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Research article

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Posted Date: March 23rd, 2020

DOI: https://doi.org/10.21203/rs.3.rs-15656/v2

Version of Record: A version of this preprint was published on January 5th, 2021. See the published version at https://doi.org/10.1186/s12889-020-09994-7.

Association between malaria-related health service readiness and malaria mortality in under 5-year-old children in Burkina Faso

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Abstract

Background: The Service Availability and Readiness Assessment (SARA) surveys generate data on the readiness of health facility services. We constructed a readiness index related to malaria services and determined the association between health facility malaria readiness and malaria mortality in children under the age of 5 years in Burkina Faso.

Methods: Data on malaria-related visits and deaths in under 5-year-old children were extracted from the national Health Management Information System (HMIS) in Burkina Faso. Bayesian geostatistical models with variable selection were fitted to malaria mortality data. The most important facility readiness indicators related to general and malaria-specific services were determined. Multiple correspondence analysis (MCA) was used to construct a composite facility readiness score based on multiple factorial axes. The analysis was carried out separately for 112 medical centers and 546 peripheral health centers.

Results: Malaria mortality rate in medical centres was 4.8 times higher than that of peripheral health centres (3.46 vs 0.72%, $p<0.0001$). Essential medicines was the domain with the lowest readiness (only 0.1% of medical centres and 0% of peripheral health centres had the whole set of essential medicines tracer indicators). Basic equipment readiness was the highest. The composite readiness score explained 30% and 53% of the original indicators for medical centers and peripheral health centers, respectively. Mortality rate ratio (MRR) was by 59% (MRR = 0.41, 95% Bayesian credible interval (BCI): 0.19-0.91) lower in the high readiness group of peripheral health centers, compared to the low readiness group. Medical centers readiness was not related to malaria mortality. The geographical distribution of malaria mortality rate showed that regions with high mortality rate have also high proportion of health facilities with low readiness and vice versa.

Conclusion: Performant health services in Burkina Faso are associated with lower malaria mortality rates. Health system readiness should be strengthened in the regions of Sahel, Sud-Ouest and Boucle

du Mouhoun. Emphasis should be given to improving the management of essential medicines and to reducing delays of emergency transportation between the different levels of the health system.

Keywords: Bayesian geostatistical models, Burkina Faso, Composite readiness index, Malaria, Service Availability and Readiness Assessment

Background

Over the past 20 years, considerable progress has been made in the fight against malaria. Indeed, a reduction of 41% of clinical malaria incidence, and a 69% reduction in malaria mortality rates, have been observed [1]. This success is mainly explained by the scaling up of cost-effective health interventions, such as insecticide-treated nets (ITNs), indoor residual spraying (IRS) and artemisinin-based combination therapy (ACT) [2]. Globally, 19 countries eliminated malaria and six of them have been certified disease-free [1]. Notwithstanding, malaria remains a major public health issue in sub-Saharan Africa. Indeed, in 2017, 92% of the 219 million new cases of malaria and 93% of the 435,000 attributable deaths worldwide occurred in this part of the world. The disease burden is particularly high in children under the age of 5 years [1]. Burkina Faso accounts for 4% and 6% of the global clinical malaria incidence and malaria-related deaths, respectively. The malaria indicator survey of 2014 estimated that the prevalence of malaria parasitaemia determined by rapid diagnostic tests (RDTs) was 61%, compared to 76% in 2010 [3].

The importance of health systems strengthening to reach health-related goals and targets is stressed since the early 2000s [4,5]. Human resource shortages and inadequate training, poor supply chain management, inadequate infrastructure and equipment, and weak health information systems prevent the health facilities from responding adequately to populations needs [6–8]. Consequently, existing tools, designs and frameworks need to be improved in order to strengthen health systems [8–10]. In sub-Saharan Africa, only few counties regularly implement health systems assessment. In recent years, the World Health Organization (WHO) developed the Service Availability and Readiness Assessment (SARA) survey that is designed to assess the readiness of health facilities to respond to population's need [11]. SARA surveys collect a set of binary tracer items on several domains related to the availability of basic equipment, basic amenities, essential medicines, diagnostic capacity and delivery of health interventions. The data cover readiness of health facilities to provide general services as well as services related to 20 health programmes, including malaria,

HIV, tuberculosis, antenatal care, family planning and non-communicable diseases (NCDs).

Several authors have analysed the SARA survey tool or similar methodologies proposing statistical approaches to create a measure of health facility readiness and to relate readiness to health outcomes. Shawon and colleagues (2018), in their study following WHO guidelines, calculated separate readiness scores for each tracer item as the proportion of health facilities possessing the item [11,12]. Domain-specific readiness scores were also calculated as the mean of the tracer scores belonging to the domain. A similar approach has been adopted by Kanyangarara et al. (2018) to assess obstetric service readiness in 17 low- and middle-income countries (LMICs) [13]. Ali et al. (2018) obtained a general service score as the average of domain-specific scores to compare family planning service availability and readiness in 10 African countries [14]. This average composite measure takes into account the different aspects of health facility readiness. However, it assumes an equal contribution of the tracer items to the overall readiness. Boyer and colleagues (2015) applied principal component analysis (PCA) on the tracer items and defined a readiness index based on the first principal component (PC). The index was utilized to assess the association between facility readiness with child survival, low birth weight, maternal and neonatal death in Ghana [15]. PCA has been applied to relate general service readiness and health financing factors in 10 countries in sub-Saharan Africa and Asia [16], health facility readiness to pregnancy delivery services and service utilization in Haiti [17] or to assess facility readiness to maternal health services over time in Nigeria [18]. Of note, Ssempiira et al. (2019) criticized the use of PCA on binary items and derived a readiness index based on multiple correspondence analysis (MCA) [19]. To obtain a meaningful readiness score ensuring that the absence of any tracer item from a facility will contribute to a lower score than its presence, the authors proposed a composite measure based on more than one MCA axis.

Thus far, Burkina Faso has conducted two SARA surveys; in 2012 and in 2014. The data have been used to assess readiness of surgical [20], obstetric [13] and family planning [14] services.

However, no studies have been carried out to date to investigate the relationship between health service readiness and health outcomes in Burkina Faso. Therefore, to fill this gap, we focused our research on malaria-related services and determined the extend at which malaria services readiness is effective and able to prevent malaria deaths in children under the age of 5 years. Our findings will help to optimize resources allocation and improve SARA survey analyses for Burkina Faso and other LMICs.

Methods

Study area

Burkina Faso lies mostly between latitudes 9° and 15° N and longitudes 6° W and 3° E. The annual precipitation ranges from 600 to 1,200 mm. The country is divided into three climatic zones: the Sahel, the Sudan-Sahel and the Sudan-Guinea. Malaria transmission occurs throughout the year and two mosquito species are implicated; namely *Anopheles gambiae* and *An. funestus*. Malaria is the main cause of consultation, hospitalisation and mortality in under 5-year-old children[21].

