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Leveraging transportation providers to deploy lay first responder (LFR) programs in three sub-Saharan African countries without formal emergency medical services: Evaluating longitudinal impact and cost-effectiveness

Peter G. Delaney [a,*], Zachary J. Eisner [b], Haleigh Pine [c], Max Klapow [d], Alfred Harun Thullah [e], Richard Bamuleke [f], Issa Mohamet Nuur [g], Krishnan Raghavendran [b]

[a] Cleveland Clinic, Cleveland, OH, USA
[b] University of Michigan Medical School, Ann Arbor, Michigan, USA
[c] Washington University in St. Louis, St. Louis, Missouri, USA
[d] Oxford University, Oxford, England, United Kingdom
[e] LFR International, Makeni, Sierra Leone
[f] Uganda Red Cross Society, Iganga, Uganda
[g] Red Cross of Chad, Am Timan, Chad

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ABSTRACT

Introduction: In 2019, the World Health Assembly declared emergency care essential to achieve the 2030 Sustainable Development Goals. Few sub-Saharan African (SSA) countries have developed robust approaches to sustainably deliver emergency medical services (EMS) at scale, as high-income country models are financially impractical. Innovative reassessment of EMS delivery in resource-limited settings is necessary as timely emergency care access can substantially reduce mortality.

Materials and methods: We developed the Lay First Responder (LFR) program by training 1,291 pre-existing motorcycle taxi drivers, a predominant form of short-distance transport in sub-Saharan Africa, to provide trauma care and transport for road traffic injuries. Three pilot programs were launched in staggered fashion between 2016 and 2019 in West, Central, and East Africa and a 5.5 h curriculum was iteratively developed to train first responders. Longitudinal data on patient impact (patient demographics, injury characteristics, and treatment rendered), emergency care knowledge acquisition/retention, and social/financial effects of LFR training were collected and pooled across three sites for collective analysis. Novel cost-effectiveness ratios were calculated based on prospective cost data from each site. Previously projected aggregate disability-adjusted life years (DALYs) addressable by LFRs were used to inform cost-effectiveness ratios($USD cost per DALY averted). Cost-effectiveness ratios were then compared against African per capita gross domestic product (GDP), following WHO—CHOICE guidelines, which state ratios less than GDP per capita are "very cost-effective."

Results: In 2,171 total patient encounters across all three pilot sites, LFRs most frequently provided hemorrhage control in 61 % of patient encounters and patient transport by motorcycle in 98.5 %. Median pre-/post-test scores improved by 34.1 percentage points (39.5% vs.73.6 %, $p < 0.0001$) with significant knowledge retention at six months. 75 % of initial participants remain voluntarily involved 3 years post-course, reporting increased local stature and customer acquisition(income 32.0 % greater than non-trained counterparts). Locally sourced first-aid materials cost $6.54USD/participant. Cost-effectiveness analysis demonstrated cost per DALY averted= $51.65USD.

Conclusion: LFR training is highly cost-effective according to WHO—CHOICE guidelines and expands emergency care access. The LFR program may be an alternative approach to formal ambulance-reliant EMS that are cost-prohibitive in resource-limited, sub-Saharan African settings. A novel social/financial mechanism appears to incentivize long-term voluntary LFR involvement, which may sustain programs in resource-limited settings.

* Corresponding author.
E-mail address: delanep@ccf.org (P.G. Delaney).

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Introduction

Global injury burden

Injury is the leading cause of death for people aged 15–45, accounting for 32 % more mortality than malaria, tuberculosis, and HIV/AIDS combined [1]. Road traffic injuries (RTIs) are the largest contributor to global injuries and among the five leading causes of disability-adjusted life years (DALYs) [2]. RTIs disproportionately affect low- and middle-income countries (LMICs), comprising 96 % of the 25 countries with the greatest RTI-related DALY burden, and decreasing GDP by an estimated 6 % [3]. Motorcycle taxis are the fastest-growing form of informal transportation due to a lack of affordable publicly-funded alternatives, becoming a predominant form of short/-intermediate distance transport, associated with an increase in RTIs, especially in sub-Saharan Africa (SSA) where they exist in at least 60 % of countries [4]. RTI control spectrum spans surveillance, prevention, and management. Despite the importance of management when prevention fails, trauma management remains weakest link on this spectrum, as financial barriers most significantly impede emergency medical services (EMS) development [5].

Emergency medical services

In 2019, the 72nd World Health Assembly declared emergency care essential to achieve Sustainable Development Goals, calling for timely, high-quality care [6]. SSA has the highest rates of RTI-related mortality (26.6/100,000) and is ill-equipped to address injuries, with EMS unavailable for 91.3 % of Africans [5]. Mortality is six times higher for injuries in low-income countries than high-income countries, though expansion of prehospital and emergency care potentially addresses 54 % of the 45 million annual LMIC deaths [7].

High-income country models may not be relevant in resource-limited settings, given a lack of strict legislation, trained personnel, and resource scarcity [8]. Improving trauma outcomes in LMICs requires understanding how victims access care to develop interventions that augment delivery by integrating into existing systems [9]. LMIC EMS models are heterogeneous and may lack scalability and financial sustainability, with ambulances mainly used for transport, rather than emergency care [10]. Despite advocacy, high equipment/operational costs suggest ambulance-based EMS will not be scaled in many LMICs, requiring alternative approaches [11].

