managing it. The findings we present in this paper confirm that this is in fact the case.

We performed an ethnographic study with 22 such mid-level managers – known as Assistant Superintendent Vaccinators or *ASVs* – in Punjab, Pakistan, as a case study. Our research questions were:

- What strategies do ASVs employ to identify intentional falsification in administrative data collected by vaccinators?
- Are there any patterns or trends in the data falsification strategies used by ASVs that could lead to design recommendations?

We find that intentional data falsification is commonplace in Punjab – all 22 ASVs were aware of it, and had devised multiple techniques based on triangulation, anomaly detection, supplementary data collection, and interrogation to identify instances of data falsification. Our findings not only build on the considerable literature that acknowledges data falsification as a problem [25, 45, 47, 53], but go well beyond in providing details of the types of falsification and ways to catch it that are essential in any attempt to develop digital tools to improve vaccine delivery in global development contexts with formal record-keeping. We also observed a possible pattern – that requires further research to verify – that the managerial style of ASVs affects their strategies of choice with respect to detecting falsified data. ASVs who prefer largely supportive supervision tend to use triangulation more often. In comparison, ASVs who follow a more punitive management style focus on supplementary data collection and interrogation techniques to find mistakes quickly. Based on these strategies to identify intentional falsification, we provide design recommendations that could be implemented within digital immunization platforms. We also provide recommendations to use statistical analysis tools to identify low-performing areas.

2 CONTEXT: BACKGROUND

In many developing countries, healthcare systems have a mid-level cadre of worker-managers who serve as a bridge between the field workers and district administration, and who supervise the work of front-line workers [4]. In Pakistan, these mid-level managers are known as "Assistant Superintendents Vaccination," or ASVs. ASVs do not have administrative power to hire, promote, or terminate vaccinators, but they have a supervisory mandate and are responsible for immunization coverage and management of their vaccinators.

Our study took place in the province of Punjab, which is the most populous province in Pakistan. Punjab has 36 districts. Each district has a Chief Executive Officer (CEO) Health, a District Health Officer (DHO) for public health management, and a District Superintendent Vaccination (DSV). The DSV is solely responsible for immunization and is answerable to the CEO and DHO and to the EPI heads at a provincial level. Districts are further divided into 4 to 7 administrative subdivisions called *tehsils* based on the population and geographical area. Every tehsil has an ASV. Tehsils are further divided into Union Councils (UCs), which constitute the smallest administrative unit. The number of UCs in a tehsil varies from 20 to 40 depending upon the population. Every UC has a Basic Health Unit (BHU) that provides the minimum degree of health care considered to be necessary to maintain adequate health and protection from diseases. Typically, every BHU is supervised by a Union Council Monitoring Officer (UCMO), who is in charge of all the health-related activities performed at the BHU by the health workforce, the latter composed of Lady Health Workers (LHWs), Lady Health Supervisors (LHSs), Lady Health Visitors (LHVs) and front-line immunization workers or "vaccinators."

Vaccinators are government employees assigned to administer routine immunization to children 0-15 months of age in their assigned UC. State-assigned responsibilities of vaccinators include: (1) inoculating children in the field; (2) creating child health records on paper-based registers; (3) filling out immunization cards given to the parents; (4) preparing monthly reports of immunization coverage; (5) documenting children who missed a visit in a list called the defaulter list; (6) managing vaccine stock lists; and (7) performing field duties as part of special immunization campaigns called "Supplementary Immunization Activities (SIAs)" for polio, measles, and other vaccine-preventable diseases. One vaccinator covers a population of around 25,000 people. Vaccinators further divide each UC into towns or villages and visit particular towns/villages following an assigned detailed immunization coverage strategy called a *micro-plan*. At each village, they establish a temporary vaccination booth called a *kit station*. The kit station is usually set up at a house of a reputed person in the village or at the house of an LHW. In order to inform the community about their kit station location, and to remind them about their children's scheduled immunization, vaccinators make announcements at the local mosque.

There are about 3,750 vaccinators in Punjab; the vast majority are male. Vaccinators are provided with an official motorcycle [49], a monthly fuel allowance with which to perform immunization activities, and mobile phone minutes to coordinate vaccinations. Along with this dedicated immunization workforce, there is a parallel workforce at each hierarchical level that is responsible for non-vaccination efforts related to maternal health, sanitation, nutrition, communicable diseases, and other health issues. Generally, these two entities do not interact very often; however, during special SIAs or in case of staff shortages, the district-level health administration allows staff from other public health domains to assist the immunization team [43]. An organogram that details the dedicated and additional workforce for immunization related activities is shown in Figure 1.

3 RELATED WORK

In order to understand data falsification by health workers in field data and the strategies used to identify such falsification, we review existing literature on identification of both unintentional and intentional errors by front-line health workers. We also explore formalized strategies deployed by global health organizations as well as HCI and CSCW researchers to ensure the quality of data collected

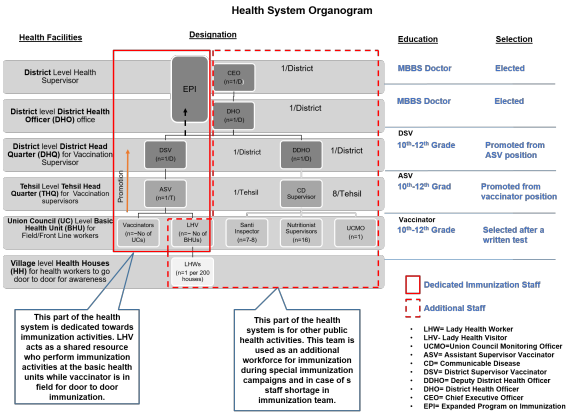

Figure 1: Immunization department Organogram depicting the two different hierarchies in Punjab's public health system

from the field, especially in the developing world context. Moreover, to understand the roles of mid-level managers in managing data quality, we outline literature that details the roles of mid-level managers and their different styles of supervision. Throughout, we focus on literature highlighting technological interventions to facilitate data gathering by front-line workers and quality monitoring of this data by their supervisors.

3.1 Health Data Falsification in Developing Countries

Poor data quality is a major concern for health data collected in the field, and literature has identified both unintentional and intentional causes of poor data quality. Unintentional errors arise from approximation [25], outright errors [45], and omissions [53]. Approximations are front-line health workers' guesswork and estimations while collecting field data [25]. Workers may make approximations due to missing information and respondents' discomfort in sharing requested information [25]. Errors related to spelling, linguistic differences and varying levels of literacy may also emerge [25, 45]. Missing values have been linked to time and language constraints [25].

In addition to unintentional errors, researchers have also discussed deliberate falsification in survey data. Such data fabrication is also known as "curb-stoning" or "systematic interviewer errors" [6, 7]. In this case, survey enumerators fabricate data when they cannot reach intended respondents, are uncomfortable asking sensitive questions, or are paid based on the number of surveys completed [6, 7]. Intentional fabrication of survey data is characterized by unusual amounts of unavailable respondents, missing contact information [30, 38], fast interviews [11], and low variance in fabricated values [7, 10]. According to literature, fabrication may be more common in low- and middle-income countries due to limited supervision, chaotic environments, language barriers, and low literacy [6, 7]. However, intentional and unintentional errors in health survey data have both been discovered and reported in studies around the world. For instance, a survey from the United States Census Bureau found at least 6.5% of interviewers falsified at least some of their data [51]. In another survey, 13% of interviewers admitted to fabricating at least part of an interview despite being supervised in a telephone call center [27]. Such fabrication threatens the ability of decision-makers to use survey data effectively.