National health system

The health system of Burkina Faso is pyramidal and consists of three levels [22]. The peripheral level is formed by the health district and includes the "Centre de Santé et de Promotion Sociale (CSPS)", medical centres, isolate dispensaries, delivery centres and district hospitals. The latter serve as referral centres of the former health facilities. The second level is made of the regional hospitals, which are the reference structures for the district hospitals. The third level comprises the national and teaching hospitals and is the highest level of referral care providing specialized services. In 2016, there were approximately 1,760 CSPS, 47 district hospitals, eight regional hospitals and five national and teaching hospitals. The theoretical circuit of a patient is to start with

148 the CSPS, pass by the district, the regional and finally the national or teaching hospital, depending
149 on the severity of a medical issue.
150
151 **Data sources**
152 **The 2014 SARA survey**
153 We analysed health facility data from the Burkina Faso SARA survey carried out in 2014 that
154 included 786 health facilities grouped in three strata: (i) 19 teaching hospitals, private polyclinics
155 and regional hospitals (stratum 1); (ii) 90 district hospitals and medical centres (stratum 2); and (iii)
156 671 CSPS, isolate dispensaries and delivery centres (stratum 3). Strata 1 and 2 correspond to a rather
157 homogeneous group as they are staffed with physicians (in most cases), and hence, we combined
158 them to increase the sample size and created two hierarchical levels of health facilities: medical
159 centers (highest level) consisting of strata 1 and 2 and peripheral health centers (lowest level),
160 including those of stratum 3. Medical centers are mostly staffed by physicians while peripheral
161 health centres are managed by nurses.
162 The items in the SARA questionnaire are specific to the services provided by the health facilities
163 and remain the same across health facility levels for a specific service. As facility levels differ in
164 terms of the services and health programs they offer, the items have different importance or weights
165 depending on the facility level. For example, electric power source is mostly found in medical
166 centers as they are situated mainly in urban areas while solar power is the main source of energy in
167 rural areas. Medicines for chronic diseases or surgery, anesthesia and X-ray equipments are mainly
168 part of the medical centers rather than peripheral health centers.
169 We created readiness indicators (i) for the general services and (ii) for the malaria-specific
170 services. The services were defined as binary variables taking the value “1” if the tracer item was
171 available in the facility and “0” otherwise. Furthermore, we created domain readiness indicators for
172 each domain corresponding to the general (i.e. basic amenities, basic equipment, standard

precautions for infection prevention, diagnostic capacity and essential medicines) and malaria services (i.e. staff and guidelines, diagnostics, medicines and commodities). Domain readiness indicators received the value "1" if all tracer items belonging to the domain where available at the health facility and "0" otherwise.

Health outcome: malaria related mortality among children below the age of 5 years

Mortality data were extracted from the Health Management Information System (HMIS) for a full year (January-December 2014). Malaria mortality in children below the age of 5 years was defined as the number of malaria-related deaths among all in-patient visits to a health facility of that age group. The mortality outcome was linked to the SARA database according to the health facility.

Statistical analysis

Bayesian negative binomial models were fitted on the number of malaria-related deaths at the health facility. We assumed that the number of malaria-related deaths at the health facility follows a negative binomial count distribution and therefore, Bayesian negative binomial models were fitted on the malaria deaths data. The number of children hospitalized in the facility due to malaria (i.e. the denominator of the mortality rate outcome) was considered as an offset term in the model, that is the logarithmic transformation of it was introduced as a covariate with fixed regression coefficient equal to 1. The tracer items were included as covariates in the model. Bayesian variable selection was applied to determine the most important tracers associated with the malaria mortality rate. A separate analysis was carried out for each facility level, i.e. medical centers and peripheral health centers.

MCA was applied to the most important tracers following the approach of Ssempiira et al. (2018) [19]. In short, let K be the set of selected tracers, X^k, $k = 1,....K$ and $X_{0,i}^k$ and $X_{1,i}^k$ be two binary indicators corresponding to the presence and absence of the X^k from the facility i,

198 respectively, that is, $X_{0,i}^{k}$ takes value 1 when the tracer k is absent ($X_i^k = 0$) and 0 otherwise.
199 Likewise, $X_{1,i}^{k}$ takes value 1 when the tracer k is present in health facility i (i.e. $X_i^k = 1$) and 0
200 otherwise.

201 The readiness score for health facility i, based on the a^{th} factorial axis is defined by $F_i^a = \frac{1}{K}$
202 $\sum_{k=1}^{K}\sum_{j_k=0}^{1} W_{j_k}^{a,k} X_{j_k,i}^{k}$, where j_k indicates the value of X^k and the weights $W_{j_k}^{a,k}$ are the columns
203 standards coordinates on the a^{th} factorial axis corresponding to $X_{j_k,i}^{k}$. Following the procedure of
204 Asselin (2009), we define a composite readiness score as $F_i^a = \frac{1}{K}\sum_{k=1}^{K}\sum_{j_k \in \{0,1\}}^{1}\sum_{a=1}^{L}\delta(k-a)\, W_{j_k}^{a,k}$
205 $X_{j_k,i}^{k}$, where L is the number of factorial axes used in the composite score and $\delta(k-a)$ is the Dirac
206 delta function, which takes the value 1 when the weights related to $X_{j_k,i}^{k}$ are selected from the
207 factorial axis and 0 otherwise, that is, $\delta(k-a) = 1$ if $k = a$ and $\delta(k-a) = 0$ if $k \neq a$. The
208 factorial axes that will represent the X^k tracer are identified based on a discrimination measure,
209 which is calculated for each tracer and axis and measures the contribution of the tracer to the total
210 variance explained by the axis. To improve interpretation of the score, we translated the weights so
211 that the absence category $j_k = 0$ of the X^k tracer received a zero weight and the presence one $j_k = 1$
212 received a strictly positive weight indicating the gain in the readiness increase measured by the axis
213 a when a facility i acquires the k^{th}tracer. Therefore, the $W_{j_k}^{a,k}$ in F_i is replaced by $W_{j_k}^{+a,k}$, where
214 $W_0^{+a,k} = 0$ and $W_1^{+a,k} = W_1^{+a,k} - W_1^{+a,k}$ [23]. The composite readiness score was converted into a
215 readiness index with three categories by dividing the ordered distribution of the score values into
216 three parts, each containing a third of the values.

217 Furthermore, we assessed the association between malaria mortality rate and the readiness
218 index described above, using a geostatistical Bayesian negative binomial model. Locational random
219 effects were included in the model to take into account spatial correlation. We assumed a Gaussian
220 process with an exponential correlation function of the distance between health facilities. The

221 analysis was adjusted for the type of health facility location (urban/rural) and of administrative status
222 (public/private). Further details of the statistical methods are provided in Additional file 1.
223 The descriptive analyses were carried out in STATA version 14 (StataCorp.; College Station,
224 TX, USA) and Bayesian models were fitted in OpenBUGS version 3.2.3 (Imperial College and
225 Medical Research Council; London, UK). Maps were produced in ArcGIS version 10.2.1 (Esri Inc.;
226 Redlands, CA, USA).
227
228 **Results**
229 **Health facility characteristics and malaria mortality**
230 The SARA survey carried out in Burkina Faso in 2014 included 766 health facilities. Among these
231 health facilities, 658 (85.9%) reported complete malaria mortality data, and hence, they were used
232 for subsequent analyses. Seventeen percent of the facilities (n=112) belonged to medical centers.
233 Around 80% of medical centers are located in urban areas, while in peripheral health centers, more
234 than 80% of the facilities are in rural zones (Table 1). Most of the facilities are managed by the
235 government (77% of medical centers and 93% of peripheral health centers). The malaria mortality
236 rate in medical centers is 4.8 times higher than that of peripheral health centers (3.46 vs 0.72%,
237 $p<0.0001$).

238 Table 1: Health facility characteristics and malaria mortality rates

Characteristics	Medical centers (n=112) n (%)	Peripheral health centers (n=546) n (%)
Location		
Urban	90 (80.4)	83 (15.2)
Rural	22 (19.6)	463 (84.8)
Administrative management		
Public	86 (76.8)	510 (93.4)
Private	26 (23.2)	36 (6.6)
Regions		
Boucle du Mouhoun	9 (8.0)	65 (11.9)
Cascades	4 (3.6)	25 (4.6)
Centre	27 (24.1)	54 (9.9)
Centre-Est	10 (8.9)	38 (7.0)
Centre-Nord	6 (5.4)	41 (7.5)

Centre-Ouest	11 (9.8)	53 (9.7)
Centre-Sud	4 (3.6)	30 (5.45)
Est	9 (8.0)	40 (7.3)
Hauts Bassins	9 (8.0)	55 (10.1)
Nord	8 (7.1)	53 (9.7)
Plateau Central	4 (3.6)	38 (7.0)
Sahel	4 (3.6)	27 (5.0)
Sud-Ouest	7 (6.35)	27 (5.0)
Malaria		
Number of deaths (a)	1,860	347
Number of consultations (b)	53,768	48,524
Mortality rate = a/b	3.5%	0.7%

Domain readiness and tracer indicators

Table 2 summarizes general service and malaria-specific service indicators and tracer items. Among the general service domain indicators, basic equipment readiness was the most attainable domain (reached by 64.2% and 48.4% of medical centers and peripheral health centers, respectively). On the other hand, essential medicines was the domain with the lowest readiness (only 0.1% of medical centers and 0% of peripheral health centers had the whole set of essential medicines tracer indicators). Malaria services consisted of nine tracer items covering three domains. Apart of the diagnostic domain, which had one tracer, readiness of the staff and guidelines domain was higher in peripheral health centers compare to medical centers (57.7 and 45.5, p=0.027). Medicines and the commodities readiness was also higher in peripheral health centers but the difference to medical centers was borderline significant (31.5% and 18.8%, p=0.051).