Lay first responders

The World Health Organization (WHO) recommended training lay first responders (LFRs) as the first step toward formal EMS development in 2005 [12]. Community-based practices reinforce existing networks of informal providers who are involved on the front lines of informal trauma care in settings without formal EMS using a culturally-informed approach [13]. However, guideline adoption has been incongruous, as few have capitalized on bystander networks, despite high bystander involvement [10]. A systematic review of successful LFR training initiatives demonstrated four consistent themes:(1)initial needs assessment of existing trauma system and layperson emergency care knowledge informing interventions; (2)adapting/leveraging existing resources; (3) anticipating participants with low levels of education/literacy; and (4) post-implementation evaluation for curriculum improvement [13]. Despite the consensus emerging around curriculum development, there remains no consensus on a blueprint to develop LFR infrastructure as efforts to strengthen bystander networks lack a clear path to initiate EMS [7].

Private transportation as an ambulatory alternative

With timely access to emergency care as a key factor in addressing mortality, innovative targeting of EMS is essential [14]. With significant penetrance across SSA, motorcycle taxis possess three inherent advantages as LFRs: (1)wide geographic coverage as drivers are economically motivated to search for customers, which facilitates self-dispersion, (2) rapid response without reliance upon traditional emergency dispatch infrastructure as taxis await customers in highly trafficked areas more likely to experience RTIs, and (3)patient transport using their existing vehicle. In remote SSA areas with terrain not well-suited for ambulances and the ability to function on poorly-maintained roads inaccessible to other vehicles, motorcycle taxis are the only motorized public transport available in many areas [15]. In SSA, trauma patients are already transported using non-traditional ambulatory vehicles [10]. Motorcycle taxis maneuver through heavy traffic congestion and provide door-to-door service. Taxis are familiar with roads, navigating traffic, and transportation challenges, previously found to be primary contributors to emergency care delays in Brazil [16]. In Ghana, 78 % of people believed taxis were faster than ambulances, while in hypothetical emergency scenarios, taxis were their preferred means of emergency transportation [17]. This approach must ensure unstable injuries are not exacerbated by defining contraindications to motorcycle transport.

Innovative reassessment of EMS delivery in resource-limited settings is essential, as timely emergency care access can substantially reduce mortality. In this study, we aim to describe a scalable approach for emergency care deployment that may provide a foundation for nascent formal EMS development in resource-limited settings.

Materials and methods

Objective

To address the absence of formal EMS and lack of consensus on LFR program development, we piloted programs training existing transportation providers as LFRs as an approach to create a scalable EMS system. We launched three pilot projects across West, Central, and East Africa in staggered fashion over a five-year period. We collected and pooled longitudinal data on patient impact (patient demographics, injury characteristics, and treatment rendered), emergency care knowledge acquisition/retention, and socioeconomic effects of LFR training across three sites for collective analysis.

Curriculum development

The LFR curriculum was informed by WHO Guidelines for Essential Trauma Care, the American College of Surgeons Prehospital Trauma Life Support (PHTLS) course and “Stop The Bleed” Initiative, and iteratively refined via local expert consultation. The curriculum follows a lecture format, interspersed with five small-group breakout sessions for skills practice, covering seven curricular categories (Table 1). A method to transport patients by motorcycle and associated contraindications due to injury severity was developed, facilitating rapid transport by motorcycle for unilateral lower limb injuries (Table 2). Course duration is 5.5 hours, minimizing opportunity cost of attendance. Attendance was incentivized by providing a free first aid kit, meal, and the acknowledgement their profession is fraught with road trauma and a desire to learn skills to assist fellow injured transportation colleagues or themselves. Informed by previous EMS instructor and Red Cross first aid course instructional experience, target participant-to-instructor ratio was 25:2, with an additional assistant present during small-group breakout sessions.

Study settings

Three pilot projects were conducted in East, Central, and West Africa and costs were prospectively tracked (Fig. 1). Ethics approval was obtained from Washington University in St. Louis, University of Michigan, and local government authorities.

Uganda. The first East African pilot project was launched in 2016 in

Table 1
LFR course curriculum.

Area of emphasis	Major components	First aid kit / Modification from standard high-income country EMS protocol
Principles/ Definitions	Introduction to/objectives of FA, Qualities of a competent first aider	None
Scene Safety	BSI, Scene Safe (through DR ABC), Triage	Personal protective equipment, use tools at disposal for help (motorcycle and its light, bystanders)
Airway, Breathing	Airway Management (open and assess)	No CPR*
Circulation	Bleeding Control/ hemorrhage management	Gauze, Tourniquets**
Fracture Splinting	Focus on limb and neck immobilization demonstrations	Wooden board splints and fabric ties, bath towel for c-spine immobilization***
Victim Transport	Safe movement of victims and using motorcycles for transport	Motorcycle usage for patient transport****

* CPR training is not warranted without an existing comprehensive cardiac chain-of-survival, with financial, ethically deleterious, and unintended consequences given the likely relatively poor cardiac arrest patient outcomes[33].
** A systematic review demonstrated commercial tourniquet use in civilian settings to control life-threatening extremity hemorrhage is associated with improved survival and reduced need for blood transfusion [34].
*** A non-inferiority trial demonstrating its efficacy as a non-inferior means of immobilizing c-spine in extension and rotation, but not flexion, versus cervical-collars for supine patients [35].
**** With specific contraindications (Table 2).

