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ORIGINAL SCIENTIFIC REPORT

Deficiencies in the Availability of Essential Musculoskeletal Surgical Services at 883 Health Facilities in 24 Low- and Lower-Middle-Income Countries

D. A. Spiegel · A. Nduaguba · M. N. Cherian · M. Monono · E. T. Kelley

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Abstract

Background The sequelae of acute musculoskeletal conditions, especially injuries and infections, are responsible for significant disability in low- and middle-income countries. This study characterizes the availability of selected musculoskeletal surgical services at different tiers of the health system in a convenience sample of 883 health facilities from 24 low- and lower-middle-income countries.

Methods Selected data points from the World Health Organization's (WHO) tool of situational analysis of surgical availability were extracted from the WHO's database in December, 2013. These included infrastructure, physical resources and supplies, interventions, and human resources. For a descriptive analysis, facilities were divided into two groups based on number of beds (<100, 100–300, and >300) and level of facility (primary referral, secondary/tertiary, and Private/NGO/Mission). Statistical comparison was made between public and Private/NGO/Mission facilities based on number of beds (≤100, 100–300, and >300) using a Chi-Square analysis, with statistical significance at $p < 0.05$.

Findings Significant deficiencies were noted in infrastructure, physical resources and supplies, and human resources for the provision of essential orthopedic surgical services at all tiers of the health system. Availability was significantly lower in public versus Private/NGO/Mission facilities for nearly all categories in facilities with ≤100 beds, and in a subset of measures in facilities with between 100 and 300 beds.

Interpretation Deficiencies in the availability of orthopedic surgical services were observed at all levels of health facility and were most pronounced at facilities with ≤100 beds in the public sector. Strengthening the delivery of essential surgical services, including orthopedics, at the primary referral level must be prioritized if we are to reduce the burden of death and disability from a variety of emergent health conditions.

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D. A. Spiegel (✉) · A. Nduaguba
Division of Orthopaedic Surgery, Children's Hospital of Philadelphia, 2nd Floor Wood Building, 34th Street and Civic Center Blvd, Philadelphia, PA 19106, USA
e-mail: spiegeld@email.chop.edu

A. Nduaguba
e-mail: afam.nduaguba@gmail.com

A. Nduaguba
Harvard University School of Medicine, Boston, MA, USA

M. N. Cherian
Emergency and Essential Surgical Care (EESC) Program, Service Delivery and Safety Department (SDS), Health Systems and Innovation, World Health Organization- HQ, Avenue Appia 20, 1211 Geneva 27, Switzerland
e-mail: cherianm@who.int

M. Monono
World Health Organization -Regional Office for Africa, Cité du Djoué, P.O. Box 06, Brazzaville, Republic of Congo
e-mail: ekekemononom@who.int

Introduction

Information concerning the burden of acute musculoskeletal conditions, coupled with experiential evidence, suggests that sequelae of injuries and infections are responsible for significant disability in low- and middle-income countries (LMICs) [1–9]. Injuries alone cause more than 5 million deaths per year [1], more than HIV/AIDS, malaria, and tuberculosis combined [2], and for every death, there may be twenty non-fatal outcomes and one case of permanent disability [3, 4], many related to the musculoskeletal system.

Alongside this growing burden comes the realization that there are gross disparities in access to surgical care globally. Weiser et al. estimated that only 3.5 % of the world's surgical procedures are performed in countries at or below the lowest third for per capita health expenditure [10]. Inadequate access to health services has lead to increased mortality for many conditions, or to delayed or "neglected" presentations for non-fatal conditions. Such cases require treatment strategies that are more complex, more costly, and are less likely to achieve a suitable outcome. Within the realm of musculoskeletal surgery, prompt reduction of fractures and joint dislocations often eliminates the need for complex open surgical procedures. Simple drainage of an abscess and debridement of devitalized bone complicating acute osteomyelitis may reduce the risk of chronic osteomyelitis, which would require multiple surgical procedures to eradicate the infective focus, reconstruct osseous defects, and treat coexisting problems such as angular deformity and/or limb length discrepancy.

The provision of safe and timely musculoskeletal surgical services may be viewed as "primary prevention" of disability, especially at the primary referral level in LMICs where a significant percentage of the population receives their health care. While a number of previous investigations have documented deficiencies in the availability of surgical services in LMICs [11–33], none have focused on musculoskeletal care. The goal of this study is to describe the availability of musculoskeletal surgical services at different tiers of the health system in a convenience sample of 883 health facilities from 24 low- and lower-middle-income countries.