Within immunization, the World Health Organization (WHO) assessed the consistency and reliability of child immunization administration data from 217 countries and territories worldwide (including Pakistan). WHO categorized 30% of the reported values as containing potential inaccuracies [42, 50]. Further studies showed that these inconsistencies come from data collected manually by front-line health workers at the lower level health facilities such as Basic Health Units (BHUs). This analysis shows that, whether intentional or unintentional, there are significant inconsistencies in immunization data. This undermines effort to create and implement data-driven policies and hampers countries' abilities to manage immunization programs[42, 50].

3.2 Strategies for Identifying Health Data Falsification

In recent decades, a growing amount of health data has been collected digital on computers, PDAs and mobile phones [15, 23, 45, 46, 48]. Use of digital devices for data collection can make it easier to detect intentional falsification through automated anomaly detection. [6, 7]. For survey data anomalies, such algorithms may identify interviewer fabrication with an accuracy of up to 96% [6].

However, administrative data collected in the field is more complex than survey data, leading to additional difficulties. This complexity arises from the use of a combination of various paper-based data collection instruments. To identify falsification in the quality of administrative immunization data, WHO developed the Data Quality Audit (DQA) protocol. The DQA protocol compares data on Diphtheria, Pertussis and Tetanus (DPT3) coverage at the level of the nation or province to district-level DPT3 coverage data. This is used to identify inconsistencies between aggregated and individual reports [42]. The DQA thus uses a form of triangulation, a common technique that compares data from multiple perspectives, sources, or methods, to verify the authenticity of information [22, 29]. Studies using the DQA protocol have found local data in health facility registers to be incomplete. It also has low concordance with other data sources [2, 21, 32, 33, 52]. Analysts suggest that these data quality problems can be linked to: (1) redundant data collection tools; (2) lack of transportation; (3) poorly defined roles among local workers; (4) a lack of training for mid-level supervisors on supportive supervision; and (5) lack of airtime or internet access for electronic data reporting. If applied correctly and consistently, DQA can an effective method for identifying discrepancies in administrative data concerning vaccination [50].

However, DQA recommendations only look at data aggregated at the district level and do not identify individual instances of falsification, which is necessary to address the causes of it. Because mid-level managers are supposed to inspect data up close, they are the most likely to have insights about false data. To the best of our knowledge, no prior research has investigated mid-level managers' methods for detecting intentional data falsification in administrative field data collected by front-line health workers. Our

work addresses this critical gap by exploring ASVs' strategies for detecting falsified vaccination data.

3.3 Role of Mid-Level Managers in Ensuring Health Data Quality

In most developing countries, healthcare systems have a mid-level cadre of health worker-managers who serve as a bridge between the field workers and district administration [4]. Despite being a vital part of the health care system, there has been limited worldwide investment in building the capacity of these mid-level managers.

While exploring improvements in quality of collected field data, previous studies highlight the importance of supervision. However, prior work has primarily focused more on designing interventions for front-line health workers [16–18, 25, 31, 37, 45, 47]. The few studies that do focus on supervisors have considered their roles in the continuous monitoring of front-line health workers [15, 17, 18]. Three levels of monitoring interventions have been seen in literature: (1) interventions that inform front-line health workers proactively about their daily tasks; (2) interventions that involve supervisors by informing them about workers' performance; and (3) interventions that provide health workers with feedback on their own performance without letting supervisors into the system [15, 17, 18, 37, 47]. These studies support supervisors' mandatory roles in in managing front-line health workers. However, all such supervisory interventions were designed from the perspectives of front-line health workers, not their supervisors. In our study, we focus on the perspective of mid-level supervisors.

Developing countries such as Pakistan usually follow a top-down hierarchical model of supervision [8]. This type of supervision focuses on inspection and line management, where mistakes are identified and blame is allocated, with no or only negative feedback [3]. Such supervision is named *punitive supervision*, and it places the onus for fixing problems on the subordinate staff by finding faults in their work [3, 19]. Top-down approaches to supervision, mostly used by postcolonial developing countries, need to change in order to improve health service staff performance [19]. An alternative to punitive supervision is *supportive supervision*, defined as a process that promotes quality at all the levels of the health care system by strengthening relationships within the system. It focuses on identifying and resolving problems, creating an environment of effective teamwork, and encouraging two-way communication [13]. In short, it focuses on facilitation instead of inspection [3].

Past research claims that supportive supervision is an efficient tool for strengthening healthcare systems because it enhances not only professional development, but also promotes personal growth through job satisfaction, valuation, and empathy [3, 8, 9, 19, 33]. The effectiveness of supportive supervision also rests upon the quality of the relationship between supervisor and supervisee [28]. Clements et al. argue that while supportive supervision is undoubtedly an improvement over the traditional model of punitive supervision, it will not succeed to any great extent until there is a better understanding of the human interactions involved in supervision, i.e., the quality of interaction between supervisors and their subordinates, which in turn reflect cultural boundaries [13]. Building on the idea of interaction and cultural sensitivity given by Clements et al., we lightly explore the possibility of supportive supervision within a typical top-down hierarchical setting, and uncover how supervision styles may impact the types of approaches implemented by ASVs to identify data falsification.

4 METHODS

We conducted fieldwork in five districts of Punjab, Pakistan, including central and south Punjab, focusing on the ASVs whom we believed would have the most insight about vaccinator data falsification. We used qualitative, mixed-methods to study our research questions. The Institutional Review Boards at both Information Technology University in Pakistan and the University of Michigan in the United States approved this study.

4.1 Participant Recruitment

Because ASVs are government employees, in order to interview and observe them in the field, we needed approvals from multiple people holding roles of authority in the health system. To obtain access to the field, we presented our study to the Health Ministry of Punjab, leadership team of the EPI department and the respective districts. We received approval in the form of a signed letter from the Ministry, stating that we could conduct field research in any of the districts listed on the letter.

We intentionally sampled five districts from the list of available districts based on a combination of convenience, geographical spread, and performance of districts in terms of stated immunization coverage in order to explore the variation among them. We interacted with all DSVs and ASVs in each of these five districts, except for one ASV, who was on leave during our visit to that district.

4.2 Data Collection

Overall, we interviewed a total of 30 members of the EPI department — 22 ASVs, 5 DSVs and 3 members from the EPI provincial leadership team. With our participants, we conducted 14 one-on-one interviews [1], 3 focus group discussions, 6 informal interactions, and 5 field observations. Along with interviews and observations, we gathered 139 artifacts from the field (mostly photos of documents). The fieldwork was conducted from August 2019 to December 2019, involving 57 hours of interviews, focus groups, and observations. Additional time was required to schedule meetings, travel to sites, conduct informal interactions, and collect artifacts.