Table 2
Indications and contraindications to LFR motorcycle transportation.

Indications	Contraindications
Alert and breathing	Unconscious (at any point during encounter)
Controlled bleeding	Uncontrolled bleeding
Upper or lower extremity fracture	Bilateral lower extremity fractures
Minor Trauma	Cervical/Thoracic/Lumbar point tenderness
	Pelvic instability
→ Use any transport	**→ Use car/ambulance**

Iganga along the Pan-African highway, with the Ugandan Red Cross Society. Iganga had no formal prehospital emergency care for 154,000 residents. 154 LFRs were trained while knowledge was evaluated pre/post-course, patient encounters were longitudinally followed for 6 months, and qualitative follow-up was conducted with participants using semi-structured interviews and surveys after 3 years.

Chad. The next pilot project was launched in 2018 in Central Africa in southeastern Chad with first aid trainers from the Chadian Red Cross in Am Timan, considered the "poorest region" globally by multidimensional poverty index. Am Timan had no formal prehospital emergency care for 38,000 residents. 108 LFRs were trained while knowledge was evaluated pre/post-course, patient encounters were longitudinally followed for 6 months, and qualitative follow-up was conducted with participants after 12 months.

Sierra Leone. The final pilot project was launched by the First Responder Coalition of Sierra Leone in 2019 in Makeni, the capital of Bombali District in the Northern Province of Sierra Leone, which suffers a signficiant RTI burden, the leading cause of injury-related mortality [18]. 1029 LFRs were trained while knowledge was evaluated pre/post-course and at six and nine-month follow-ups for a random sampling, patient encounters were longitudinally followed for 6 months, and a novel prehospital care provision survey was administered after 14 months.

Knowledge evaluation

Curriculum evaluation utilized pre-/post-course tests validated in prior pilots to evaluate knowledge acquisition [19,20]. Both pre-/-post-tests utilized identical question stems and answers, with questions randomly rearranged between administration. Uganda and Chad had the same 15-question test, expanded to 23 questions in Sierra Leone. To study knowledge retention, tests were repeated at six-/nine-months post-course in Sierra Leone (Fig. 2). The primary outcome was pre-/-post-test difference using Wilcoxon Signed-Rank tests, while responder demographic analysis was secondary.

Longitudinal incident reporting

Responders completed incident reports, detailing patient encounters in each pilot site for 6 months post-course to understand demographics, injury characteristics/mechanisms, and skills use. Reports utilized a picture-based format, based on previously developed forms from Uganda [19]. LFRs were taught incident reporting as part of the curriculum to promote accuracy. Correlations between LFR demographics/associated intervention frequencies were investigated.

Prehospital emergency trauma care assessment tool development

In 2019, the Prehospital Emergency Trauma Care Assessment Tool (PETCAT) was developed in Sierra Leone as a 7-question survey of first-line hospital-based healthcare providers, comprising quality indicators including bleeding control, rapid transport, airway and burn management, and cervical spine and fracture immobilization, to independently assess prehospital care by LFRs, with higher scores indicating more prevalent prehospital care provision. PETCAT demonstrated high reliability as a survey tool (Cronbach's $\alpha = 0.93$,Cohen's $K = 0.62$). It was developed after pilot projects in Uganda and Chad and was solely administered in Sierra Leone to first-line hospital-based healthcare providers given both their continuous first-hand professional exposure to injuries and knowledge as local community members informing their understanding. LFR prehospital intervention was independently assessed utilizing a difference-in-differences approach over a 14-month period to evaluate changes in emergency care provision in Makeni (pilot) and Kenema (control) to control for secular trends.

Cost-effectiveness calculation

Cost data was prospectively collected to study cost-effectiveness in all study sites for project launch/maintenance. Modelling disability-adjusted life years (DALYs) due to RTIs in SSA, we projected cost-effectiveness ratios($USD cost per DALY averted), which were subsequently compared to per capita gross domestic product (GDP) thresholds, following WHO—CHOICE guidelines [21].

Results

Knowledge evaluation

1291 LFRs were trained, with 692 completing pre-/post-tests (Table 3). In Chad and Uganda, 106/108 LFRs (98.1 %) and 121/154 LFRs (78.6 %) completed tests, respectively [22,23]. In Sierra Leone, due to the additional burden of survey administration for a larger sample, 500 of 1029 total participants (48.5 %) were randomly selected using a random number generator and 465 completed pre-/post surveys (93 %). A weighted average of pooled participant performance measured by pre-/post-tests demonstrated median knowledge improved by 34.1 percentage points across settings (39.5% vs. 73.6 %, $p < 0.0001$). Significant improvement was measured across all curricular categories, independent of age, gender, or education. Six-/nine-month retention in Sierra Leone demonstrated median score decreased to 60.9

Fig. 1. Pilot project site countries.