Bayesian variable selection identified 29 tracers that are related to malaria deaths out of the 49 items across all domains of the general service offered by medical centers (Table 2). These are privacy room and emergency transportation (under basic amenities), light source (basic equipment), safe disposal of sharp materials, safe disposal/storage of infectious wastes, latex gloves and precaution guidelines (standard precautions for infection prevention), haemoglobin and glucose in urine (diagnostic), medicines for the management of NCDs (diabetes, cardiovascular and respiratory chronic diseases) and availability of two antibiotics (gentamycin and ceftriaxone) commonly used

in medical centers (essential medicines). Five out of nine tracers were selected in the malaria-specific service of medical centers (i.e. staff trained in malaria diagnostic and treatment, trained in intermittent preventive treatment of malaria, the first line of malaria treatment, paracetamol and ITNs).

For peripheral health centers, 29% (10/34) tracers were selected in the general service. These are similar to those in medical centers with the exception of the essential medicines, as most of them were not available in peripheral health centers. Regarding malaria-specific services offered by peripheral health centers, readiness to the first line of antimalarial drugs (96.3%) and to malaria diagnostics (85.5%) was similar as observed in medical centers.

Table 2: Frequency distribution of readiness indicators and tracer items as well as posterior inclusion probabilities of general and malaria-specific tracers estimated from the Bayesian variable selection. Tracers with inclusion probabilities higher than 50% were selected for the MCA.

Indicators/tracer items	Medical centers (n=112)		Peripheral health centers (n=546)	
	Frequency (%)	Posterior inclusion probability[2] (%)	Frequency (%)	Posterior inclusion probability (%)
General service				
Basic amenities[1]	***39 (34.8)***		***6 (1.1)***	
Power (**electric or solar device**)	86 (76.8)	8.5	362 (66.3)	21.4
Improved water source inside or within the ground of the facility	110 (98.2)	-[3]	476 (87.2)	60.9
Room with auditory and visual privacy for patient consultations	81 (72.3)	100	284 (52.0)	39.2
Access to adequate sanitation facilities for clients	109 (97.3)	-	519 (95.1)	-
Communication equipment (phone or SW radio)	111 (99.1)	-	535 (98.0)	-
Facility has access to computer with E-mail/Internet access	56 (50.0)	6.9	10 (1.8)	-
Emergency transportation	106 (94.6)	61.7	515 (94.3)	88.0
Basic equipment	***72 (64.2)***		***264 (48.4)***	
Adult scale	108 (96.4)	-	527 (96.5)	-
Child scale	82 (73.2)	13.2	428 (78.4)	15.1
Thermometer	112 (100)	-	544 (99.6)	-
Stethoscope	112 (100)	-	540 (98.9)	-
Blood pressure apparatus	109 (97.3)	-	533 (97.6)	-
Light source	92 (82.1)	100	349 (63.9)	16.2
Standard precautions for infection prevention	***52 (46.4)***		***223 (40.8)***	
Safe final disposal of sharp materials	85 (75.9)	84.7	422 (77.3)	28.2
Safe final disposal of infectious wastes	82 (73.2)	62.9	336 (61.5)	18.2
Appropriate storage of sharp waste	110 (98.2)	-	535 (98.0)	-
Appropriate storage of infectious waste	103 (92.0)	85.3	494 (90.5)	50.8
Disinfectant	111 (99.1)	-	544 (99.6)	-
Single use (standard disposable or auto-disable syringes)	111 (99.1)	-	543 (99.5)	-
Soap and running water or alcohol based hand rub	105 (93.8)	33.6	518 (94.9)	99.2

Latex gloves	100 (89.9)	56.1	499 (91.4)	99.3
Guidelines for standard precautions	98 (87.5)	98.3	469 (85.9)	21.2
Diagnostic capacity	***37 (33.0)***		***3 (0.6)***	
Haemoglobin	72 (64.3)	100	9 (1.7)	-
Blood glucose	50 (44.6)	48.2	6 (1.1)	-
Malaria diagnostic capacity	101 (90.2)	17.5	467 (85.5)	21.3
Urine dipstick-protein	103 (92.0)	49.0	501 (91.8)	50.1
Urine dipstick-glucose	104 (92.9)	80.6	491 (89.9)	31.4
HIV diagnostic capacity	106 (94.6)	32.9	512 (93.8)	39.8
Urine test for pregnancy	96 (85.7)	26.0	412 (75.5)	42.3
Essential medicines	***2 (0.1)***		***0 (0)***	
Amoxicillin tablet	101 (90.2)	40.6	523 (95.8)	-
Ampicillin for inject	104 (92.9)	21.7	519 (95.1)	-
Gentamicin injectable	101 (90.2)	77.7	472 (86.5)	30.3
Oxytocin injectable	98 (87.5)	100	502 (91.9)	77.8
Amoxicillin dispersible	94 (83.9)	10.6	475 (87.0)	20.1
Oral rehydration solution (ORS)	95 (84.8)	16.8	476 (87.2)	20.3
Zinc	77 (68.8)	100	418 (76.6)	14.9
Aspirin	94 (83.9)	100	377 (69.1)	19.6
Magnesium sulfate	78 (69.6)	100	121 (22.2)	20.9
Amlodipine	25 (22.3)	100	12 (2.2)	-
Enalapril	20 (17.9)	26.1	6 (1.1)	-
Insulin injectable	8 (7.1)	35.9	5 (0.9)	-
Betablockers	20 (17.9)	100	8 (1.5)	-
Beclomethasone inhaler	14 (12.5)	100	9 (1.7)	-
Ceftriaxone injection	103 (92.0)	93.8	492 (90.1)	58.4
Thiazidic	25 (22.3)	14.2	41 (7.5)	50.6
Glibenclamide tablet	39 (34.8)	100	10 (1.8)	-
Metformin	41 (36.6)	22.9	9 (1.7)	-
Omeprazole	65 (58.0)	10.1	110 (20.2)	20.2
Salbutamol inhaler	86 (76.8)	63.3	288 (52.8)	24.9
Carbamazepine	28 (25.0)	69.9	0 (0.0)	-
Haloperidol	27 (24.1)	96.6	0 (0.0)	-
Simvastatin	4 (3.6)	-		
Fluoxetin	3 (2.7)	-		-
Malaria-specific service				
Staff and guidelines	***41 (45.5)***		***313 (57.7)***	
Guidelines for diagnosis and treatment of malaria	105 (93.8)	22.4	536 (98.2)	-
Guidelines for Intermittent Preventive Treatment	75 (67.0)	13.0	481 (88.1)	31.1
Staff trained in malaria diagnosis and treatment	79 (70.5)	97.5	453 (83.0)	40.9
Staff trained in Intermittent Preventive Treatment	74 (66.1)	100	370 (67.8)	58.9
Diagnostics	***101 (90.2)***		***467 (85.5)***	
Malaria diagnostic capacity	101 (90.2)	17.5	467 (85.5)	21.3
Medicines and commodities	***21 (18.8)***		***172 (31.5)***	
First-line antimalarial in stock	99 (88.4)	58.8	526 (96.3)	-
Paracetamol cap/tab	104 (92.9)	100	418 (76.2)	34.6
Intermittent preventive treatment of malaria in pregnancy (IPTg) drug	62 (55.4)	28.4	356 (65.2)	17.1
ITNs	29 (25.9)	73.2	185 (33.9)	26.2