We conducted 14 one-on-one interviews with ASVs from four districts of Punjab. We will not refer to districts by name, to preserve participant anonymity. Rather, we call them district A (2 ASVs), district B (4 ASVs), district C (6 ASVs), and district D (2 ASVs). Each interview lasted for 1.5 hours on average. We also conducted three focus group discussions in districts A (2 ASVs and 1 DSV), C (2 ASVs) and E (4 ASVs and 1 DSV). Each focus group lasted for 2 hours on average. Demographic details of participants, along with their types of participation, are provided in Table 1. All interviews and focus group discussions were conducted at district-level health offices. Interviews and discussions were audio-recorded after obtaining participant consent, and were conducted in Urdu, the national language of Pakistan. Interviews were later transcribed first into Roman Urdu (Urdu written in Roman script instead of the traditional Arabic script) and then translated into English by two

of the authors. In some cases, ASVs requested that the researchers write down certain pieces of information that they thought was important. In such cases, researchers jotted down participant expression, along with particular quotes, location, or the names that help to recall the incident later [20].

In addition, to understand how ASVs work when they were in the field, we conducted five observation sessions with the same ASVs we interviewed in districts A (1 session), B (2 sessions), C (1 session) and D (1 session). Each observation session took 3 hours on average. Field observations were recorded by the researchers in the form of field notes and audio recordings. As we needed approval from DSVs to engage in their districts, we also had an informal interaction with the DSVs from all the four districts. In these informal interactions, we explained the purpose of our study and recorded any initial DSV comments. Apart from DSVs, we had informal interactions with three members of the leadership of the EPI department. We also collected 139 different artifacts from the field – mostly photographs of paper documents or screenshots of digital devices. These artifacts included pictures of daily registers, monthly reports, checklists, cluster assessment forms, defaulter lists, monthly plans, monitoring charts, screenshots of EPI mobile application used by ASVs, and work-related WhatsApp group conversations. All artifacts were taken with ASVs permission and, in some cases, at their request.

4.3 Analysis and coding

All data, including transcripts, field notes, and information from artifacts, were thematically analyzed using the inductive process outlined by Willing et al. [54]. During the first round of open coding, two of the authors coded the text, and thematically organized it according to our research questions. Generated codes were shared and discussed by all authors after two cycles of open coding. The second round of coding was more high-level and resulted in codes such as "the roles and responsibilities of ASVs in a hierarchical government environment," "strategies to identify data falsification," and "motivations behind detecting falsification." In the third round of coding, we combined different strategies and motivations behind identifying falsification into different sub-themes.

4.4 Researcher Positionality

Three of the authors (Batool, Fatima, Naseem) are Pakistani, and together have more than 10 years of research experience with Pakistan's public sector. Two (Batool, Fatima) conducted the primary research for this study; the third (Naseem) also assisted with gaining access to the field. These authors have worked closely with the Punjab health department since 2013 and have extensive experience with the social dynamics of Pakistani public health organizations and those who work for them [5, 49].

As researchers, we experienced several issues in which our positionality might have affected data collection. First, Pakistan is a deeply patriarchal society, especially in the peri-urban and rural areas in which we worked [24, 55]. Women are not expected to travel much outside their homes, so vaccinators are almost always men. Thus, all interview participants were male, whereas all interviews were conducted by women (Batool, Fatima). In order to adhere to local cultural expectations, a male colleague accompanied both women researchers during all field visits. As far as we could tell, however, the salient class difference between interviewers and the field staff overwhelmed any gender dynamics as often happens. In any case, the female co-authors experienced no instances of overt discrimination or hostility, and while there may have been some points of omission by the participants (as sometimes happens with gender and healthcare), we do not believe there were significant misrepresentations based on gender dynamics.

Second, there was a difference of power as the researchers were comparatively wealthier, better educated, and better connected to health ministry leaders than the participants – a fact that was immediately apparent to the participants based on dress, language, other observable traits, and our research approval letter. We are experienced at establishing rapport with interview participants in related contexts, and we attempted to distance ourselves from the health ministry hierarchy by introducing ourselves as independent researchers. Nevertheless, those we interviewed were likely to have felt some degree of deference and sense of being evaluated, leading to a desire to impress us. This might be reflected in attempts to inflate the extent to which they used their practices for detecting data falsification, or to misrepresent their actual supervision strategies. We suspect some such bias was inevitable in our findings, but we also believe that the substance, if not the degree, of what the ASVs told us is largely reliable. The detection methods we detail below seem very unlikely to have been conjured up on the spot, and in their demonstrations to us, ASVs appeared facile and accustomed to identifying instances of data falsification.

5 FINDINGS

We begin by contextualizing our findings with the details of ASV roles and responsibilities. The remainder of our findings focus on the nature of vaccinators' data falsification and strategies used by ASVs to identify it. We also present preliminary findings about ASVs supervisory styles and how it relates to detection strategies.

5.1 Roles and Responsibilities of ASVs

ASVs are responsible for supervising vaccinators, and to ensure smooth operations of all the immunization related activities in their tehsil. Their key tasks are:

- Monthly immunization report: ASVs prepare and submit a consolidated immunization report of the entire tehsil by combining individual reports of all vaccinators under their supervision.
- Monthly route planning and daily UC visits: ASVs prepare a 24-day plan that constitutes a visit to one or two UCs daily to monitor immunization activities.
  - Visit the BHU to keep track of immunization activities, including vaccine stock monitoring as well as keeping a track of the vaccinations administered by the LHV. ASVs fill out standard state-provided checklists based on immunization activities performed at the BHU.
  - Visit a kit station to observe vaccinators in action. ASVs monitor vaccinator performance and record their observations in a state-provided checklist.
  - Perform a randomized cluster assessment to monitor on-time vaccination status of children under each vaccinator's

Table 1: Demographic details of participants

ID	District	Age	Education (Grade)	Years in Service (Exp.)	Vaccinators under Supervision	Participation
ASV5	A	40	12th	18	19	Interview+Observation
ASV6	A	50	10th	20	08	Interview
ASV7	A	48	10th	20	51	Focus Group 1
DSV1	A	55	10th	30	NA	Focus Group 1
ASV9	B	54	12th	34	17	Interview+Observation
ASV10	B	33	12th	13	41	Interview+Observation
ASV11	B	54	10th	30	11	Interview
ASV12	B	52	10th	32	27	Interview
DSV2	B	58	10th	30	NA	Interview
ASV13	C	57	12th	37	23	Interview+Observation
ASV14	C	33	10th	12	25	Interview
ASV15	C	35	12th	11	10	Interview
ASV16	C	59	12th	37	19	Interview
ASV17	C	52	10th	30	35	Interview
ASV18	C	28	14th	06	25	Interview
DSV4	C	58	10th	30	NA	Informal Interaction
ASV19	D	58	12th	36	52	Interview+Observation
ASV20	D	55	12th	36	29	Interview
ASV21	D	56	10th	35	39	Focus Group 2
ASV22	D	58	10th	36	34	Focus Group 2
DSV3	D	40	10th	20	NA	Informal Interaction
ASV1	E	45	10th	25	38	Focus Group 3
ASV2	E	48	10th	22	34	Focus Group 3
ASV3	E	50	10th	25	NA	Focus Group 3
ASV4	E	45	10th	20	NA	Focus Group 3
DSV5	E	50	10th	30	NA	Focus Group 3
Leadership Member1	EPI Dept.	62	NA	35	NA	Informal Interaction
Leadership Member2	EPI Dept.	NA	NA	31	NA	Informal Interaction
Leadership Member3	EPI Dept.	NA	NA	33	NA	Informal Interaction

UC. ASVs visit ten random households in the same community where a vaccinator has currently set-up a kit station, and note down the on-time immunization status of the children in the community. This gives them an accurate assessment of the status of immunization in that locality. ASVs mark state-provided cluster assessment forms, recording each child's status as 'on-time', 'partial', or 'not vaccinated'.