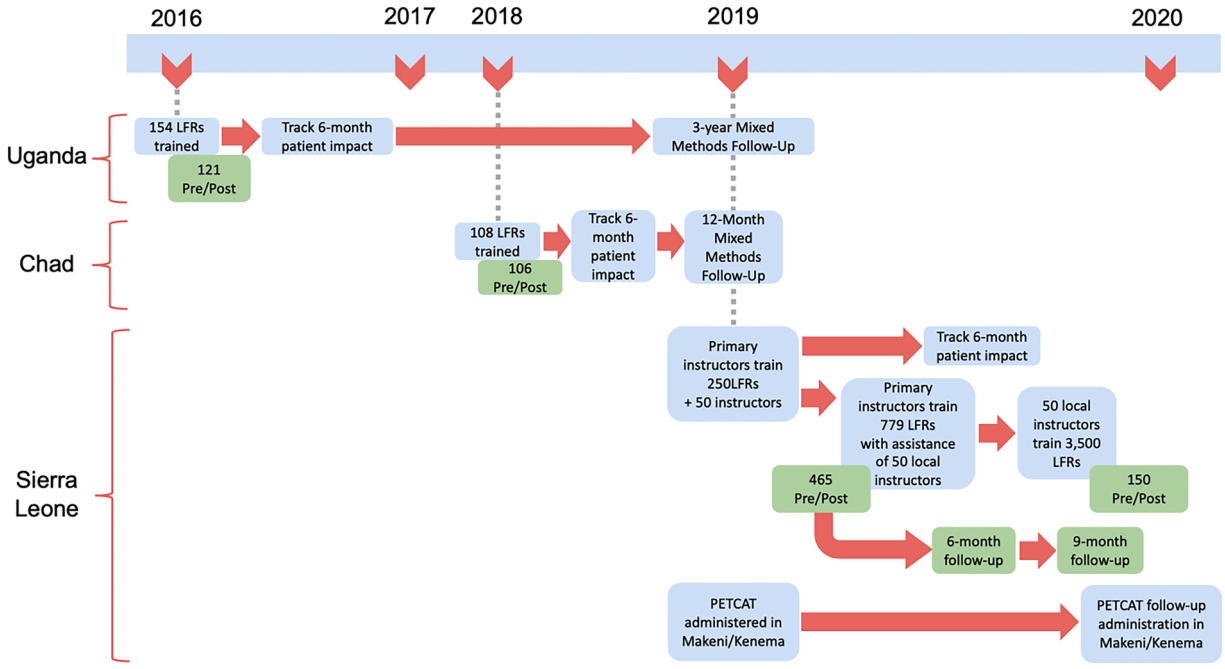

Fig. 2. Pilot project timeline.

% at six months and 43.5 % at nine months, suggesting six-month refresher training intervals for airway management/hemorrhage control in future programs.

Fifty local instructors were trained in Sierra Leone as part of an First Responder Coalition of Sierra Leone initiative to expand to rural areas in Bombali District using a training-of-trainers (TOT) model. TOTs trained 3500 additional LFRs over six months in 2019. 150 randomly selected participants in TOT LFR courses demonstrated participant median score

Table 3
Pre-/post-course knowledge assessment outcomes.

Pre-/post-course knowledge assessments								
	Pilot country location		Curriculum category				Total	
			Scene safety	Airway	Bleeding	Transport	PRE	POST
	Uganda	Pre	37.6	43.4	56.9	88.2	**56.5**	**71.4**
n=	121	Post	59.5	51.6	80.2	94.3		
% of total n	17.49 %							
	Chad	Pre	38.4	33.0	41.6	83.7	**49.2**	**64.4**
n=	106	Post	60.9	49.5	61.3	85.9		
% of total n	15.32 %							
	Sierra Leone	Pre	43.4	37.4	21.1	29.8	**32.9**	**76.3**
n=	465	Post	74.2	78.1	77.1	75.7		
% of total n	67.20 %							
	TOTAL	**Pre**	**41.6**	**37.8**	**30.5**	**48.3**	**39.5**	
	692	**Post**	**69.6**	**69.1**	**75.2**	**80.5**		**73.6**

*12 of 15 questions represented by scene safety, airway, bleeding, and transport categories for Ugandan and Chadian data.
**% of total n – this refers to the percentage of the total number of trainees included in our study from each specific project location.

improved by 30.4 percentage points (21.7% vs. 52.2 %, $p < 0.0001$), suggesting the TOT approach transfers knowledge [24]. However, lower post-test scores may be due to a combination of lower rates of education in rural areas and increased variability in courses administered by TOTs.