Method

A tool for situational analysis of the availability of surgical and anesthetic services at individual health facilities was developed by members of the World Health Organization's (WHO) Global initiative for Emergency and Essential Surgical Care (GIEESC) in 2007, focusing on (1) infrastructure, (2) human resources, (3) interventions, and (4) equipment and supplies [34]. The items listed in the questionnaire have been extracted from the teaching materials from the WHO's Emergency and Essential Surgical Care (EESC) project, and "Essential" might also be defined as those services which should be available within the context of universal access [35, 36]. Recognizing that the specific interventions will be refined by local contextual variables, these target "high priority" conditions (1) which have a large public health burden, (2) for which there is an intervention which is highly successful, and (3) for which the intervention is cost-effective and can be promoted globally [37]. The musculoskeletal interventions included in the tool are wound debridement, irrigation and drainage of abscesses, closed treatment of fractures, open treatment of fractures, joint dislocation treatment drainage of osteomyelitis/septic arthritis, amputation, and clubfoot. Selected equipment and supplies related to musculoskeletal services and included in the questionnaire include tourniquet and splints.

Since that time the tool has been utilized in more than 50 countries; facilities have been selected by the Ministries of Health, and questionnaires have been administered by representatives from the Ministries of Health, the WHO country offices, and/or GIEESC members. The forms are then sent to WHO headquarters in Geneva and entered into a database.

This database was accessed in early December 2013, at which time information was available for 1,076 health facilities in 56 countries. We chose to remove countries from which less than 10 facilities were sampled, and those facilities with incomplete datasets. We also removed data from the only high-income country (Trinidad and Tobago). The data on clubfoot were not included in the present study, having been presented in another publication.

Recognizing the variability in terminology used to describe a particular level of facility within a country's health system, we have elected to present the data based on both the number of beds and the type of health facility, recognizing that there is some degree of overlap. Facilities have been divided into three categories based on the number of beds, according to WHO's textbook Surgical Care at the District Hospital [38], as (1) <100 beds, (2) 100–300 beds, and (3) >300 beds. Typically, facilities with less than 100 beds are rural hospitals or health centers with minor surgical capacity, while those with more than 300 beds are tertiary level facilities that would be expected to perform more complex surgical procedures. Three levels of facility have been selected, namely (1) primary referral level (health center, district/rural/community hospital), (2) secondary/tertiary

E. T. Kelley
Service Delivery and Safety Department, World Health Organization-HQ, Avenue Appia 20, 1211 Geneva 27, Switzerland
e-mail: kelleye@who.int

level (provincial or general hospital), and (3) Private/NGO/Mission.

With the goal of evaluating any differences between the availability of services at government facilities versus Private/NGO/Mission facilities, we performed a statistical comparison between these based on number of beds (≤100, 100–300, and >300) using a Chi-Square analysis, with statistical significance at $p < 0.05$.

Results

Our final dataset included 883 health facilities from 15 Low- and 9 lower-middle income countries, representing one fourth of the world's population (Table 1). Figure 1 illustrates the levels of facility for each level of beds. A subset of our data have been included in previous studies utilizing the GIEESC tool.

Data concerning the availability of infrastructure, supplies, and human resources for the entire group, type of facility, and number of beds are shown in Table 2. Deficiencies were most pronounced in facilities with ≤100 beds or primary referral level facilities, but were also identified at higher levels of service delivery in both governmental and non-governmental facilities. For example, a reliable supply of running water and electricity was available in only 68 and 64 % of facilities, respectively. Oxygen was unavailable at one in four facilities. Uninterrupted access to plain radiographs and materials for splinting and casting were available in only 27 and 48 % of facilities with ≤100 beds, respectively, versus 90 and 66 % of facilities with >300 beds. Sterile gloves were available in three of four facilities overall, and in only four of five facilities with >300 beds. The information on human resources is expressed as the average number of providers per facility, and indicated the paucity of trained surgeons at the primary referral level. Task shifting was utilized at all levels of health facility for surgical care, but was the predominant strategy utilized at smaller, primary level facilities.

The availability of selected surgical and anesthetic services for the entire group, type of facility, and number of beds is shown in Table 3. Wound debridement and drainage of abscesses are reliably performed at the majority of facilities. In contrast, less than 50 % of primary referral facilities or those facilities with less than 100 beds were able to perform any of the orthopedic interventions. Similarly, Cesarean section and laparotomy were available in only 52 and 42 % of those will less than 100 beds, respectively, and similar findings were observed with the availability of anesthetic services.