[1]Domain indicators were defined as availability of all tracer items belonging to the domain.
[2]Posterior inclusion probability: gives the probability of the tracer to be included in the final model and it is calculated by the proportion of all possible models in the variable selection procedure that include the specific tracer. For example, the posterior inclusion probability of 21.4 estimated for the power tracer indicates that this tracer was included in 21.4% of all possible models generated from all general services-related tracers.
[3]Item not included in the variable selection procedure due to low relative frequency i.e. <5%

Health facility readiness index

279 MCA was applied on the tracers selected from the variable selection procedure to obtain a readiness
280 score. Fourteen and six factorial axes were sufficient to build the composite indices for medical
281 centers and peripheral health centers, respectively. Standard coordinates of the selected tracers are
282 provided in Table 3 (medical centers) and Table 4 (peripheral health centers).

283 For medical centers, the factorial axis 1 accounted for 10 indicators, followed by axis 2 with
284 five indicators. The most weighted rescaled indicators were the emergency transportation and
285 appropriate storage of infectious waste picked from factorial axes eight and six, respectively. On
286 the first factorial axis, a subset of four tracers met the Global First Axis Ordering Consistency
287 (FAOC-G) requirement in the positive direction, while a second subset of 25 indicators met this
288 condition in the negative direction (i.e. the score monotonically increases/decreases for all
289 indicators) [23]. Hence, there are two subsets of indicators that are inconsistent and one subset
290 should have been discarded, leading to a loss of information if we had constructed the score using
291 the first factorial axis. With regard to peripheral health centers, four indicators showed a high
292 discrimination measure on factorial axis 1. The highest weighted tracers are "thiazidic" and "running
293 water source or soap" from axes 4 and 5, respectively. The discrimination measures of the tracers
294 and the rescaled weights are given in Tables 2.1 and 2.2 (in Additional file 2) for medical centers
295 and peripheral health centers, respectively.

296 Figure 1 shows the proportion of variation in the tracers explained by the first factorial axis and
297 the composite readiness score based on (i) the whole set of tracers and (ii) the subset of tracers
298 identified by the Bayesian variable selection. The results show that the composite score explains
299 more than twice the variance explained by the first factorial axis (medical centers: 30% vs 15%;
300 peripheral health centers 53% vs 18%). Furthermore, the composite score based on the subset of
301 tracers explained more variation than the composite score based on the whole set (medical centers:
302 30% vs 26%; peripheral health centers: 53% vs 30%)
303

304 Table 3: Standard coordinates of tracers on the first 14 factorial axes (medical centers).

Tracers	Category	Frequency	Factorial axes*													
			1	2	3	4	5	6	7	8	9	10	11	12	13	14
Privacy room	No	31 (27.7)	**-0.281**[a]	**-1.196**	0.358	**-2.537**	1.257	**-1.370**	**-0.195**	0.746	0.171	***-5.265***	**-3.066**	1.560	0.252	1.213
	Yes	81 (72.3)	**0.107**	**0.458**	-0.137	**0.971**	-0.481	**0.524**	**0.075**	-0.285	-0.065	***2.015***	**1.173**	-0.597	-0.097	-0.464
Emergency transportation	No	6 (5.4)	0.063	**-3.332**	**-2.716**	4.195	0.012	**-7.946**	**4.844**	***-11.193***	**-0.109**	**-1.787**	1.657	3.354	**-2.609**	2.616
	Yes	106 (94.6)	-0.004	**0.189**	**0.154**	-0.237	-0.001	**0.450**	**-0.274**	***0.634***	**0.006**	**0.101**	-0.094	-0.190	**0.148**	-0.148
Light power	No	20 (17.9)	**-0.925**	***-3.350***[b]	0.885	0.805	0.298	2.439	**-4.057**	**-1.751**	**-0.649**	**-3.378**	2.240	**-4.542**	**-0.070**	**-0.001**
	Yes	92 (82.1)	**0.201**	***0.728***	-0.192	-0.175	-0.065	-0.530	**0.882**	**0.381**	**0.141**	**0.734**	-0.487	**0.987**	**0.015**	**0.000**
Safe final disposal of sharps	No	27 (24.1)	1.254	**-0.656**	***-4.856***	**-2.973**	**-0.352**	0.664	**-0.421**	**-0.995**	1.152	**-0.588**	2.051	**-0.445**	**-0.888**	**-0.100**
	Yes	85 (75.9)	-0.398	**0.208**	***1.542***	**0.944**	**0.112**	-0.211	**0.134**	**0.316**	-0.366	**0.187**	-0.652	**0.142**	**0.282**	**0.032**
Safe final disposal of infectious wastes	No	30 (26.8)	0.859	**-0.684**	***-4.958***	**-2.727**	0.017	0.163	**-1.408**	**-0.591**	1.160	0.798	**-0.069**	0.185	**-0.102**	**-0.391**
	Yes	82 (73.2)	-0.314	**0.250**	***1.814***	**0.998**	-0.006	-0.060	**0.515**	**0.216**	-0.424	-0.292	**0.025**	-0.068	**0.037**	**0.143**
Appropriate storage of infectious waste	No	9 (8.0)	1.198	**-2.643**	0.035	1.036	**-1.691**	***-9.057***	**-1.236**	**-0.570**	**-1.376**	2.107	5.636	**-5.990**	3.825	3.190
	Yes	103 (92.0)	-0.105	**0.231**	-0.003	-0.091	**0.148**	***0.791***	**0.108**	**0.050**	**0.120**	-0.184	-0.492	**0.523**	-0.334	-0.279
Latex gloves	No	12 (10.1)	**-0.252**	**-3.347**	0.867	0.983	**-4.095**	**-0.858**	***-6.782***	3.797	**-3.464**	0.525	2.358	0.705	**-3.537**	**-1.541**
	Yes	100 (89.9)	**0.030**	**0.402**	-0.104	-0.118	**0.491**	**0.103**	***0.814***	-0.456	**0.416**	-0.063	-0.283	-0.085	**0.424**	**0.185**
Guidelines for standard precautions	No	14 (22.5)	***-3.610***	0.980	**-1.949**	**-1.532**	**-1.850**	**-1.734**	4.077	1.023	**-2.052**	**-3.909**	**-0.936**	**-3.326**	**-1.546**	1.195
	Yes	98 (87.5)	***0.516***	-0.140	**0.278**	**0.219**	**0.264**	**0.248**	-0.582	-0.146	**0.293**	**0.558**	**0.134**	**0.475**	**0.221**	-0.171
Haemoglobin test	No	40 (35.7)	**-1.086**	**-1.396**	**-0.563**	0.630	**-2.200**	0.331	0.568	**-0.251**	**-2.686**	1.100	**-0.855**	1.830	***-3.237***	0.473
	Yes	72 (64.3)	**0.603**	**0.775**	**0.313**	-0.350	**1.222**	-0.184	-0.316	**0.139**	**1.492**	-0.611	**0.475**	-1.017	***1.798***	-0.263
Glucose dipstick	No	8 (7.1)	**-2.850**	0.482	**-4.354**	0.289	***-6.397***	2.569	3.601	4.457	**-1.015**	**-5.601**	0.354	**-5.051**	**-0.402**	**-0.182**
	Yes	104 (92.9)	**0.219**	-0.037	**0.335**	-0.022	***0.492***	-0.198	-0.277	-0.343	**0.078**	**0.431**	-0.027	**0.389**	**0.031**	**0.014**
Amlopdipin	No	87 (77.7)	**-0.329**	**-0.723**	0.354	**-0.378**	**-0.280**	**-0.416**	**-0.848**	0.125	1.106	0.339	**-0.459**	0.036	0.424	0.184
	Yes	25 (22.3)	**1.144**	**2.515**	-1.231	**1.315**	**0.974**	**1.448**	**2.953**	-0.436	-3.848	-1.180	**1.597**	-0.125	-1.477	-0.640
Aspirin	No	18 (16.1)	***-3.484***	3.093	**-0.109**	**-0.623**	1.267	**-1.229**	0.818	2.121	**-2.599**	1.476	0.217	**-2.705**	1.985	1.667
	Yes	94 (83.9)	***0.667***	-0.592	**0.021**	**0.119**	-0.243	**0.235**	-0.157	-0.406	**0.498**	-0.283	-0.042	**0.518**	-0.380	-0.319
Beclomethasone inhaler	No	98 (87.5)	**-0.205**	**-0.683**	0.214	**-0.707**	**-0.065**	**-0.013**	0.293	**-0.313**	**-0.362**	0.313	0.484	0.025	0.342	**-0.079**
	Yes	14 (12.5)	**1.435**	**4.781**	-1.495	**4.948**	**0.452**	**0.094**	-2.052	**2.190**	**2.536**	-2.189	-3.386	-0.177	-2.394	**0.555**
Beta-blockers	No	92 (82.1)	**-0.433**	**-0.793**	0.614	**-0.473**	**-0.185**	0.294	0.561	**-0.134**	0.132	**-0.074**	0.098	0.032	0.439	0.587
	Yes	20 (17.9)	**1.990**	**3.648**	-2.824	**2.176**	**0.849**	-1.355	-2.581	**0.616**	-0.609	**0.339**	-0.450	-0.145	-2.021	-2.701
Ceftriaxone	No	9 (8.0)	***-6.392***	1.090	0.991	**-0.869**	3.199	**-1.868**	**-2.313**	**-2.918**	2.354	**-0.844**	3.647	1.036	**-6.562**	**-1.918**
	Yes	103 (92.0)	***0.558***	-0.095	-0.087	**0.076**	-0.280	**0.163**	**0.202**	**0.255**	-0.206	**0.074**	-0.319	-0.090	**0.573**	**0.168**
Gentamicin	No	11 (9.8)	***-4.331***	**-1.279**	**-2.234**	4.478	2.838	2.256	**-0.629**	**-0.754**	1.864	1.838	**-1.003**	**-2.284**	**-0.105**	6.498
	Yes	101 (90.2)	***0.472***	**0.139**	**0.243**	-0.488	-0.309	-0.246	**0.069**	**0.082**	-0.203	-0.200	**0.109**	**0.249**	**0.011**	-0.708
Glibenclamide	No	73 (65.2)	**-0.724**	**-0.211**	**-0.581**	0.607	0.655	0.053	**-0.176**	**-0.305**	**-1.378**	**-0.786**	0.346	0.540	1.845	***-1.922***
	Yes	39 (34.8)	**1.356**	**0.395**	**1.088**	-1.137	-1.225	-0.099	**0.329**	**0.571**	**2.580**	**1.471**	-0.648	-1.011	-3.453	***3.598***
Insulin injectable	No	104 (92.9)	**-0.123**	***-0.424***	0.222	**-0.186**	**-0.106**	**-0.147**	**0.493**	0.038	0.378	0.233	**-0.339**	**-0.364**	**-0.207**	**-0.641**