Longitudinal incident reporting

In total, 2171 patient encounters were reported by LFRs during the first 6 months post-implementation across all three pilot sites. In Uganda, 250 patients were treated (10 % overall mortality encountered), with hemorrhage control used most in 61 % of encounters. Similarly, in Chad, hemorrhage control used most by LFRs in 55 % of 71 patient encounters (7 % overall mortality encountered). In Sierra Leone, LFRs reported 1850 patient encounters, using hemorrhage control most (61.2 % of encounters). 1102 of 2171 patients had lower extremity injuries (50.8 %), while 732 of 2171 patient had upper extremity injuries (33.7 %). Of all 2171 total encounters, 59.5 % were RTI-related (83 %, 71 %, and 51.6 % in Uganda, Chad, and Sierra Leone, respectively). Patient transport by motorcycle occurred in 98.51 % of encounters, employing listed contraindications to motorcycle transport, and was contraindicated in the remainder (1.5 %) (Table 2). Demographic analysis/associated intervention data from a pooled sample of 887 of 1291 total LFRs (68.7 %) demonstrated most LFRs do not submit incident reports (median LFR reported interventions=0.0 interventions/year [IQR:0.0,5.0]), which could indicate a lack of reporting or responding, or both. However, high-responding outlier groups ("super-responders") were present across all pilot sites($p < 0.0001$) and disproportionately respond (median rate of 26.0[IQR:16.7,35.0] interventions per year). Demographic analysis suggests this group had greater RTI exposure pre-course($p = 0.033$) and were older($p = 0.002$), though we hypothesize other factors like psychosocial characteristics may be better predictors [25]. After training a larger sample of participants from a broad occupational spectrum in Sierra Leone, motorcycle taxi drivers responded to RTIs at disproportionately higher rates, likely due to profession-related exposure to RTIs [24].

Qualitative follow-up

Qualitative semi-structured interviews were conducted with participants at 3 years post-course in Uganda and 12 months post-course in Chad.

Three years post-training, 75.0 % of LFRs surveyed remained active in Uganda (115/154) compared to 88.7 % of motorcycle taxi operators surveyed remaining active in Chad after one year (47/53), yielding a combined yearly attrition rate of 10.6 % (self-reported continued involvement deemed "active"). Qualitative follow-ups with LFRs revealed ongoing voluntary participation driven by new knowledge/skills, altruism, confidence post-course, and increased social stature in their local community, which motivated continued longitudinal LFR involvement [23,26]. Income was reportedly 32.0 % higher than non-trained motorcycle taxi counterparts among respondents from Uganda and Chad. In both Uganda and Chad, 96.5 % (111/115) and 88.7 % (47/53) of surveyed LFRs reported using skills at least once at follow-up, respectively, suggesting under-reporting of patient encounters via longitudinal incident reports.

Prehospital emergency trauma care assessment tool evaluation

PETCAT was administered to 90 hospital providers. Pre-course, baseline prehospital intervention was rare both in Makeni and Kenema (1.2/10 vs. 1.8/10, respectively, equivalent to "never"/"rarely" provided). Upon re-administration 14 months post-course, results showed PETCAT scores increased to 5.2/10 in Makeni("sometimes"/"mostly" provided) while remaining constant in Kenema(1.2/10), for an adjusted difference of +4.6 points/10($p < 0.0001$), suggesting LFRs significantly expand prehospital care provision, controlling for secular trends [27].

Cost-effectiveness

Training cost per day fluctuated between $79.12-$103.18USD, while supply costs per responder fluctuated between $6.67-$14.74 (Table 4). Overall cost per responder demonstrates an inverse relationship. Average annual cost per LFR trained was calculated to be $15.68USD (training=$3.68USD, supplies = $12.00USD). Following WHO and Disease Control Priorities recommendations for adequate emergency catchment, training of 750 LFRs/100,000 would cost $11,760USD with projected total annual DALYs averted equal to 227.7/100,000. Cost per DALY averted would therefore be $51.65USD, less than half SSA GDP per capita ($1585.40USD) and the lowest SSA GDP per capita(Burundi, $261.20USD), suggesting training LFRs is highly cost-effective. Investment in basic/intermediate prehospital care can be on par with the cost-effectiveness of more widely implemented health interventions. PHTLS implementation in Mexico demonstrated morality reduction per dollar was highest with PHTLS versus Trauma Life Support/Advanced Cardiac Life Support/airway management/PHTLS [28]. Attaching a trailer to a motorcycle for obstetric emergency transport was also 19 times cheaper than traditional ambulances while annual operating costs were 24 times cheaper($508USD).53

Discussion

Improving trauma outcomes in LMICs requires both understanding how victims access care as well as developing interventions that

Table 4
LFR course cost.

		Uganda (Delaney et al.)	Chad (Hancock et al.)	Sierra Leone (Eisner et al.)	**Weighted average (USD)**
# Responders Receiving First Aid Kits: (*n*=_)		159	150	2029	Total ($n = 2338$)
Training costs (per training day)	Training Space	$29.52	$37.50	$5.12	$8.86
	Trainer Salary	$14.76	$9.00	$16.00	$15.47
	Projector	$5.90	N/A	$8.00	$7.85
	Food	N/A	$16.50	$10.40	$10.82
	Final Exam/IDs	$53.00	$50.00	$50.00	$50.20
	Total (per day):	**$103.18**	**$113.00**	**$89.52**	**$91.96**
Supply costs (per responder)	Responder Uniform	$2.36	$1.46	N/A	$1.92
	First Aid Kit Bag	$2.66	$1.80	$0.92	$1.09
	First Aid Kit Materials	$6.20	$9.53	$4.17	$4.65
	Total (per responder):	**$11.22**	**$12.79**	**$5.09**	**$6.00**
Total (per responder)	**(2 x Daily Training cost (divided by 50 trainees)) + 2 x Supply Total per responder**	**$26.57**	**$30.10**	**$13.76**	**$15.68**