Our statistical analysis revealed that for facilities with ≤100 beds, availability of infrastructure, physical resources and supplies, and surgical and anesthetic interventions was significantly lower at public versus Private/NGO/Mission facilities for every item except a blood bank and abscess drainage (Table 4). Similar findings were observed in facilities with 100–300 beds for the availability of the following: electricity, postoperative care unit, blood bank, guidelines for surgical care, sterilizer, sterile gloves, splints/casts, and regional anesthesia. No significant differences were found when comparing facilities with more than 300 beds.

Discussion

The burden of acute musculoskeletal conditions in LMICs is substantial, and the available evidence suggests that considerable morbidity can be averted by the provision of safe and timely orthopedic services, especially for injuries and infections. Ninety percent of the more than 5 million mortal injuries each year occur in LMICs [1, 5], and for each death, there may be one case of permanent disability [3, 4]. Findings from the most recent iteration of the global burden of disease study indicate that injury-related years lived with disability (YLD's) have increased by 6.5 %, and it is projected that YLD's will increase by 38.4 % by 2030 [6]. Improvements in trauma care will likely increase the volume of non-fatal injuries, elevating the importance of orthopedic care. Acute osteomyelitis is most commonly due to hematogenous seeding, or as a complication of open fractures or surgical procedures on bone. The incidence of acute hematogenous osteomyelitis (AHO) varies from 43 to 200 cases per 100,000 persons in developing countries [39]. We are unaware of any reliable figures concerning the incidence of open fractures or surgical site infections in LMICs, and the burden of musculoskeletal infections (osteomyelitis and septic arthritis) has not been quantified with existing metrics.

While there is evidence to suggest that approximately 15 % of the world's population is living with a disability [40], information concerning that component due to musculoskeletal causes is limited and is mainly experiential. There are 20–40 million non-fatal injuries each year from road traffic crashes alone [2, 5], and the reported prevalence of disability varies from 2 to 87 % [7]. Mock et al. found that 0.83 % of Ghanaians were disabled because of an injury, 78 % of which involved the extremities [8]. Atijosen et al. estimated that 5.2 % of the Rwandan population was disabled due to a musculoskeletal condition, including injuries (31 %) and infections (4 %) [9]. Based on these two studies, assuming a 1.1 % prevalence of permanent disability, we would estimate that more than 64 million people in LMICs may be permanently disabled because of an acute musculoskeletal condition.

Our study revealed deficiencies in the availability of infrastructure, equipment and supplies, and human resources required to deliver essential orthopedic surgical

Table 1 Selected indicators

WHO region	Country (# facilities sampled)	Pop (000's) (2011)	World bank class	Hum dev index × (186)	Urban (%)	GNI per capita (PPP int. $)	Age <15 yo (%)	Life expect (2011)	MMR (per 100,000 live births, 2011)	Under 5 mortality (per 1,000 live births, 2011)	Physicians per 1,000 (2005–2012)	Births by C-section (2005–2012)	Pvt exp health as % of total exp (2010)	OOP exp as % of pvt exp (2010)	Per cap govt exp on health (US$) (2010)
AFRO	Nigeria* (122)	162,471	LMIC	153	50	2,290	43	53	630	124	4	2	68.5	95.6	21
	Gambia (74)	1,776	LIC	165	57	1,750	44	58	360	101	1.1	3	43.9	48.4	15
	Kenya* (66)	41,610	LIC	145	24	1,710	42	60	360	73	1.8	6	59.8	76.6	14
	United Republic of Tanzania (49)	46,210	LIC	152	27	1,500	45	59	460	68	0.1	5	60.8	52.4	14
	Uganda* (38)	34,509	LIC	161	16	1,310	48	56	310	90	1.2	5	76.9	64.8	10
	Liberia* (24)	4,129	LIC	174	48	540	44	59	770	78	NR	4	81	25.8	8
	Ghana (22)	24,966	LMIC	135	52	1,810	38	64	350	78	0.9	7	41.8	66.7	40
	Ethiopia* (22)	84,734	LIC	173	17	1,110	41	60	350	77	0.3	2	47.1	80.1	8
	Niger* (21)	16,069	LIC	186	18	720	49	56	590	125	0.2	1	50.8	84	9
	Democratic Republic of the Congo* (19)	67,758	LIC	186	3	340	46	49	540	168	NR	7	71.6	65	4
	Malawi* (19)	15,381	LIC	170	16	870	46	58	460	83	0.2	5	25.8	53.3	21
	Sierra Leone* (12)	5,997	LIC	177	39	840	43	47	890	185	0.2	5	84.7	91.4	10
SEARO	India (172)	1,241,492	LMIC	136	31	3,590	30	65	200	61	6.5	8	71.8	86	14
	Sri Lanka* (39)	21,045	LMIC	92	15	5,520	25	75	35	12	4.9	24	54.4	81.9	37
	Myanmar* (20)	48,337	LIC	149	33	NR	25	65	200	62	5	NR	87.9	92.7	2
	Bangladesh* (14)	150,494	LIC	146	28	1,940	31	70	240	46	3.6	17	63.5	96.6	9
WPRO	Mongolia (43)	2,800	LMIC	108	69	4,290	28	68	63	31	27.6	21	43	93.1	71
	Papua New Guinea (25)	7,014	LMIC	156	12	2,570	39	63	230	58	0.5	NR	24.8	55.9	43
	Vietnam (19)	88,792	LMIC	127	31	3,250	23	75	59	22	12.2	20	62.9	93	31