	Yes	8 (7.1)	**1.596**	***5.512***	-2.880	**2.420**	**1.375**	**1.909**	**-6.404**	-0.489	-4.911	-3.035	**4.404**	**4.737**	**2.688**	**8.330**
Magnesium	No	34 (30.4)	***-2.083***	**-2.028**	**-0.340**	1.431	0.424	0.597	**-1.968**	0.063	0.339	**-0.313**	**-2.323**	0.905	0.300	**-0.988**
	Yes	78 (69.6)	***0.908***	**0.884**	**0.148**	-0.624	-0.185	-0.260	**0.858**	-0.028	-0.148	**0.136**	**1.013**	-0.395	-0.131	**0.431**
Oxytocin	No	14 (12.5)	***-3.089***	**-0.951**	**-3.370**	5.102	**-0.779**	2.837	**1.260**	**-2.386**	2.970	1.110	**-1.926**	**-2.982**	0.951	**-0.272**
	Yes	98 (87.5)	***0.441***	**0.136**	**0.481**	-0.729	**0.111**	-0.405	**-0.180**	**0.341**	-0.424	-0.159	**0.275**	**0.426**	-0.136	**0.039**
Salbutamol	No	26 (23.2)	***-3.000***	**-0.517**	**-1.091**	**-1.330**	**-0.915**	**-0.662**	**-0.223**	1.480	**-2.038**	1.850	**-0.362**	1.727	0.879	1.003
	Yes	86 (76.8)	***0.907***	**0.156**	**0.330**	**0.402**	**0.277**	**0.200**	**0.067**	-0.448	**0.616**	-0.559	**0.109**	-0.522	-0.266	-0.303
zinc	No	35 (31.3)	***-2.157***	0.502	**-0.495**	**-0.975**	0.011	2.273	**0.503**	**-0.816**	1.147	0.610	1.572	2.790	1.487	0.844
	Yes	77 (68.8)	***0.980***	-0.228	**0.225**	**0.443**	-0.005	-1.033	**-0.229**	**0.371**	-0.522	-0.277	-0.715	-1.268	-0.676	-0.383
ITN	No	83 (74.1)	**-0.220**	0.045	**-0.747**	**-0.247**	0.762	**-1.081**	**-0.434**	**-0.005**	**-0.520**	0.795	***-1.332***	**-0.377**	0.161	**-0.081**
	Yes	29 (25.9)	**0.628**	-0.128	**2.139**	**0.708**	-2.180	**3.093**	**1.242**	**0.015**	**1.487**	-2.276	***3.811***	**1.079**	-0.461	**0.231**
Staff trained in malaria diagnosis and treatment	No	33 (29.5)	***-1.091***	1.604	**-0.341**	**-0.226**	***-3.506***	**-0.728**	**-1.149**	1.928	2.217	**-0.102**	0.246	0.246	1.343	**-0.185**
	Yes	79 (70 5)	***0.456***	-0.670	**0.143**	**0.094**	***1.465***	**0.304**	**0.480**	-0.806	-0.926	**0.043**	-0.103	-0.103	-0.561	**0.077**
Staff trained in IPTg	No	38 (33.9)	**-0.158**	**-0.459**	**-0.829**	2.575	**-1.426**	***-2.856***	**0.619**	0.713	1.757	**-1.492**	1.060	2.415	0.922	0.162
	Yes	74 (66.1)	**0.081**	**0.236**	**0.426**	-1.322	**0.732**	***1.467***	**-0.318**	-0.366	-0.902	**0.766**	-0.544	-1.240	-0.474	-0.083
First line treatment of malaria	No	13 (11.6)	***-4.606***	2.906	0.766	**-1.353**	0.142	**-1.435**	**0.786**	0.550	2.369	1.904	2.504	0.379	**-0.856**	**-4.781**
	Yes	99 (88.4)	***0.605***	-0.382	-0.101	**0.178**	-0.019	**0.188**	**-0.103**	-0.072	-0.311	-0.250	-0.329	-0.050	**0.112**	**0.628**
IPTg drug	No	50 (44.6)	***-5.589***	3.721	1.822	**-2.447**	5.322	**-2.872**	**-2.985**	0.352	1.426	**-2.683**	3.527	**-0.455**	**-4.909**	2.079
	Yes	62 (55.4)	***0.430***	-0.286	-0.140	**0.188**	-0.409	**0.221**	**0.230**	-0.027	-0.110	**0.206**	-0.271	**0.035**	**0.378**	-0.160
Carbamazepine	No	84 (75.0)	**-0.144**	0.764	0.367	**-0.450**	***-1.050***	0.110	**-0.594**	**-1.146**	**-0.364**	0.136	**-0.686**	0.030	0.566	0.637
	Yes	28 (25.0)	**0.432**	-2.292	-1.101	**1.349**	***3.149***	-0.331	**1.782**	**3.438**	**1.093**	-0.408	**2.057**	-0.091	-1.698	-1.911
Haloperidol	No	85 (75.9)	**-0.183**	0.825	0.330	**-0.199**	**-0.894**	**-0.172**	**-0.410**	**-1.475**	**-0.025**	**-0.361**	**-0.402**	**-0.354**	**-0.078**	**-0.660**
	Yes	27 (24.1)	**0.577**	-2.599	-1.039	**0.627**	**2.815**	**0.541**	**1.292**	**4.644**	**0.079**	**1.136**	**1.266**	**1.116**	**0.244**	**2.078**
Inertia explained by the factorial axis (%)			**14.5**	**8.9**	**6.7**	**6.1**	**5.9**	**5.3**	**4.7**	**4.4**	**4.0**	**3.7**	**3.6**	**3.4**	**3.0**	**2.9**