*50 trainees can be trained per two instructors per day. Calculations projected using 50 trainees per day estimate.
**total supply cost per responder calculated by dividing by 50 participants per day multipled by 2 given 6 month retraining requiring 2 training days per year.
***total training cost per responder calculated by dividing by 50 participants per day multiplied by 2 given 6 month retraining requiring 2 training days per year.

augment healthcare delivery models by integrating emergency care into existing systems using modest, low-cost steps [8]. A culturally-informed approach to improving community-based practices reinforces existing networks of informal providers with LFR training, who are consistently on the front lines of informal trauma care in settings without formal EMS [13]. Low start-up capital and maintenance costs, high youth unemployment, and lenient existing regulatory frameworks that have facilitated motorcycle taxi proliferation also present an opportunity to leverage the same transportation providers as LFRs [26].

In SSA, transport mode and referral pathway are the only factors significantly associated with post-trauma mortality in the prehospital setting, while no significant associations between prehospital interventions or providers with post-trauma mortality have been demonstrated [10]. In Malawi, an SSA country where EMS is limited, 8006 patients transported by emergency vehicles had higher mortality (8.2 %) compared to 38,581 patients transported by private motorized vehicles (1.0 %,$p < 0.001$). An adjusted in-hospital mortality odds ratio of 2.09 (1.24–3.54;$p = 0.006$) for indirect transfer versus direct transfer after injury suggests non-ambulance transport conferred significant survival benefits by reducing delay to definitive intervention [29]. LFRs transported patients by motorcycle in 98.5 % of 2171 encounters, reducing the burden on traditional cost-prohibitive ambulances. LFRs determined when alternative transportation was needed for severe injury using listed contraindications to motorcycle transport, appearing rarely contraindicated, substantiated by incident reports demonstrating the majority of injuries occurred in extremities [24]. However, contraindications merit further dedicated investigation. Ideally, LFRs would evolve to receive the most advanced training possible, but this is not often feasible from an opportunity cost standpoint, especially in resource-limited settings leveraging laypeople. Fortunately, BLS interventions have been found to be as impactful as ALS for mortality reduction, as a meta-analysis of 18 studies found no difference in survival for trauma patients receiving ALS versus BLS [30]. Further, a Cochrane review found no benefit to ALS training for ambulance crews in LMICs, as mortality increased among patients with GCS < 9 receiving care from ALS-trained ambulance crews, even when pre-hospital trauma scores were considered [31]. Development of advanced EMS should not be at the expense of a broad base of basic prehospital care [7].

Our findings suggest current *Disease Control Priorities* recommendations to train 0.5–1 % of a given population as LFRs to achieve adequate emergency catchment may be inefficient and should be revised to optimize future LFR training [25]. In addition to the three inherent advantages of LFR-trained transportation providers (wide geographic coverage, rapid response to witnessed emergencies, and existing vehicle usage), selectively recruiting super-responders who are more likely to use their skills post-training improves return on investment by achieving similar coverage while conserving training resources. Additional personal characteristics of this subgroup must be identified in future studies to inform recruitment efforts, which may inform strong recruitment choices for LFR programs and potentially staffing future professional EMS supported by dispatch infrastructure and dedicated ambulatory vehicles that evolve as EMS systems mature from initially training LFRs, which should first occur to establish a broad base of basic care. Though emergency response from LFR-trained transportation providers is not reliant upon communication infrastructure for dispatch given occupational RTI exposure, unlike centrally-dispatched professional EMS personnel, recent developments in cellular technologies may facilitate increasingly coordinated and efficient emergency response from layperson networks. A simulation study we subsequently performed in Sierra Leone with 10 super-responders equipped with a mobile dispatch platform demonstrated a median total response interval of 5 minutes 39 seconds(IQR = 0:03:51; 0:09:18) along 10 kilometers of highway to simulated emergencies [32]. Dispatch infrastructure may also facilitate improved communication between the LFRs and the notification of receiving hospitals in the future. After training LFRs, equipping with dispatch infrastructure is the next step.

Our study is not without limitations. Given cultural variability across SSA, it is not possible to know if findings are applicable to other African settings, however, we attempted to launch pilot projects in various SSA settings in West, Central, and East Africa to demonstrate efficacy regardless of broad geographic setting. Our patient encounter data also likely underestimated impact due to monitoring and evaluation challenges related to LFR under-reporting, as 96.5 % of qualitatively surveyed LFRs reported using at least one of their skills in a patient encounter. Incident reports were only collected for 6 months in each pilot setting due to budgetary limitations preventing further longitudinal assessment. Robust trauma registries do not exist in the hospitals where the projects were conducted, so longitudinally tracking patient outcomes during and after admission was not possible. With more granular data collection in the future using trauma registries, we expect to glean more nuanced findings regarding the management of specific injuries and outcomes. EMD systems integrated with future LFR program iterations may permit optimized emergency incident tracking and coverage that limits data discrepancies. Given the iterative nature of development and the staggered fashion in which pilots were launched, standardization of survey instruments and methods was not possible. Unfortunately, though specific patient encounters were tracked, due to a data collection protocol miscommunication, mortality was not recorded in one project location (Sierra Leone). Given limitations in methodology and instrument use, we attempted to synthesize preliminary findings with an understanding that future research should develop a robust theory of change and intervention standardization guidelines.