Table 1 continued

WHO region	Country (# facilities sampled)	Pop (000's) (2011)	World bank class	Hum dev index × (186)	Urban (%)	GNI per capita (PPP int. $)	Age <15 yo (%)	Life expect (2011)	MMR (per 100,000 live births, 2011)	Under 5 mortality (per 1,000 live births, 2011)	Physicians per 1,000 (2005–2012)	Births by C-section (2005–2012)	Pvt exp health as % of total exp (2010)	OOP exp as % of pvt exp (2010)	Per cap govt exp on health (US$) (2010)
	Soloman Islands* (10)	552	LMIC	143	20	2,350	40	70	93	22	2.2	6	6.2	56.7	88
EMRO	Afghanistan* (26)	32,358	LIC	175	24	1,140	46	60	460	101	1.9	4	77.5	94	10
	Somalia* (15)	9,557	LIC	NR	38	NR	45	50	1,000	180	0.4	NR	NR	NR	NR
	Pakistan* (10)	176,745	LMIC	146	36	2,870	35	67	260	72	8.1	7	23.4	NR	8
PAHO	Haiti* (54)	10,124	LIC	161	53	1,180	36	63	350	70	NR	3	60	39	18
Average		2,294,940			32	1,963	39	61	344	83	3.8	8	53	72	22
HIC		1,095,054			80	38,690	17	80	14	6	27.1	30	38.2	36.1	3,026
UMIC		2,503,866			61	10,566	22	74	53	20	17.8	31	44.5	75.1	211
LMIC		2,529,253			39	3,666	33	66	260	62	7.8	9	63.9	87.8	27
LIC		813,734			28	1,313	39	60	410	95	5.1	6	61.5	77.7	10

Selected indicators for the countries in our analysis may be compared with average values for high-income countries (HIC), upper-middle-income countries (UMIC), lower-middle-income countries (LMIC), and low-income countries (LIC). The World Bank classifies countries on a yearly basis; in the most recent analysis, countries were grouped as low income (LIC, $\leq$$1,035/year), lower-middle income (LMIC, $1,036–4,085/year), upper-middle income (UMIC, $4,086–12,615/year), and high income (HIC, $\geq$$12,616/year) (http://data.worldbank.org/about/country-classifications/country-and-lending-groups#Low_income). Other statistical information has been extracted from the World Health Statistics 2013 (http://www.who.int/gho/publications/world_health_statistics/EN_WHS2013_Full.pdf, accessed 3/24/14). Rankings on the Human Development Index were obtained from the United Nations Development Programme website (https://data.undp.org/dataset/Table-1-Human-Development-Index-and-its-components/wxub-qc5k) (Accessed 3/24/14). Those states labeled with an asterisk are considered "fragile" by the OECD (http://www.oecd.org/dac/incaf/FragileStates2013.pdf). *AFRO* African regional office, *SEARO* Southeast Asian region office, *WPRO* Western Pacific region, *EMRO* regional office for the eastern mediterranean, *PAHO* Pan American health organization, *pop* population, *Hum* human, *Dev* development, *GNI* gross national income, *Urban* % of population living in an urban environment, *MMR* maternal mortality ratio, *Pvt* private, *Exp* expenditure, *OOP* out of pocket, *Pvt* private, *Cap* capita, *Govt* governmental