[*]First 14 factorial axes to build the composite readiness score as there is no information gain beyond axis 14

[a]Four tracers consistent with the FAOC-G in negative direction (not bold) and 25 consistent in positive direction (bold)

[b]Highlighted in bold and italic are the weights of tracers from factorial axes selected to build the composite readiness score

Table 4: Standard coordinates of tracers on the first six factorial axes (peripheral health centers).

Tracers	Category	Frequency	Factorial axes*					
			1	2	3	4	5	6
Improved water source	no		0.457[a]	0.048	**-5.424**	0.301	***-5.699***	0.095
	yes	476 (87.2)	-0.067	-0.007	**0.798**	-0.044	***0.838***	-0.014
Emergency transportation	no		***-5.770***[b]	**-0.594**	**-1.284**	**-0.830**	**-1.483**	3.543
	yes	515 (94.3)	***0.347***	**0.036**	**0.077**	**0.050**	**0.089**	-0.213
Soap or running water	no		**-1.239**	**-0.895**	8.502	**-5.784**	***-7.725***	**-0.620**
	yes	518 (94.9)	**0.067**	**0.048**	-0.460	**0.313**	***0.418***	**0.034**
Storage infectious waste	no		0.602	***-6.612***	**-0.633**	1.732	**-0.529**	0.274
	yes	494 (90.5)	-0.063	***0.696***	**0.067**	-0.182	**0.056**	-0.029
Latex gloves	no		0.418	***-7.016***	1.337	1.780	**-0.218**	0.025
	yes	499 (91.4)	-0.039	***0.661***	-0.126	-0.168	**0.021**	-0.002
Urine dipstick	no		***-4.999***	0.574	**-0.718**	1.596	**-1.019**	2.063
	yes	501 (91.8)	***0.449***	-0.052	**0.065**	-0.143	**0.092**	-0.185
Ceftriaxone	no		***-3.772***	**-1.310**	**-1.489**	**-1.567**	3.602	1.638
	yes	492 (90.1)	***0.414***	**0.144**	**0.163**	**0.172**	-0.395	-0.180
Oxytocin	no		***-5.750***	**-0.119**	1.406	0.905	**-0.920**	0.604
	yes	502 (91.9)	***0.504***	**0.010**	-0.123	-0.079	**0.081**	-0.053
Thiazidic	no		0.048	**-0.190**	**-0.263**	***-0.751***	0.136	0.041
	yes	41 (7.5)	-0.586	**2.338**	**3.235**	***9.250***	-1.672	-0.510
IPTg training	no		**-1.518**	**-0.266**	**-0.552**	**-0.122**	0.163	***-4.223***
	yes	370 (67.8)	**0.722**	**0.127**	**0.263**	**0.058**	-0.077	***2.009***
Inertia explained by the factorial axis (%)			**20.0**	**14.2**	**10.5**	**10.3**	**9.9**	**8.8**

*First 6 factorial axes to build the composite readiness score as there is no information gain beyond axis 6

[a]Four tracers consistent with the FAOC-G in negative direction (not bold) and 6 consistent in positive direction (bold)

[b]Highlighted in bold and italic are the weights of tracers from factorial axes selected to build the composite readiness score

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Figure 1: Proportion of variance explained by the first factorial axis (red) and the composite readiness score (blue) based on the whole set and the subset of tracers identified by the Bayesian variable selection.

Association between health facility readiness and malaria mortality

The composite readiness score was converted into a categorical index with three categories defined by the tertiles of its distribution. Results of the Bayesian geostatistical negative binomial model fitted on malaria mortality indicated that medical centers with the highest and moderate readiness experienced a lower mortality rate by 19% and 6%, respectively, compared to the facilities with the lowest readiness (Table 5). However, this difference lacked statistical

significance. The type of management and the location of health facilities do not influence malaria mortality.

Peripheral health centers at the highest readiness category had a mortality rate ratio (MRR) of 0.41 (95% Bayesian credible interval (BCI): 0.19-0.91) compared to those with the lowest readiness. Furthermore, urban health facilities were associated with a statistically important reduction of malaria mortality compared to those in rural areas (MRR: 0.49, 95% BCI: 0.31-0.78). The median spatial range distance (distance over which the spatial correlation is no more important) was higher in medical centers compared to peripheral health centers.

Table 5: Posterior estimates (median and 95% BCI) of the association between health facility readiness and malaria mortality obtained from a Bayesian geostatistical negative binomial model.

	Medical centers	**Peripheral health centers**
Readiness index	MRR[a] (95% BCI)	MRR (95% BCI)
Low	1.00	1.00
Middle	0.94 (0.76-1.25)	0.74 (0.54-1.00)
High	0.81 (0.74-2.51)	0.41 (0.19-0.91)*
Location		
Rural	1.00	1.00
Urban	0.97 (0.48-1.77)	0.49 (0.31-0.78)*
Administrative status		
Private	1.00	1.00
Public	1.12 (0.51-2.17)	0.69 (0.46-1.01)
Spatial parameters		
Spatial variance	0.26 (0.14-0.53)	0.46 (0.29-0.67)
Spatial range (km)	43.27 (13.63-89.92)	26.32 (6.39-83.1)

[a]MRR: mortality rate ratio
*: Statistically important association

The geographical distribution of malaria mortality rate showed a similar pattern with that of the proportion of health facilities with lowest readiness (Figure 2), indicating that regions with high malaria mortality rate have high proportion of facilities with low readiness and vice versa. In particular, the region of Centre (first region in terms of health infrastructure and population) showed for both health facility levels low malaria mortality rates, while Sud Ouest, Sahel and Boucle du Mouhoun were those among the highest mortality and highest proportion of low performing facilities.

Figure 2: Spatial distribution of malaria-related mortality rate among children under the age of 5 years in Burkina Faso for medical centers (A) and peripheral health centers (B) and the proportion of health facilities medical centers (C) and peripheral health centers (D) in the lowest category of the corresponding composite readiness index.

Discussion

Malaria services readiness and malaria-related mortality.

The aim of our study was to estimate the extent in which malaria services readiness in Burkina Faso was associated with malaria mortality. Service delivery is an essential building block of the WHO health systems framework [8]. Our results showed that the readiness of malaria health services is indeed associated with malaria mortality in peripheral health centers; the higher the readiness, the lower the malaria-specific mortality rate. Our results corroborate with previous investigations done in Ghana, Mozambique, Tanzania, Nigeria, Bangladesh and Haiti that also used SARA or similar survey data and revealed a positive effect of readiness on health outcome [15–18,24,25].