- Managing other immunization activities: ASVs are responsible for managing SIAs that are organized in case of a disease outbreak or in case of exceptionally low immunization coverage detected through the randomized cluster assessment. As part of organizing SIAs, ASVs organize tehsil level immunization meetings while also attending district level immunization-related meeting as a regular part of their job.

Previously these checklists and cluster assessment forms were paper-based. However, since 2019, EPI Punjab has switched to digitized checklists and randomized cluster assessments are also submitted using a custom Android smartphone application rolled out by the health department.

5.2 Authority of ASVs

We found that ASVs have limited authority within the immunization system of Punjab (Pakistan). Though nominally supervisors, they have very limited ability to affect vaccinators, either in terms of negative consequences for poor performance or positive outcomes in terms of allocating job-related resources. At best, they can make warning calls to the DSV, which results in a reprimand and a red line in the permanent record of the vaccinator. In our fieldwork, only in one instance did these warning calls lead to the deputation of a vaccinator to a remote area as punishment. However, no amount of such warnings lead to termination. Furthermore, ASVs are unable to affect the delivery of fuel, travel and daily allowance, and mobile data packages for their vaccinators. One ASV told us:

"When we ask [vaccinators] why they have not marked attendance and submitted records on Evaccs [the digital immunization system], they tell us that they don't have mobile data packages because the department did not reload their data plans... When we raise this issue or any such small technical issue in our administrative meeting, [our supervisors] only say that it will be done... Why will [vaccinators] listen to us when they know that we don't have the power to even get them their data plans on time?" ***[ASV7, District A, Exp.: 20]***

To make matters worse, 17 of the 22 we interviewed were only auxiliary ASVs - an additional charge of ASV given to a vaccinator who gets additional pay to perform the duties of a regular ASV instead of a vaccinator. They received additional pay to perform the duties of a regular ASV, but were not provided the permanent position of ASV. According to ASVs, this additional charge title further limits their power in the system, as other vaccinators see them more as peers than supervisors.

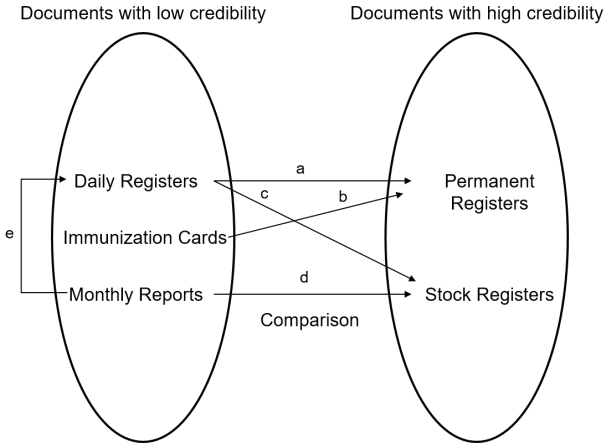

Figure 2: Comparisons between different documents used for triangulation

To buttress their power, ASVs resort to a range of tactics. They would publicly shame vaccinators during meetings, or they would offer public praise on Whatsapp groups (about which, more in Section 5.4). In some cases, they faked authority they did not have. For example, ASVs cast field visits from higher-ups as opportunities for vaccinators to air grievances and concerns; the ASV hopes in these cases to deceive vaccinators into believing he has influence with authority. (We experienced exactly this tactic in one meeting with vaccinators – the ASVs present requested our team to spend a few minutes listening to vaccinator complaints, even though they knew we could nothing to address them. To minimize ethical issues, we fulfilled the ASVs' request, but clarified our position to vaccinators). Such tactics help ASVs to establish their power at least for a short period of time.

5.3 ASV Strategies for Identifying Data Falsification

Our participant ASVs believed data falsification was frequent among vaccinators and that the formal protocols of the health system were insufficient to catch intentional falsification. To address this gap, ASVs have developed strategies to detect falsification themselves. Below, we describe a range of strategies, organized into four major types: triangulation, data supplementation, anomaly detection, and interrogation.

5.3.1 Triangulation. Triangulation refers to the cross verification of two or more data documents [22]. 6 out of 22 ASVs used some form of triangulation. Out of all the instruments vaccinators record data, ASV's consider the permanent register and stock register to be the most accurate as they are kept in BHUs under the supervision of UCMOs; vaccinators are required to enter data in these registers within the BHU premises. Therefore, most triangulation methods involve at least one of these two registers, as shown Figure 2.

Triangulation 1 – Comparison with Permanent Registers: According to ASVs, vaccinators sometimes falsify the date of vaccination on children's immunization cards so that the vaccination appears 'on time,' even though they may have missed the due date. In this case, the right child gets the right vaccine(s), but not on time. However, vaccinators cannot go back and add these instances to past records in the permanent register. Therefore, ASVs compare the data copied from immunization cards into cluster assessment forms with the permanent register. (See line *b* in Figure 2). While explaining this strategy, an ASV told us:

"These vaccinators sometimes enter [vaccine inoculation] dates in [immunization] cards according to the date of birth of the child to give us an illusion that they have done 'on-time' vaccination but they can't enter the wrong date in [permanent] registers because they have to justify their daily target. So they enter the correct date in the register but fake date on cards. So when I compare both [cluster assessment forms with permanent register], I get the idea that the vaccinator has done something wrong here." ***[ASV12, District B, Exp.: 32]***.

Similarly, ASVs told us that in order to meet their daily vaccination target, vaccinators create fake entries in their daily registers with fictitious names and vaccination status. This creates an inflated coverage at the end of the month. ASVs will sometimes bring permanent registers to the vaccinator's kit station and compare daily register entries with permanent registers (line *a* in Figure 2). While explaining this strategy for identifying this type of falsification, an ASV told us:

"Sometimes when they enter fake data in the daily register, they don't enter it in the permanent register. Like, we inoculate measles-1 to a child at 9 months of age so if a vaccinator has inoculated measles-1 to a child today and has entered this vaccination in the daily register. Then, this child should have been registered [by] this vaccinator in the permanent register 9 months ago, but if that child has no entry in permanent register 9 months ago, it means this entry is fake." ***[ASV10, District B, Exp.: 13]***.