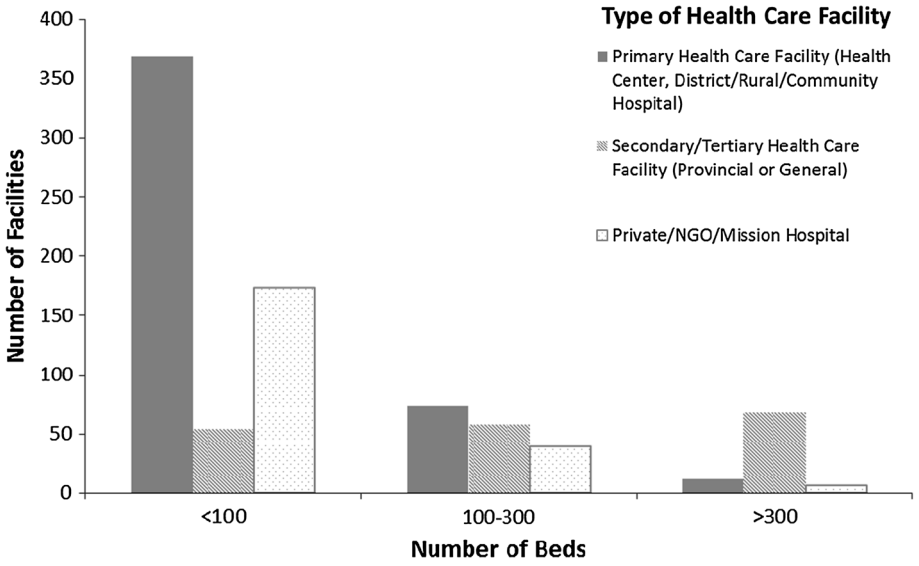

Fig. 1 Type of health facility and number of beds. We chose to analyze out data based on (1) type of health facility as Primary (health center, district/rural/community hospital) (*Black*), Secondary/Tertiary (provincial or general hospital) (*Gray*), and Private/NGO/mission, and (2) the number of beds (≤100, 100–300, and >300) (*white*). This figure illustrates the degree of overlap between the groups in our analysis

services, especially at smaller or primary referral level facilities. These observations support those of previous studies using the GIEESC tool (10), the tool developed by the Harvard Humanitarian Initiative (5), the PIPES tool (2), and demographic health surveys/service provision assessments (Hsia). These reports have also involved a convenience sample of facilities, public and private, from the primary referral level through the tertiary level, and selected data are shown in Table 5. We also found that for most data points, availability was lower in public facilities versus Private/NGO/Mission facilities for those facilities with ≤100 beds, and for a smaller number of indicators in facilities with 100–300 beds.

The information on infrastructure is germane to the delivery of any facility-based health services, medical or surgical. Previous studies have noted that an uninterrupted supply of water was available in 18–100 % [12–20, 22–27, 29], electricity in 48–89 % [13–20, 22–27, 29], and oxygen in 28–100 % of facilities [11–20, 22–27, 29] (Table 5). Frequent power outages were noted in Bangladesh, Uganda, and Rwanda. The costs of electricity and/or diesel fuel for a generator may also be a challenge. While a blood bank was always available on-site in 23–64 % [12–15, 19, 23–27, 29], versus 13–84 % in our study, some facilities have access to local or regional blood banks, or can process on-site, immediate donations. Only five studies commented on the availability of plain radiographs (0–44 %) [15, 18, 19, 23, 29]. Hsia et al. studied surgical care in five African countries (Kenya, Tanzania, Rwanda, Uganda, and Ghana) and noted deficiencies in infrastructure, equipment, medical storage, infection control, education, and quality control [30]. The authors found that less than 50 % of facilities had the capacity to repair or maintain equipment [30].

With regard to equipment and supplies, a sterilizer was present in 41–100 % of facilities, and sterile gloves in only 52–90 % of facilities [11, 13, 15–19, 21, 26, 29], similar to the findings of our study. Materials for splinting and casting were available in 14–85 % in the five studies in which this was measured [13, 19, 21, 23, 29]. Only two studies reported whether or not a tourniquet was available, with values ranging from 30 to 79 %, versus 61–86 % in the present study.

The availability of these musculoskeletal interventions varied considerably in previous studies utilizing the GIEESC tool. Simple wound care and irrigation and debridement of abscesses were available at the majority of facilities. Closed management of fractures was performed in 30–100 % [11, 13–16, 19–23, 29], open management of fractures in 6–100 % [11, 13, 14, 17, 19–23, 29], treatment of joint dislocations in 43–100 % [13, 14, 19–21, 29], amputations in 39–100 % [11, 13–17, 19–23, 29], and drainage of osteomyelitis or septic arthritis in 32–100 % [11, 13, 14, 17, 19–23, 29] (Table 5). Significant deficiencies were noted at the primary referral level or in facilities with <100 beds. In Malawi, orthopedic procedures are typically performed at the central hospitals, and procedures for fracture care and osteomyelitis accounted for only 6 and 2 % of the volume at district hospitals, respectively [31]. While delayed management of acute musculoskeletal conditions often results in disability, a lack of timely access to other essential surgical services such as Cesarean section, which was available at 41–96 % of facilities in our literature review, leads to countless unnecessary deaths of mothers and infants. There are also gross deficiencies in the number of surgeons in LMICs, especially at primary referral level facilities, and the majority