The lack of a statistically important association between facility readiness and malaria mortality in medical centers might be explained by the severity of malaria cases seeking treatment in medical centers. Indeed, peripheral health centers refer complicated cases to medical centers. Hence, although the latter are better equipped and staffed, the mortality rate is partially influenced by the seriousness of their cases. On the other hand, the reduced mortality rate in peripheral health centers with highest readiness is certainly related to prompt diagnosis and adequate treatment, since peripheral health centers receive patients at an early stage of the disease. This is consistent with the important association of the emergency transportation tracer

with malaria mortality. In medical centers, emergency transportation obtained the highest weight. Reducing the delay of reference from peripheral health centers to medical centers will reduce the probability of deaths due to a severe malaria [26–29]. In addition, training health workers of peripheral health centers would allow for early reference decisions. At community level, populations must be encouraged to consult very early. In peripheral health centers, we noticed that medicines for NCDs management had low availability, although one drug devoted to chronic diseases had the highest weight. The low availability could be explained by an insufficiency in the supply of this type of drug and thus a low quality of the management of chronic diseases. On the contrary, its presence may mean competent health workers in the provision of drugs and thus a better quality of care and therefore to the management of malaria cases as well.

Tracer indicators and domains readiness

Results of the individual tracers and domain readiness indicators are consistent with the role assigned to each level. peripheral health centers are the first contact with any health issues and thus they provide the so call “minimum package” of equipment, structure and human resources, while medical centers provide the “complementary package”. Basic equipment was the most available domain for both levels of health care and for general services. The most widely available items within this domain are thermometer, stethoscope, adult scale and blood pressure apparatus, which represent minimum essential equipment to manage patients. However, their availability is almost 50% in peripheral health centers meaning that the quality of health care is not guaranteed in about half of the peripheral health centers, which are the first contact of patients according to health system organisation of the country. This can be explained by lack of financial resources and lack of management of supplies in peripheral health centers.

The weakest domain for both levels for general services was the essential medicine with an availability of less than 1%. Two types of medicines appeared in this domain; medicines for

401 infectious diseases (availability >80%) and medicines for chronic diseases (availability <10%).
402 The situation depicts the epidemiological profile of Burkina Faso, where infectious diseases are
403 still predominant, but also indicates that services towards chronic diseases and NCDs are
404 inadequate, particularly in view of NCDs rapidly gaining importance in LMICs [21,30–32].
405 This also indicates the weakness in the drug supply circuit of health facilities from the
406 expression of adequate needs, to the availability of drugs at the point of purchase [33,34].
407 The diagnostic capacity domain is very weak in peripheral health centers (0.6%) compared
408 to medical centers (33%) even if in peripheral health centers, large number of biological
409 diagnostic tests do not need sophisticated equipment. Peripheral health centersgenerally refer
410 patients who need further biological testing. Nevertheless, the level of availability of malarial
411 diagnosis capacities is >80% appreciable in both levels and reflects the high workload relative
412 to malaria in consultations. In 2014, 58% and 33% of consultations in peripheral health centers
413 and medical centers, respectively, were due to malaria [22].
414 The basic amenities domain is related to the health infrastructure investment and depends
415 heavily on the financial support of the government. At the time of our study, only 1.9% of
416 peripheral health centers had a computer. This low proportion drastically reduces the readiness
417 of the domain indicator. The use of computers is the exception rather than the norm in peripheral
418 health centres. In fact, health workers lack specific training and essential resources such as
419 access to the power grid and the Internet are either absent or inadequate.
420 Regarding malaria-specific services, the average availability of "staff and guidelines" and
421 the "medicine and commodity" domains is higher for health facilities in peripheral health
422 centers than medical centers. More than 80% of them have their staff trained and know the
423 guidelines for malaria management. In addition, more than 95% in these facilities also possess
424 first-line treatment for malaria. Malaria is the most important cause of morbidity and mortality
425 in under 5-year-old children, which explains that substantial efforts are being made to train

peripheral health facility workers, render medicines and other medical supplies available for malaria case management at all levels of the health system. In recent years, there has been a shift from first-line medicines to ACTs, introduction of RDTs, and ITN campaigns [35,36]. However, the availability of ITNs in health facilities had reduced the availability of malaria readiness in general because it is mostly during mass campaign that ITNs are distributed to pregnant women.

Variables selection

The variable selection highlighted facts that are consistent with the health system in Burkina Faso. In both health facility levels and for general services, the inclusion of "emergency transportation", which reduces the delay to reach a health centre. In general, emergency transportation (ambulances) are made available in medical centers. Peripheral health centers use mainly motorcycles for transportation. The malaria management policy in Burkina Faso requests that cases are confirmed before treatment; yet, there is still considerable empiric treatment [21]. Without a diagnostic test, malaria might be confused with other infectious diseases, which has ramifications on disease management, including treatment [37,38]. This may explain the heavy prescription not only of antimalarial but also antibiotics, such as "gentamicin", "ceftriaxone".

Geographical distribution of readiness and mortality rate

The geographical distribution of the under-5 malaria-related mortality corresponds almost to the HMIS statistics suggesting that the regions of the Boucle du Mouhoun, Sahel and Sud-Ouest have the highest mortality rates and that malaria is the leading cause of deaths in this age group. Regions with low mortality rates are concentrated in central and eastern part of the country for both levels. Apart from the fact that there is a greater concentration of health workers around the central region, there is no evidence to explain this distribution of mortality [21]. Similarly to the mortality rate, the geographical distribution of the readiness index is

heterogeneous for both levels. Nevertheless, the regions of Centre and Hauts Bassins are the best equipped and have the highest numbers of health facilities. They gather more than half of health human resources in Burkina Faso and possess most performant medical centers.

Strengths and limitation

Our findings clearly favoured the construction of a composite readiness indicator rather than one derived from the first factorial axis. Indeed, the proportion of variance explained has more than doubled in both health facility levels compared to the first component. The composite index takes also into account the multifactorial and multidimensionality of the readiness allowing to capture tracers that are represented better by high order axes. The variable selection identifies the subset of the most important tracers that are related to malaria mortality producing a score which explains even more variation in the tracers and it is directly related to a specific health outcome and thus, can led comprehensive policy decisions to strengthen the specific health services and care.

However, SARA survey assess availability of item the day of the survey and thus do not take into account the variability over time of the items and one day may not be sufficient to get the mean availability of an item in a health facility over the time.

Conclusion

Our results indicate that investing in health services is an effective means for reducing the burden of malaria in Burkina Faso. The broad implication is that resources and efforts must be maintained and strengthened, particularly at medical centers. The emergency transportation mechanisms between the different levels of the health system need to be further enhanced. The composite readiness score created by exploiting more than one MCA factorial axis produces a more informative and consistent health facility readiness measure that captures all aspects of readiness unlike the index based on only the first axis.

Abbreviations

ACT, Artemisinin-based combination therapy; BCI, Bayesian credible interval; CSPS, Centre de Santé et de Promotion Sociale; FAOC-G, Global First Axis Ordering Consistency; HMIS, Health Management and Information System; IPT, intermittent preventive treatment of malaria; IRS, indoor residual spraying; ITN, insecticide-treated net; LMICs, low- and middle-income countries; MCA, multiple correspondence analysis; MRR, mortality rate ratio; NCD, non-communicable disease; ORS, oral rehydration solution; PC, principal component; PCA, principal component analysis; RDT, rapid diagnostic test; SARA, Service Availability and Readiness Assessment; WHO, World Health Organization.

Declarations

Acknowledgements

We are grateful to the Ministry of Health of Burkina Faso and its Department of Statistics for providing the SARA survey database and allowing us access to the Health Management Information System database. This study obtained financial support by the Swiss National Science Foundation (SNSF) Swiss Programme for Research on Global Issues for Development (R4D).