Triangulation 2 – Comparison with Stock Registers: According to ASVs, in order to achieve their monthly target, sometimes vaccinators enter fake counts of vaccine consumption in monthly reports. ASVs verify these monthly reports in one of the following ways:

- ASVs picks a random date and counts the consumption of one vaccine on that particular date from the daily register and then compares the same vaccine's count from the stock register on that particular date (comparison *c* in Figure 2).
- ASVs match the vaccine counts of monthly reports with the stock registers to identify discrepancies in count (see *d* in Figure 2). While explaining this comparison, an ASV told us:

"I pick the count of one vaccine from the monthly report and count that vaccine in the stock register to verify if both counts match or not. If a vaccinator has done any falsification in his daily register, it will reflect in his monthly report but he has to enter the exact amount of vaccine he took from the BHU's stock in the stock register." ***[ASV20, District D, Exp.: 36]***.

Triangulation 3 – Comparing Monthly Reports with Daily Register (comparing two low credibility documents): Aware of the fact that vaccinators inflate coverage to achieve their monthly targets, ASVs do an initial screening of monthly reports submitted by the vaccinators. In this screening, ASVs select the monthly consumption count of vaccines from the monthly report and verify

Table 2: Description, location, time of entry and credibility of Vaccinators' and ASVs' Data Collection Documents

Document	Description	Physical Location	Time of Data Entry	Credibility (According to ASVs)
Documents used by Vaccinators				
Permanent Register	A paper-based register with a summarized record of each child's immunization. Each row in this register represents the whole immunization record of one child	At Basic Health Unit (BHU)	At the end of the day	High: Vaccinator enters the record in this register at BHU in front of Union Council Monitoring Officer (UCMO)
Daily Register	A paper-based register with granular level entries of children e.g.: demographics and vaccines. Each row represents one visit. Multiple entries for one child depending upon the number of visits that the child has made.	With vaccinators, they carry it along to the kit station.	At the moment of vaccination	Low: Prone to falsification because the vaccinator carries it along
Stock Register	A paper-based register with the entries of all the vaccines a vaccinator takes along in the field from the stock and puts back at the end of the day	At Basic Health Unit (BHU)	At the start and end of the day	High: Vaccinator enters the record in SR in BHU in front of UCMO
Due-Defaulter List	A paper-based list containing granular level details of children due on a day including vaccination due, parents' information, contact details, etc.	With vaccinators. They carry it along to the kit station.	At the start of the day	Low: Prone to falsification because vaccinators create this list on a plain paper every morning by traversing their daily register and/or permanent register and look for children who are due for vaccination on a day.
Monthly Reports	A paper-based report created at the end of each month, summarizing the vaccination details of a month.	With vaccinators. They carry it along to the DDHO office.	At the end of each month	Low: Prone to falsification with inflated coverage to achieve the monthly target.
Immunization Card	A paper-based card given to parents to keep a track of their child's immunization status.	With parents. They carry it along to the kit station.	At the moment of vaccination	Low: Prone to falsification because it cannot be verified.
Evaccs	An android-based mobile application for vaccinators' monitoring. Vaccinators enter details of the location where they inoculate vaccines and children they inoculate vaccines.	With vaccinators. They carry it along to the kit station.	At the start of the day to check-in. At the moment of vaccination to enter vaccination details. At the end of the day to check-out.	Low: Prone to falsification because no one looks into the data that is being recorded in the application
Documents used by ASVs				
Checklist	An android-based checklist for ASVs to mark vaccination activities of staff at BHU and kit station during their visits.	With ASVs. They carry it along to BHU and kit station	At the moment of supervisory visits in facilities	NA
Cluster Assessment Form	An android-based form to enter vaccination details of 10 kids from the community.	With ASVs. They carry it along to community visit	At the moment of supervisory visits in the community	NA
Supervisory Application	With ASVs. They carry it along.	With ASVs. They carry it along	At the moment of supervisory visits	NA

these counts from the daily register (comparison *e* in Figure 2). Any discrepancy between the counts leads to a full record verification. While explaining this strategy, an ASV told us:

"We pick two random antigens from the (monthly) report and verify it from the daily register. If the count of both (antigens) are same in the report and daily register, it means data is OK. And if the count of one of the antigens mismatches, we count all antigens." ***[ASV9, District B, Exp: 34]***

Triangulation 4 – Comparing Three Documents: ASVs told us that they sometimes compare both immunization cards and daily registers with permanent registers. While explaining the details of this strategy, an ASV said:

"When we go for checking, we note records of three children from the permanent register... While in the field, we ask the vaccinator to show us the record of these three children in the daily register and ask the lady health worker to go and get the cards of these children from the community...We then match the record on the immunization card with the daily and permanent register to see if all three entries match or not." ***[ASV22, District D, Exp.: 32]***

The leadership of the EPI department was aware of triangulation and considered it as a highly credible technique to improve the quality of immunization data. Moreover, the department showed an inclination to adopt this strategy as a formal approach for measuring the accuracy of data.

5.3.2 Collecting Supplementary Data: Supplementary data is the collection of additional data to validate the accuracy of records entered by vaccinators. 7 out of 22 ASVs collected supplementary data as one of the strategies to identify falsification. The primary source of supplementary data is contacting parents of children - ASVs either call parents on their mobile phones or talk to them in person while visiting the community to ask them about their children's immunization status. Supplementary data helps ASVs to verify data recorded in two of the documents mentioned in Table 2 , i.e. children's immunization cards and defaulter list. Two such verification techniques were uncovered:

Collecting Supplementary Data 1—Due-Defaulter List and Calling Parents: Due-defaulter lists help vaccinators identify children that have missed a routine vaccination, such that they can follow up with them and identify the cause of the delay. It takes significant effort to manually go through paper-based records to identify children who are due for a routine immunization but haven't completed it as yet. According to ASVs, some vaccinators believe that visiting a community and making an announcement in mosques about their presence and kit station location is sufficient to remind parents about their children's upcoming vaccination. Therefore, they feel that a due-defaulter list is not required. While explaining the indifference of vaccinators, an ASV told us:

"What they do is that they will go to their kit station and make an announcement in mosques about their arrival and then inoculate vaccine to children who appear at the kit station and will not take any tension about those who don't show up. Instead of making defaulter list to identify such kids, he will sit idle and come back after some time." ***[ASV12, District B, Exp.: 32]***

However, since ASVs may ask for such a list during their surprise visits to the kit station, vaccinators simply write down fake names

of children with false contact numbers of guardians. Creating a fake list may lead to parents of children who've missed a vaccination to not be reminded about their oversight. This lack of a reminder notice leads to a reduction in immunization coverage in the region. Consequently, during their visit to a kit station, ASVs check if a vaccinator has a defaulter list and if the list is accurate. To verify the accuracy of the list, some ASVs call the guardians' mobile number listed on the due-defaulter list and ask parents if their child is due for immunization. While explaining a similar situation, an ASV told us:

*"I asked him [vaccinator] to show me the defaulter list. He gave me the list. Some of the mobile numbers seemed familiar to me so I called one of the numbers. A lady picked the call. I asked her if any of her children are due today… [It turns out, she was] a health worker [the lady health worker of that region] and not a mother [of a child who had missed a shot] and the vaccinator had entered fake data in the defaulter list. That is why these [cell phone] numbers looked familiar to me."**[ASV5, District A, Exp 18]***

Collecting Supplementary Data 2—Immunization Card and Mothers' Recall: Sometimes, vaccinators inoculate one injection to a child but mark all injections of a visit in the immunization card. With this forgery, children are harmed as they miss important vaccines. Therefore, to ensure the accuracy of data entered in immunization cards, ASVs, while inspecting the immunization card during their community visits, ask parents to recall the last immunization inoculation details of their children. While explaining the technique, an ASV told us:

*"They [vaccinators] inoculate one injection and mark all [inoculations due for that visit as complete] in the immunization card. So the best way to check this is to ask the mother... A mother might not know which injection was inoculated to her child but she surely knows how many needles were injected because she has to take care of these injection spots... Then we match what the mother is saying with the card and get an idea if the vaccinator is adding false data on cards or not." **[ASV20, District D, Exp.: 32]***

Some ASVs check injections marks to get an idea about the number of injections inoculated to a child in the last visit.