Table 2 Availability of infrastructure, supplies, and human resources

	Total		Type of facility						# beds					
			1°		2° or 3°		Private or NGO or mission		≤100 beds		100–300 beds		>300 beds	
	Always	Never	Always	Never	Always	Never	Always	Never	Always	Never	Always	Never	Always	Never
Infrastructure and Supplies														
Running water	68	12	61	16	72	7	81	7	62	18	75	4	86	1
Oxygen	57	26	44	35	71	13	76	16	48	35	67	14	85	4
Electricity or power generator	64	7	55	10	64	2	79	4	58	9	71	4	80	0
Anasthesia machine	51	44	42	54	73	21	51	40	31	63	78	17	90	3
Emergency room	58	31	46	43	74	18	71	19	49	39	68	22	88	9
Postoperative care unit	49	41	33	59	68	24	67	21	39	51	59	33	84	9
Blood bank	29	57	17	66	61	30	28	60	13	77	46	31	83	7
X-ray machine	46	46	34	54	73	15	49	44	27	65	71	11	90	4
Sterilizer	68	9	62	13	69	4	84	4	64	12	74	3	81	4
Sterile gloves	77	4	71	5	69	7	94	2	77	5	76	3	82	6
Splints/casts	52	27	42	36	54	16	71	12	48	35	56	13	66	13
Tourniquet	67	15	61	19	62	14	86	6	67	17	68	13	70	8
Human resources														
Full time surgeons	3.3		1.4		8.4		2.1		0.6		2.2		18	
General doctors (full time)	3.9		2.6		8.1		2.9		1.2		3.4		20.7	
General doctors (part time)	0.5		0.1		1.9		0.7		0.3		0.3		4.1	
Clinical/assistant medical officers (full time)	1.8		1.2		3.6		1.4		0.8		2.5		6.5	
Clinical/assistant medical officers (part time)	0.25		0.1		0.7		0.4		0.2		0.2		1.4	

Our data are presented according to (1) the group as a whole, (2) the type of health facility, and (3) the number of beds. All numbers for infrastructure and supplies reflect percentages, while the values for human resources reflect the average number of providers per facility

Table 3 Availability of orthopedic and anesthesia services

Surgical and anesthetic procedures (% who perform)		Total	Type of facility			# Beds		
			Primary	Secondary and tertiary	Private or NGO or mission	≤100 beds	100–300 beds	>300 beds
Orthopedic	Abscess drainage	93	88	98	99	89	99	100
	Wound debridement	85	76	95	95	78	95	100
	Closed treatment of fractures	61	46	83	74	45	84	96
	Open treatment of fractures	42	26	69	51	25	62	94
	Joint dislocation	63	50	85	71	49	84	94
	Amputation	51	33	85	56	29	81	94
	Drainage of osteomyelitis or septic arthritis	50	31	79	63	30	76	94
Anesthesia	General	51	37	77	57	29	81	98
	Spinal	61	43	92	61	42	90	99
	Ketamine	69	48	92	92	55	91	98
	Regional	52	32	74	70	39	66	91

Our data are presented according to (1) the group as a whole, (2) the type of health facility, and (3) the number of beds. Cesarean section and laparotomy are included for comparison. All values listed are percentages of facilities who offer that service

Table 4 Uninterrupted availability of infrastructure, physical resources and supplies, human resources, and interventions