Conclusion

Leveraging pre-existing transportation providers to deploy LFRs appears to be an effective approach to cost-effectively expand pre-hospital emergency care in resource-limited communities without formal EMS, which may limit cost-prohibitive ambulatory infrastructure expenses in rural settings. Social/financial incentives appear to promote long-term voluntary LFR involvement, which may sustain programs in resource-limited settings. With no prior consensus on a blueprint to develop LFR program infrastructure to strengthen bystander networks, this approach may be a scalable foundation for nascent EMS development in resource-limited settings.

CRediT authorship contribution statement

Peter G. Delaney: . **Zachary J. Eisner:** . **Haleigh Pine:** Writing – review & editing, Project administration, Investigation. **Max Klapow:** Writing – review & editing, Investigation. **Alfred Harun Thullah:** Writing – review & editing, Supervision, Project administration. **Richard Bamuleke:** Writing – review & editing, Supervision, Resources, Project administration. **Issa Mohamet Nuur:** Writing – review & editing, Supervision, Project administration. **Krishnan Raghavendran:** Writing – review & editing, Supervision, Project administration.

Declaration of competing interest

No competing interests to declare.

References

[1] Injuries and violence: the facts 2014. World Health Organization; 2014.
[2] Paniker J, Graham SM, Harrison JW. Global trauma: the great divide. SICOT J 2015;1:19. https://doi.org/10.1051/sicotj/2015019.
[3] Dalal K, Lin Z, Gifford M, Svanström L. Economics of global burden of road traffic injuries and their relationship with health system variables. Int J Prev Med 2013;4 (12):1442–50.
[4] Olvera LD, Plat D, Pochet P, Maïdadi S. Motorbike taxis in the "transport crisis" of West and Central African cities. echogeo 2012;(20). https://doi.org/10.4000/echogeo.13080.
[5] Mould-Millman NK, Dixon JM, Sefa N, et al. The State of Emergency Medical Services (EMS) Systems in Africa. Prehosp Disaster Med 2017;32(3):273–83. https://doi.org/10.1017/S1049023×17000061.
[6] Higgins A, Morriss WW, Gelb AW, et al. 72nd World Health Assembly, Geneva, Switzerland, 2019. Anesthesia & Analgesia 2020;130(3):e92–4. https://doi.org/10.1213/ANE.0000000000004594.
[7] Hsia RY, Thind A, Zakariah A, Hicks ER, Mock C. Prehospital and emergency care: updates from the disease control priorities, version 3. World J Surg 2015;39(9): 2161–7. https://doi.org/10.1007/s00268-015-2997-5.
[8] Anthony DR. Promoting emergency medical care systems in the developing world: weighing the costs. Glob Public Health 2011;6(8):906–13. https://doi.org/10.1080/17441692.2010.535008.
[9] Bhalla K, Sriram V, Arora R, et al. The care and transport of trauma victims by layperson emergency medical systems: a qualitative study in Delhi, India. BMJ Glob Health 2019;4(6):e001963. https://doi.org/10.1136/bmjgh-2019-001963.
[10] Koome G, Atela M, Thuita F, Egondi T. Health system factors associated with post-trauma mortality at the prehospital care level in Africa: a scoping review. Trauma Surg Acute Care Open 2020;5(1):e000530. https://doi.org/10.1136/tsaco-2020-000530.
[11] Mock C. Strengthening prehospital trauma care in the absence of formal emergency medical services. World J Surg 2009;33(12):2510–1. https://doi.org/10.1007/s00268-009-0239-4.
[12] Mock C. Essential Trauma Care Project (World Health Organization), World Health Organization, International Society of Surgery, International Association for the Surgery of Trauma and Surgical Intensive Care. Guidelines for essential trauma care. World Health Organization; 2004.
[13] Callese TE, Richards CT, Shaw P, et al. Layperson trauma training in low- and middle-income countries: a review. J Surg Res 2014;190(1):104–10. https://doi.org/10.1016/j.jss.2014.03.029.
[14] Ouma PO, Maina J, Thuranira PN, et al. Access to emergency hospital care provided by the public sector in sub-Saharan Africa in 2015: a geocoded inventory and spatial analysis. Lancet Glob Health 2018;6(3):e342–50. https://doi.org/10.1016/S2214-109X(17)30488-6.
[15] Olubomehin O. The development and impact of motorcycles as a means of commercial transport in Nigeria. Res Humanities Social Sci 2012;2(6):231–40.
[16] Patel A, Vissoci JRN, Hocker M, Molina E, Gil NM, Staton C. Qualitative evaluation of trauma delays in road traffic injury patients in Maringá, Brazil. BMC Health Serv Res 2017;17(1):804. https://doi.org/10.1186/s12913-017-2762-6.