5.3.3 Anomaly Detection: Anomaly detection in our context is the identification of unusual patterns in immunization data entered by vaccinators in the documents mentioned in Table 2; such anomalies raise doubts about data authenticity. 4 ASVs out of 22 used anomaly detection as one of the strategies to identify falsification. We uncovered four types of anomaly detection.

Anomaly 1 – Blanks in Daily Registers: As per department policy, vaccinators are not allowed to leave any empty space or a blank page in their daily registers. At the end of each day, vaccinators draw a line and sign on the daily register's page where they end entering data for that day as shown in Figure 3. They start entering data right below that line on the next working day. According to ASVs, leaving any empty space in the daily register means a vaccinator is planning to enter fake entries to meet his daily target. Therefore, ASVs simply scroll the daily registers and look for a blank page or empty rows on a given page.

anon.png

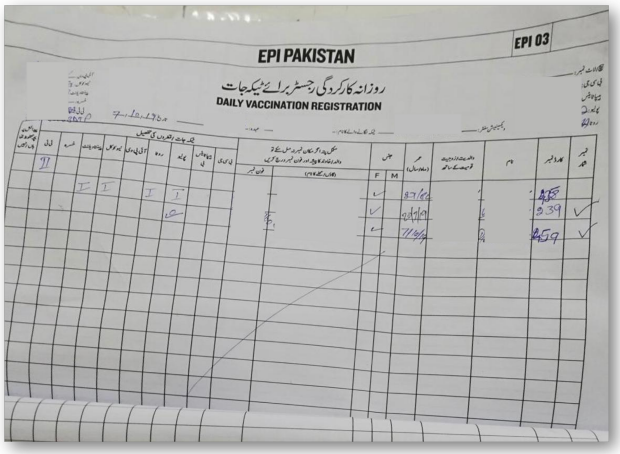

Figure 3: Daily Register

Anomaly 2 – Same Entries in Multiple Rows: In this strategy, ASVs look for duplication of rows or columns while scrolling through the various documents mentioned in Table 2 . During an observation session in the field, an ASV scrolled through a vaccinators' daily register at a kit station in front of us. In doing so, he identified a page with the same entries in two rows. He showed us the page and explained that he knew this data is fake because all the details of the child are the same in both rows except for the immunization card number. He then asked the vaccinator for an explanation of both rows' entries. The vaccinator said that this child was receiving vaccines from two health facilities (kit station and Rural Health Center (RHC)) and therefore had two cards. We asked the ASV about the possibility of one child having two cards with different card numbers from different facilities, and he said that this is not allowed. He, then, explained the EPI protocol for this situation as:

*"Vaccinators are supposed to visit the RHC of their area once a month to get the record of all the children who are either born there or get any vaccination from there... but she (the female vaccinator) did not bother to go to the RHC to get that record... I think she has made up all these entries by herself to fill the register because she recently came back from her maternity leave and has a lot of backlog. That is why she is creating these fake entries to catch up on her target..." **[ASV10, District B, Exp.: 13]***

Anomaly 3 – Fixed number of Entries every day: Another way ASVs use to detect falsification is through pattern recognition - particularly the number of daily entries recorded. While explaining this technique, ASVs told us that vaccinators who enter fake data, usually enter the same number of entries every day:

*"When I checked his [vaccinator] daily register, there were six entries each day for the last one and a half months. Neither 5 nor 8, he exactly inoculated six injections in routine for the last 1.5 months...[which is impossible]. This whole data was fake and it means he submitted his monthly report based on this false data..." **[ASV5, District A, Exp.: 18]***

Anomaly 4 – Gaps in Immunization Card Serial Numbers: Every vaccinator has a yearly target (provided by the EPI department) to register a certain number of newborn children in their UC. Vaccinators who are unable to meet their yearly target skip serial numbers and assign card numbers close to their target towards the end of the year. ASVs actively look for any gaps in card numbers in the last months of the year to identify. While explaining this strategy, an ASV told us:

"Its December and one of my vaccinators has a yearly target of registering 932 newborn children. I saw that on 16th December, he [vaccinator] issued a card with serial number 620, and on 24th December, he issued a card with a serial number of 800. So if he was registering around 50 newborns in a month on average, how can he register 250 children in 8 days. Not possible, right?! I asked him to show me the record of these children in the permanent register but he had no data of those children in the permanent register and he was speechless. If the data is fake and if we have seen that [falsified] data, then they can't dodge us with words." ***[ASV7, District A, Exp 20]***

5.3.4 Interrogation: All ASVs were previously vaccinators, and are therefore familiar with many, if not all, of the tactics for data falsification and may have even practiced some of these tactics during their appointment as a vaccinator. 8 out of 22 ASVs used their intuition to spot-check and verbally interrogate random entries in the registers.

Interrogation 1 – Direct Confrontation: ASVs told us that they are aware of the general performance of the vaccinators under their supervision, especially those who tend to perform poorly. ASVs select random entries from the daily register of low performing vaccinators and ask them to show the record of these entries in permanent registers or to fetch the immunization cards of these children from the community. If the randomly chosen entry happens to be fake, vaccinators will mostly admit to falsification. According to ASVs, based on their experience, most of the time they select entries about which they are suspicious and their hunches turn out to be true.

ASVs also use spot-checks to monitor the presence of vaccinators in the field. According to ASVs, some vaccinators do not arrive in the field on time, and then falsify data later to compensate. Therefore, to ensure that vaccinators are in the field on time and stay there for the whole duration, ASVs spot-check vaccinators' attendance. We uncovered two such strategies for this below.