Uninterrupted availability of infrastructure, physical resources and supplies, human resources, and interventions	≤100 beds		100–300 beds		>300 beds	
	Public	Private	Public	Private	Public	Private
Running water	59*	78	69	88	84	100
Oxygen	42*	75	65	72	83	100
Electricity or power generator	51*	75	68*	90	78	100
Anesthesia machine	35*	40	79	88	89	100
Emergency room	45*	68	64	78	87	86
Postoperative care unit	33*	63	50*	87	84	71
Blood bank	13	17	49*	66	81	100
X-ray machine	27*	40	76	79	89	100
Guidelines for surgical care	26*	35	54*	74	64	71
Sterilizer	57*	82	73*	95	83	83
Sterile gloves	69*	94	72*	92	82	100
Splints/casts	40*	68	52*	83	65	86
Tourniquet	59*	87	66	84	70	71
Abscess drainage	87	98	99	100	100	100
Wound debridement	74*	94	94	100	100	100
Closed treatment of fractures	39*	69	89	93	95	100
Open treatment of fractures	17*	43	72	78	94	86
Joint dislocation	46*	65	86	90	94	100
Amputation	27*	46	86	93	94	100
Drainage of osteomyelitis or septic arthritis	25*	55	79	90	94	100
General anesthesia	29*	47	82	90	98	100
Spinal anesthesia	38*	65	92	98	99	100
Ketamine anesthesia	45*	90	91	100	98	100
Regional anesthesia	31*	66	41*	60	91	91

The numeric data are presented as percentages, and * $p < 0.05$

Table 5 Review of selected items of infrastructure for surgical care and musculoskeletal surgical interventions

Country	Tool	# fac	# beds	Running water (%)	Electricity or power generator (%)	Oxygen (%)	Access to blood bank (%)	Closed treatment fractures	Open treatment fractures	Joint dislocation	Amput	Drain OM or septic arthritis
8 country study [17]	WHO	132	50–100	67 (A) 35 (S) 30 (N)	48 (A) 69 (S) 15 (N)	28 (A) 44 (S) 60 (N)	–	–	33	–	39	43
Afghanistan [14]	WHO	17	5–200	60	42	70	66	100 (R) 100 (P) 71 (D)	100 (R) 50 (P) 42 (D)	100 (R) 100 (P) 71 (D)	100 (R) 67 (P) 42 (D)	100 (R) 83 (P) 42 (D)
Mongolia [21]	WHO	44	–	45	66/45	–	23	55	48	73	41	32
The Gambia [15]	WHO	18	–	50	44/53	78	47	41	29	–	44	–
Sierra Leone [16]	WHO	10	35–450	60 (A) 20 % (S)	60 (S) 40 (N)	60 (S) 40 (N)	–	30	80	–	80	–
Solomon Islands [18]	WHO	9	60–305	100	89 (A) 11 (S)	4	–	89	–	–	–	–
Ghana [13]	WHO	17	–	94	82/82	NR	53	76	12	64	59	41
Tanzania [19]	WHO	48	15–350	56 (A) 35 (S) 8 (N)	44 (A)/58(A) 52 (S)/ 2(S) 4 (N)/40(N)	67 (A) 35 (S) 30 (N)	29 (A) 48 (S) 23 (N)	88	61	92	65	63
Liberia [20]	WHO	16	11–200	19	25	31	–	44	6	–	63	31
Sri Lanka [22]	WHO	47	<10 to 100	86	54 (A) 46 (S)	76 (A) 24 (I)	–	39	14	43	31	33
Rwanda [23]	WHO	44	–	81 (A)	81 (A)	59 (A)	61 (A)	80–100	60–79	–	80–100	60–79
Zambia [11]	WHO	103	–	–	-	63 (A)	–	75 (1°) 87 (2°)	47 (1°) 36 (2°)	–	50 (1°) 64 (2°)	50 (1°) 75 (2°)
Nigeria [29]	PIPES	41	13–31	82	50/90	NR	36	39	14	43	31	33
Liberia [27]	HHI	11	94	18 (A) 64 (S)	45 (A)	82	64	–	–	–	–	–
Uganda [26]	HHI	14	100–217	79 %	86	73	100	–	–	–	–	–
Ethiopia [12]	HHI	20	42–800	100	–	100	100	–	–	–	–	–
Rwanda [24]	HHI	21	195	–	100 (S)	60-100	NR	–	–	–	–	–
Bangladesh [25]	HHI	14	140 (D) 543 (MC)	–	100	100	29 (D) 100 (MC)	–	–	–	–	–

Most studies have included a heterogenous group of health facilities, including both level (primary through tertiary) and type (public, private, NGO/Mission). The HHI tool assesses 8 areas, namely access and availability of surgical services, access to human resources, availability of surgical and anesthesia infrastructure and equipment, operating room capacity, involvement of NGOs in the delivery of surgical services, availability of essential drugs for surgery and anesthesia, surgical outcome reporting capacity. The PIPES tool was developed by Surgeons Overseas (SOS) and collects data (105 items) on personnel, infrastructure, procedures, equipment, and supplies. *WHO* WHO GIEESC situational analysis tool, *HHI* tool developed by Harvard Humanitarian Initiative, *P* PIPES, *A* always, *S* sometimes, *N* never, *OR* operating room, *D* district, *P* provincial, *R* regional, *MC* medical college, *P/NGO/M* private/non-governmental organization/mission, *1* primary referral level, *2* secondary level. Note that in Sierra Leone, orthopedic surgery was only performed at 2 tertiary facilities. Countries included in the 8 country study were Sao Tome and Principe, the Gambia, Liberia, Afghanistan, Tanzania, Sierra Leone, Mongolia, and Sri Lanka