[17] Mould-Millman NK, Rominski SD, Bogus J, et al. Barriers to accessing emergency medical services in Accra, Ghana: development of a survey instrument and initial application in Ghana. Glob Health Sci Pract 2015;3(4):577–90. https://doi.org/10.9745/GHSP-D-15-00170.
[18] Stewart KAA, Groen RS, Kamara TB, et al. Traumatic injuries in developing countries: report from a nationwide cross-sectional survey of Sierra Leone. JAMA Surg 2013;148(5):463–9. https://doi.org/10.1001/jamasurg.2013.1341.
[19] Jayaraman S, Mabweijano JR, Lipnick MS, et al. First things first: effectiveness and scalability of a basic prehospital trauma care program for lay first-responders in Kampala, Uganda. McCulloch P, editor. PLoS ONE 2009;4(9):e6955. https://doi.org/10.1371/journal.pone.0006955.
[20] Sun JH, Wallis LA. The emergency first aid responder system model: using community members to assist life-threatening emergencies in violent, developing areas of need. Emerg Med J 2012;29(8):673–8. https://doi.org/10.1136/emermed-2011-200271.
[21] Delaney PG, Eisner ZJ, Bustos A, et al. Cost-effectiveness of lay first responders addressing road traffic injury in sub-Saharan Africa. J Surg Res 2021;270:104–12. https://doi.org/10.1016/j.jss.2021.08.032.
[22] Delaney PG, Bamuleke R, Lee YJ. Lay first responder training in eastern Uganda: leveraging transportation infrastructure to build an effective prehospital emergency care training program. World J Surg 2018;42(8):2293–302. https://doi.org/10.1007/s00268-018-4467-3.
[23] Hancock CJ, Delaney PG, Eisner ZJ, et al. Developing a Lay First Responder Program in Chad: a 12-Month Follow-Up Evaluation of a Rural Prehospital Emergency Care Program. Prehosp Disaster med 2020;35(5):546–53. https://doi.org/10.1017/S1049023×20000977.
[24] Eisner ZJ, Delaney PG, Thullah AH, et al. Evaluation of a Lay First Responder Program in Sierra Leone as a Scalable Model for Prehospital Trauma Care. Injury 2020;51(11):2565–73. https://doi.org/10.1016/j.injury.2020.09.001.
[25] Eisner ZJ, Delaney PG, Klapow MC, Raghavendran K, Klapow JC. Identifying a "super-responder" phenomenon in three African countries: implications for prehospital emergency care training. Injury 2022;53(1):176–82. https://doi.org/10.1016/j.injury.2021.09.064.
[26] Delaney PG, Eisner ZJ, Blackwell TS, et al. Exploring the factors motivating continued Lay First Responder participation in Uganda: a mixed-methods, 3-year follow-up. Emerg Med J 2021;38(1):40–6. https://doi.org/10.1136/emermed-2020-210076.
[27] Delaney PG, Eisner ZJ, Thullah AH, et al. Evaluating a novel prehospital emergency trauma care assessment tool (PETCAT) for low- and middle-income countries in Sierra Leone. World J Surg 2021;45(8):2370–7. https://doi.org/10.1007/s00268-021-06140-1.
[28] Arreola-Risa C, Mock C, Herrera-Escamilla AJ, Contreras I, Vargas J. Cost-effectiveness and benefit of alternatives to improve training for prehospital trauma care in Mexico. Prehosp Disaster Med 2004;19(4):318–25. https://doi.org/10.1017/S1049023×00001953.
[29] Boschini LP, Lu-Myers Y, Msiska N, Cairns B, Charles AG. Effect of direct and indirect transfer status on trauma mortality in sub Saharan Africa. Injury 2016;47 (5):1118–22. https://doi.org/10.1016/j.injury.2016.01.015.
[30] Bakalos G, Mamali M, Komninos C, et al. Advanced life support versus basic life support in the pre-hospital setting: a meta-analysis. Resuscitation 2011;82(9): 1130–7. https://doi.org/10.1016/j.resuscitation.2011.04.006.
[31] Jayaraman S, Sethi D, Wong R. Advanced training in trauma life support for ambulance crews. Cochrane Database Syst Rev 2014;2014(8):CD003109. https://doi.org/10.1002/14651858.CD003109.pub3.
[32] Delaney PG, Eisner ZJ, Thullah AH, et al. Evaluating feasibility of a novel mobile emergency medical dispatch tool for lay first responder prehospital response coordination in Sierra Leone: a simulation-based study. Injury 2023;54(1):5–14. https://doi.org/10.1016/j.injury.2022.10.010.
[33] Friesen J, Patterson D, Munjal K. Cardiopulmonary resuscitation in resource-limited health systems–considerations for training and delivery. Prehosp Disaster med 2015;30(1):97–101. https://doi.org/10.1017/S1049023×14001265.
[34] Eilertsen KA, Winberg M, Jeppesen E, Hval G, Wisborg T. Prehospital tourniquets in civilians: a systematic review. Prehosp Disaster Med 2021;36(1):86–94. https://doi.org/10.1017/S1049023×20001284.
[35] Eisner ZJ, Delaney PG, Pine H, et al. Evaluating a novel, low-cost technique for cervical-spine immobilization for application in resource-limited LMICs: a non-inferiority trial. Spinal Cord 2022;60(8):726–32. https://doi.org/10.1038/s41393-022-00764-3.