Interrogation 2 – Surprise Visits: Many times ASVs spot-check by making a surprise visit to a kit station without informing the vaccinator or any other staff member in advance. The goal of the spot check is to determine whether the vaccinator is in the field or not. According to ASVs, they do this activity with low performing vaccinators about whom they are already skeptical. While telling about the absence of a low performing vaccinator from the field, an ASV told us:

"Once I went to a kit station and saw that the vaccinator was not there. I called him and asked where are you? He said that he is at the kit station. I was too at the kit station and so was the other staff including Lady Health Worker (LHW)... I asked the vaccinator to let me talk to the LHW. He said she went out to get kids for immunization. I barely stopped myself from laughing… [ASV asked about all other staff members and the vaccinator lied about all of them]. I said, do you have photocopies of all these people because they are all in front of me sitting at your kit station but you are not here..." ***[ASV19, District D, Exp.: 36]***

Interrogation 3 – Bluffing about the Power of Technology: ASVs were recently provided with a mobile application by EPI to perform digital verification. Vaccinators are not aware of the technological features of that application. Therefore, ASVs use this application as a tool to deceive vaccinators by telling them that their location is being shared with ASVs through this mobile application. While explaining a version of this strategy, an ASV said to us:

"Once I was going for my regular visit when I saw a vaccinator cross paths with me on his motorbike. He was supposed to be at his kit station. I called him on his mobile phone and asked for his location. He said that he is at the kit station. I said but my application is showing me your location on this road (the road where I was standing and he just passed by). He got afraid and started apologizing...and said he will be back in an hour." ***[ASV7, District A, Exp.: 20]***

5.4 Management Styles of ASVs

Beyond specific detection strategies, our analysis also revealed different styles of management that ASVs brought to their work. Because these findings affect ASVs' use of detection strategies, we provide a description of these findings here. Overall, ASVs tend toward a supportive management style or a punitive one. Supportive ASVs seek to coach their vaccinators into better performance, providing assistance where they can; punitive ASVs tend to use punishment or its threat. These are not black-or-white categories, but they illustrate the poles of behavior between which there is a continuum of ASVs.

One ASV who epitomizes the supportive management style told us:

"If I find any miss or defaulter child during my cluster assessment then I come back to the vaccinator and get that child vaccinated. Actually, our work of mechanism is supportive supervision, which means that we are also assisting them in completing the coverage. ***[ASV5, District A, Exp.: 18]***

ASVs who favour supportive supervision seldom report to higher officials about vaccinators' mistakes and provide vaccinators room to improve their performance. They provide feedback and an opportunity to correct problems. Supportive ASVs not only support their staff for unintentional mistakes but also show support in case of deliberate falsification. One ASV told us:

"Sometimes when they (vaccinators)... create false lists before our arrival... instead of scolding them, we politely counsel them and tell them that we will not report this case, but they are not allowed to do this again." ***[ASV10, District B, Exp.: 13]***

More supportive ASVs also appear to seek vaccinator input while designing their targets in the form of monthly plans, because according to ASVs, vaccinators are more familiar with the ground realities. These ASVs also occasionally recommend changes to formal policies to accommodate vaccinators' needs. Some recommendations that ASVs made along these lines include:

- According to ASVs, vaccinators are hired at level 9 on a particular government scale and remain there until they retire or become an ASV. Moreover, the education requirement for vaccinators's hiring also changed from 10th grade to 12th grade. Certain ASVs advocated for lowering the entry level education requirement for vaccinators back to 10th grade, and promoting vaccinators with a certain level of experience to the next level on the government scale (which would increase their salary and benefits).
- Some ASVs have requested incentives for vaccinators that are on par with workers from other departments. One ASV told us:
  "A mobile application is being used by the [Pakistan Water and Power Development Authority], and they give incentives for workers to use the application. But, our vaccinators are not given similar incentives, and I think that our work is more sensitive than theirs." ***[ASV5, District A, Exp.: 18]***

Contrary to supportive supervision, ASVs who promote punitive style of supervision focus on finding mistakes and discrepancies in vaccinators' work with an intention to embarrass them publicly, report them to higher authorities, or threaten them with legal action. More punitive ASVs shared poor performance of their vaccinators on Whatsapp groups whose members include all vaccination staff of that tehsil, with an intention to publicly shame them. The ASVs who implement this practice say they do so to make vaccinators feel embarrassed, which acts as an effective strategy to improve their performance in the future. An ASV told us:

"[Vaccinators send their monthly reports on WhatsApp groups and] if their performance is low, they get 'hawwww [embarrassed emoji]' as a reply from other group members, which in itself is a punishment and they feel embarrassed." ***[ASV16, District C, Exp: 37]***

ASVs that lean towards using a more punitive approach also tend to report vaccinator problems to higher authorities without warning and with no opportunity to correct problems. We found that some ASVs send photographs of falsified data records alongside a summary of daily activities in a WhatsApp group that they share with managers of the district-level administration. Furthermore, ASVs threaten vaccinators with legal action, even though they never intend to follow through. The nature of the legal action they would take is also unclear. Nevertheless, they believe that the threat of such action can improve vaccinators' performance. While explaining this scenario, an ASV told us:

*"[When we catch cheating]... then obviously, I have to scold them, and I say to them that strict legal action will be taken against you next time. Obviously, we don't take any legal action in actuality, and we aren't authorized to, but we threaten them in case there is any serious issue"****[ASV12, District B, Exp: 32]***

As mentioned earlier, we found a continuum of ASVs lying between the supportive and punitive poles of management style, with 8 ASVs largely following punitive measures like complaining to higher authorities, threatening and public shaming; 6 ASVs largely following supportive measures like providing assistance to improve vaccinators' performance and immunization coverage, and scolding vaccinators without letting others know, and the rest follow a hybrid model of supervision with supportive as default but switch to punitive if and when needed. We also found that the categorization of ASVs' style of supervision is at an individual preference level – for instance, an ASV from a district follows a largely punitive style, another ASV from the same district prefers a largely supportive style of supervision, and another ASV prefers a mix of both based on the circumstances. We also observed a potential supervisory style, and detection strategies pattern: ASVs who prefer supportive supervision alone or with punitive measures tend to use triangulation (section 5.3.1) more often. In comparison, ASVs who follow a punitive management style tend to favor supplementary data collection (section 5.3.2) and interrogation techniques (section 5.3.4) to find mistakes quickly so that they can harangue vaccinators on the spot. ASVs who follow a hybrid supervision model mostly use triangulation and either supplementary data collection, anomaly detection, or spot-checking based on the given circumstances.

6 DISCUSSION

To our knowledge, this is the first study in a developing-world context to provide in-depth details of intentional data falsification by front-line health workers along with the detection methods used by their supervisors. What we find is an elaborate cat-and-mouse game: Vaccinators in Punjab use a considerable array of data falsification tactics to mask instances in which they failed to complete their expected rounds for whatever reason. Meanwhile, their immediate supervisors, the ASVs, have developed a sophisticated repertoire to identify instances of data falsification. What enables the latter is a mostly paper-based system of formal record-keeping protocols that makes it surprisingly difficult to falsify records in a way that cannot be detected. These findings build on the considerable literature that acknowledges data falsification as a problem [25, 45, 47, 53], but they go well beyond that literature in providing details – details which are essential in any attempt to develop digital tools to improve vaccine delivery. Our findings also provide a contrasting situation from Ismail et al., who report a healthcare system that prefers data quantity over quality [25] – our ASVs appeared diligent about trying to manage data falsification.

Equally important is what we did *not* find. ASVs tend to use relatively straightforward methods to catch cheating – none of the techniques they developed require computation. For example, ASVs perform a randomized cluster assessment as part of their routine job responsibilities, but they appear to use no strategies to determine whether clusters are in fact, random. And while as of 2019, cluster check data is digitized and stored centrally, none of that data, or analysis thereof, was provided back to ASVs as an aid to checking clusters. Digitally assisted statistical verification of aggregated vaccinator-reported numbers should be possible. No such system appears to be in place, however, and ASVs, not being applied statisticians, do not seem to be aware of the potential of such a strategy [34]. We also note that neither the EPI leadership nor the district authorities seem aware of this possibility.