practice at tertiary facilities in urban centers, often in the private sector. The majority of surgical services at the primary referral level are provided by general surgeons, or by medical doctors and/or paraprofessionals [11–16, 18–20, 22–29], such as the Orthopedic Clinical Officers (Malawi) [41] or Clinical Officers (Uganda) [26]. The limited information available concerning orthopedic subspecialists suggests that there are approximately 9 orthopedic surgeons in Rwanda [9, 23], 9 in Malawi [41], and 24 in Ghana [42], to care for more than 51 million people [43]. In contrast, Lebrun et al. found that there were an average of 1.1 orthopedic surgeons at each district facility and 5.3 at each medical college in Bangladesh [25].

We must also recognize that anesthetic services are an essential component of surgical care. An anesthesia machine was present in only 32–100 % of facilities in our literature review [14, 15, 17–21, 23–25], and the percentages of facilities offering selected anesthesia services were as follows: general (25–72 %), spinal (42–100 %), ketamine (44–100 %), and regional (18–100 %). A previous review from the WHO database involving 590 facilities in 22 countries found that general anesthesia was available in 59 %, spinal in 66 %, Ketamine in 72 %, and regional in 56 % [44].

There are a number of limitations that must be mentioned. The data have accumulated gradually over nearly 7 years, and no formal sampling methodology has been utilized. We might view the results as a "best case scenario," considering our findings were from a convenience sample. As noted previously, we recognize that there is a degree of overlap between number of beds, and how each facility chose to classify itself based on the choices available on the questionnaire, resulting in some lack of consistency. For example, while the majority of primary health facilities are smaller facilities with less than 100 beds, a small number of such facilities had more than 300 beds (Fig. 1). In addition, the findings may not accurately reflect an ever-changing landscape in which there are interruptions to the supply chain, where maintenance of equipment is variable and replacement is often delayed or not possible, and where the number and skill of health workers may be in a constant state of flux. The surgical workforce may intermittently be supplemented by surgical providers from other levels of the health system, or by health workers from NGOs or other organizations. We recognize that expectations for service delivery at each tier in a system may vary between and within countries, and is some degree of overlap based on the levels of analysis that we have selected. The surgical situational analysis tool has been shown to have high reliability on structure, but poor reliability on process of care [45]. The WHO tool was intended to inform improvements in service delivery at the individual facilities level. While we can state what percentage of facilities offered a particular service, we cannot draw any conclusions concerning the quantity or quality of services delivered, or on patient outcomes. In addition, the GIEESC tool was designed for primary level health facilities and lists only "surgeon" without the opportunity to indicate whether that provider is a subspecialist. As such, we cannot draw any conclusions about the number of orthopedic surgeons or where they practice. Finally, our data are just a snapshot, and are insufficient to inform policy changes. In addition, there is great need to integrate a monitoring strategy for service availability within each countries health information system (HIS) to improve service availability, and ultimately improve service delivery. The information collected must be tailored to specific levels within the HIS, for example, managers at individual health facilities versus health planners at the regional or national level, so questionnaires must be adapted. Monitoring tools must also be developed, for example, elements of the WHO situational analysis have been integrated into WHO's service availability and readiness assessment (SARA) [46]. While future iterations of the GIEESC tool will likely be of greatest benefit to managers at the facilities and perhaps regional level, the tool must be adapted to accurately capture process measures to ensure that safety and quality services are monitored.

Conclusion

Deficiencies in the availability of orthopedic surgical services, as well as life-saving procedures such as Cesarean section and laparotomy, were observed at all levels of health facility in this group of low- and lower-middle-income countries. These observations were most pronounced in facilities with $\leq$100 beds, especially in the public sector. Given that a majority of patients in low- and lower-middle-income countries receive their health care services at such smaller, public facilities, strengthening the delivery of surgical services including orthopedics must be prioritized if we are to reduce the burden of death and disability from a variety of emergent health conditions.

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Conflict of interest The authors include WHO staff, and the views expressed in this publication reflect their views and not necessarily that of WHO. One of the authors (DS) has served as a consultant for the WHO.

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