Authors' contributions

OM participated in the data acquisition, analysis, interpretation and drafted the manuscript; **JEOD** contributed to the data acquisition and interpretation of data; **AS** contributed to the interpretation of the data; **JU** contributed to interpretation of data and revisions of the manuscript; **PV** formulated research goals and objectives, contributed to financial acquisition,

statistical methodology, interpretation of results and revisions of the manuscript. All authors reviewed, commented and approved the final version of the manuscript prior to submission.

Funding

This research has been supported by the Swiss National Science Foundation (SNSF) Swiss Programme for Research on Global Issues for Development (R4D) project no. IZ01Z0-147286. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Availability of materials and data

The SARA database and the HMIS database are accessible via request to the Department of Statistics of the Ministry of Health of Burkina Faso (zongoaugustin@yahoo.fr).

Ethics approval and consent to participate

We used secondary data of the Service Availability and Readiness Assessment (SARA) survey and the Health Management and Information System (HMIS) that were made available by the "Direction Générale des Études et des Statistiques Sectorielles", Burkina Faso. The research was approved by the National Ethics Committee for Health Research of Burkina Faso under the deliberation N°2014-7-072. All data were anonymized.

Consent for publication

Not applicable

Competing interests

The authors have no competing interest to declare.

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Figures

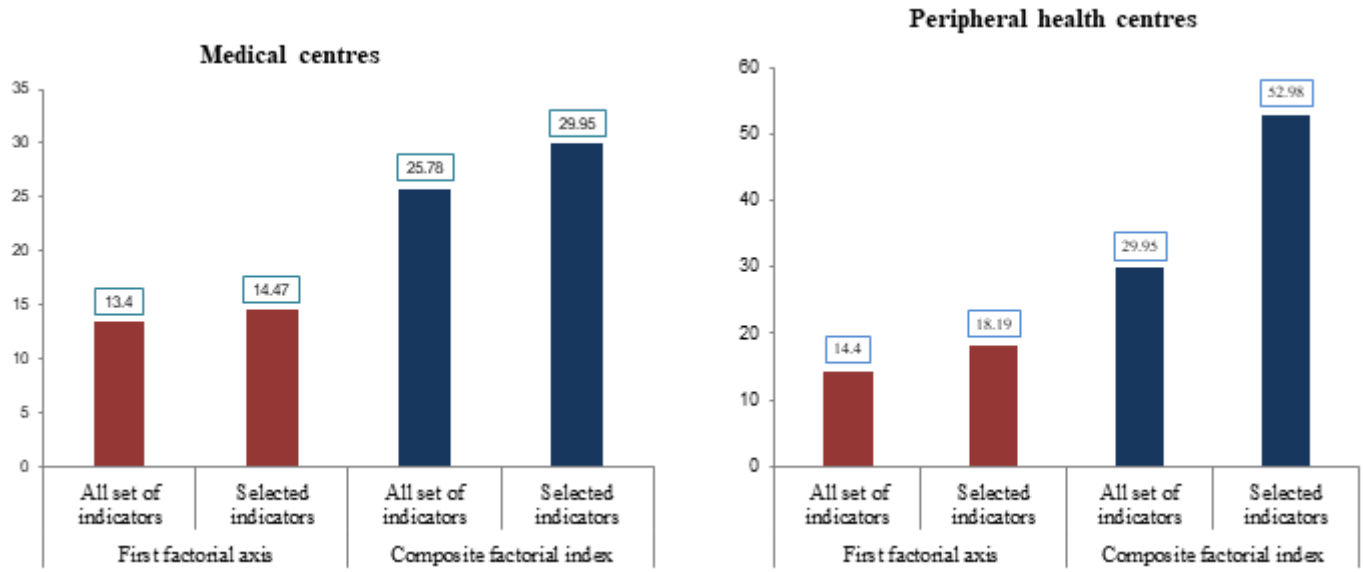

Figure 1

Proportion of variance explained by the first factorial axis (red) and the composite readiness score (blue) based on the whole set and the subset of tracers identified by the Bayesian variable selection.

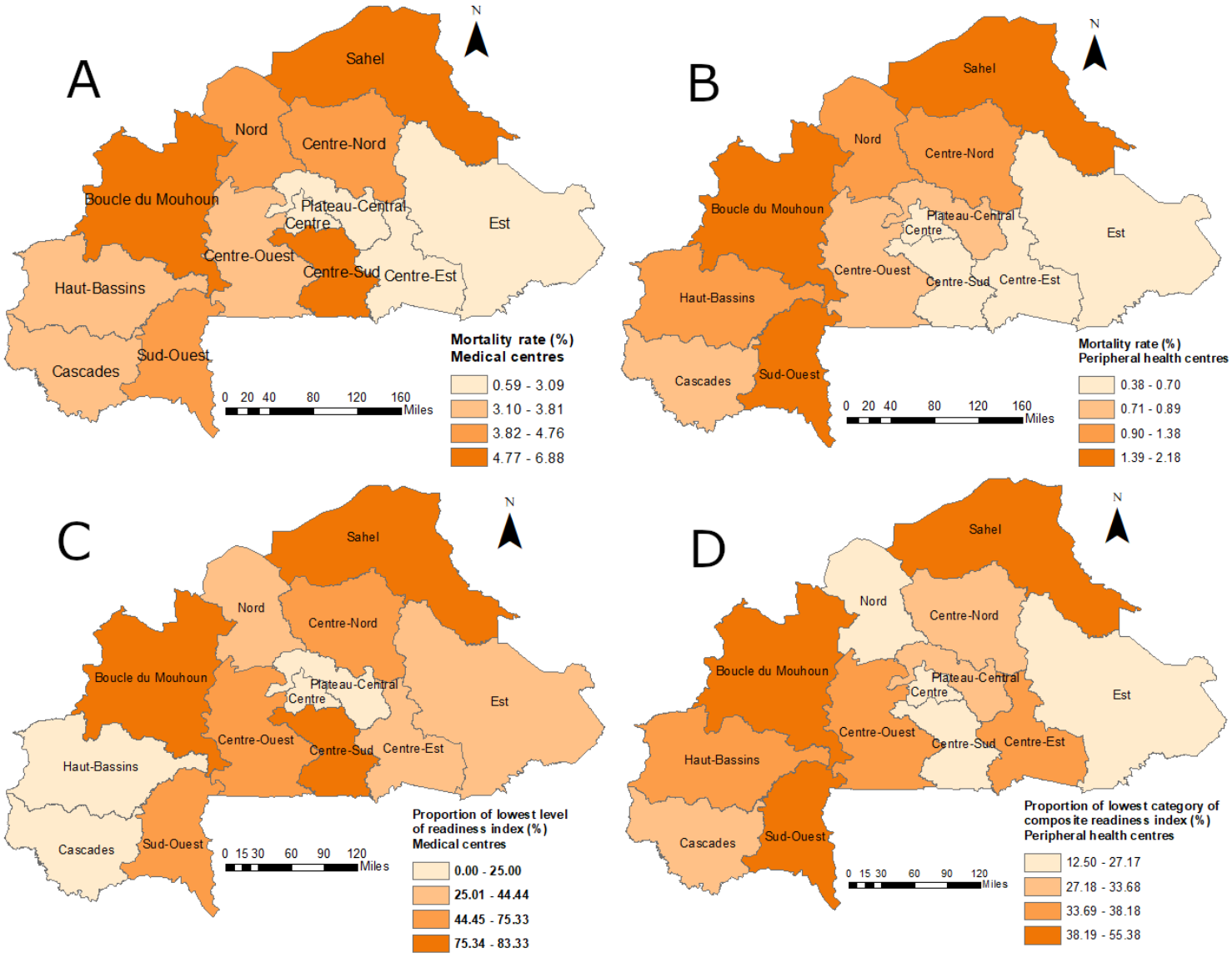

Figure 2

Spatial distribution of malaria-related mortality rate among children under the age of 5 years in Burkina Faso for medical centers (A) and peripheral health centers (B) and the proportion of health facilities medical centers (C) and peripheral health centers (D) in the lowest category of the corresponding composite readiness index.

Supplementary Files

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