We suspect overall that little of the specifics of the falsification detection strategies above would translate to contexts outside of vaccination in Punjab, Pakistan. The concrete details depend significantly on the exact record-keeping protocols. But, it seems likely that other global health or global development contexts with formal

record-keeping would admit to at least some of the following five means of detecting data falsification:

(1) Triangulation – comparing two or more document types against one another
(2) Anomaly detection – identifying deviations from strict formal procedure
(3) Data supplementation – spot checking of recorded data, or collecting supplementary data from relevant stakeholders (e.g., parents)
(4) Interrogation – directly interacting with front-line workers to identify problems with data
(5) Statistical checks – seeking deviations from statistical expectations of the data at some aggregated level

Among our participants, we found that the first four of these strategies were discovered by diligent supervisors with a secondary education on their own, and that they were both creative and reasonably exhaustive in identifying appropriate strategies. The last appeared to have been beyond our participants, though it is also possible that this was due to a lack of access to digitized data. In any case, we anticipate that in a range of development contexts, there is value in engaging with supervisors when implementing digital data verification systems.

We found the management style of ASVs to lie on a spectrum from supportive to punitive, ranging from a few ASVs largely relying on punitive measures to other ASVs predominantly being supportive in usual matters but turning to authoritative when needed. We observed a possible pattern – that requires further research to verify – that the managerial style of an ASV affects their strategies of choice with respect to detecting falsified data. More authoritarian ASVs seem to prefer "gotcha" approaches such as quick spot checks (see Section 5.3.4) which allow them to catch isolated instances of malfeasance easily. They then scold the vaccinator accordingly. More supportive, or constructive managers, appear to prefer triangulation methods that take time to identify and also indicate longer-term patterns. They seem to use that knowledge as diagnostic information that they bring up in conversations with vaccinators. Those who use a mixed model of supervision prefer triangulation for diagnostic verification and turn to spot checks with the help of supplementary data when they feel the need to transition to punitive measures. Clements et al. argue that supportive supervision may be difficult to implement in some countries [13], and our findings support this conclusion. ASVs have no real power over their vaccinators, so a purely supportive style has no hard back stop for malingerers. Some ASVS therefore resort to a hybrid model where they try to be as supportive as possible, but also use what punitive measures they can to bring underperformers in line.

As to the underlying causes of falsification, none of the ASVs we spoke with tried to address causes, presumably because they did not have the administrative power to do so. Vaccinators are known to be overworked, insufficiently resourced, and un-incentivized [5, 49], all known conditions for data errors [25, 45, 53]. The hierarchical management style of Pakistan's healthcare system does not encourage ASVs to "manage up" to change such factors.

6.1 Implications for Design and Beyond

Our findings suggest some immediate possibilities for digital systems to assist immunization efforts. Punjab's Health Ministry, for example, has already begun an attempt to digitize aspects of its immunization record-keeping, with a smartphone app for ASVs and a system of digital data collection that partially parallels the paper-based system. Both ASVs and vaccinators are already using digital systems in parallel to paper-based systems for the data collection as a part of their jobs (Table 2). There are still many challenges with the current system, but were it more thoroughly implemented, every one of the falsification detection strategies noted by our ASVs could be readily incorporated as an automated audit system.

For example, the anomaly detection strategies discussed in Section 5.3.3 could be directly implemented if the records were digitized, akin to work described by Birnbaum et al. [6, 7]. There could be automated checks for blank entries, duplicate entries, fixed frequency of entries, discontinuous serial numbers in immunization cards issued, etc. The triangulation strategies described in Section 5.3.1 would also be straightforward to implement if all data were digitized. If only some of the registers were digitized (with others on paper), digital systems could prompt ASVs (or their equivalent) to look up specific paper records to see whether they deviate from the digitally logged data. Depending on the technique, these prompts could be targeted to instances where falsification is most likely. A similar methodology could be applied to ASV strategies that depend on seeking supplementary data (Section 5.3.2)

As we found, however, there are potential forms of falsification detection that ASVs do not themselves use. These often require computation to implement, and would therefore be ideal for digital systems. For instance, both formal and informal spot checks could be based on computer-generated lists that are truly randomized. Such checks would provide better understanding of actual coverage at various geographical levels.

A key non-technical question, however, is what should be done with information about detected problems? Should vaccinators be alerted the moment they attempt to falsify data? Should ASVs receive alerts on their smartphones? Should aggregated data be provided to DSVs and other higher-ups? What is the right balance of control versus agency for each? The answers ought to be arrived at collaboratively with healthcare system workers and leaders. However, the literature is clear on the need for supportive supervision [3, 13]. The goal is to create social norms among vaccinators and supervisors to take pride in their work. If ASVs are a valuable part of the system, they need to be given some autonomy in decision-making within their jurisdiction – with respect to workload, managing staffing, etc. The corresponding tools need to be designed to leave room for human decisions [35]. To encourage a sense of growth, previous research suggests embedding constructive feedback loops in ASVs' and vaccinators' tools to encourage performance [15, 17, 18, 37, 47].

Specifically for Punjab, we do not believe the current patchwork of digital tools in Punjab to be ready for such interventions. The province has two digital systems working independently and only for the purposes of data collection. None of the data is applied to decision-making or data-driven policies. Digital data collection is not yet widely used, because the paper system is still treated as the

gold standard, and recording data twice on paper and digitally is extra work. The EPI leadership seeks better vaccination rates in the abstract, but they are not yet especially focused on good data collection or on the use of that data in decision-making.

Finally, while health systems vary greatly across countries, our findings inform work to understand or improve other health systems. While it is unlikely that our findings will translate directly, we believe our work highlights themes that could guide work in other contexts. For example, it seems likely that something of a cat-and-mouse game would exist in any context where front-line development workers are under-motivated (either intrinsically or due to an under-appreciative work environment) and managed by motivated supervisors. Interactions with supervisors could focus on the four types of detection strategies we outline above (triangulation, data supplementation, anomaly detection, interrogation), and concrete strategies seem likely to be readily implemented in digital systems. Our work suggests that it is worth investigation to understand the tactics on both sides, and that the outcomes would inform systems – both digital and paper-based – for monitoring and improving healthcare.

7 CONCLUSION

We conducted fieldwork in 5 districts of Punjab, Pakistan to investigate the role of mid-level managers in identifying discrepancies in data collected of the front-line workforce from the field. From August 2019 to December 2019, we interviewed a total of 30 members of the EPI department of Punjab – 22 ASVs, 5 DSVs and 3 members from the EPI leadership team. In our findings, we documented self-created strategies that ASVs use for identifying intentional falsification done by the vaccinators while recording immunization data. We found that state-defined roles and responsibilities of ASVs are not sufficient to verify the quality of immunization data, therefore, ASVs have come up with several self-defined strategies, which we have categorized as triangulation, data supplementation, anomaly detection, and interrogation. ASVs appear to use these strategies differently based on their management styles, which is a point that deserves further research. Finally, we detailed what our findings mean for the HCI community that designs systems to digitally collect and analyze data in low-resource settings.

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