



# The effect of mobile phone text-message reminders on Kenyan health workers' adherence to malaria treatment guidelines: a cluster randomised trial

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## Summary

**Background** Health workers' malaria case-management practices often differ from national guidelines. We assessed whether text-message reminders sent to health workers' mobile phones could improve and maintain their adherence to treatment guidelines for outpatient paediatric malaria in Kenya.

**Methods** From March 6, 2009, to May 31, 2010, we did a cluster-randomised controlled trial at 107 rural health facilities in 11 districts in coastal and western Kenya. With a computer-generated sequence, health facilities were randomly allocated to either the intervention group, in which all health workers received text messages on their personal mobile phones on malaria case-management for 6 months, or the control group, in which health workers did not receive any text messages. Health workers were not masked to the intervention, although patients were unaware of whether they were in an intervention or control facility. The primary outcome was correct management with artemether-lumefantrine, defined as a dichotomous composite indicator of treatment, dispensing, and counselling tasks concordant with Kenyan national guidelines. The primary analysis was by intention to treat. The trial is registered with Current Controlled Trials, ISRCTN72328636.

**Findings** 119 health workers received the intervention. Case-management practices were assessed for 2269 children who needed treatment (1157 in the intervention group and 1112 in the control group). Intention-to-treat analysis showed that correct artemether-lumefantrine management improved by 23·7 percentage-points (95% CI 7·6–40·0;  $p=0\cdot004$ ) immediately after intervention and by 24·5 percentage-points (8·1–41·0;  $p=0\cdot003$ ) 6 months later.

**Interpretation** In resource-limited settings, malaria control programmes should consider use of text messaging to improve health workers' case-management practices.

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## Introduction

With more than 5 billion mobile phone users worldwide, text-messaging technology has changed the face of communication globally, and is increasingly used to promote health and to prevent disease.<sup>1,2</sup> The application of text messaging for behavioural change in health is at an early stage of research. Randomised controlled trials of such use of text messaging are scarce, with only two trials from low-resource settings.<sup>3,4</sup> Most randomised controlled trials from high-income countries have focused on reminders to improve patients' adherence to treatment, and all studies assessed only short-term effects of the intervention.<sup>5–7</sup> We know of no other study that has assessed the use of text messaging to target the behaviour of health workers.<sup>5–7</sup>

In Africa, adherence by health workers to malaria case-management guidelines for artemisinin-based combination treatment is vital to maximise patients' adherence to treatment,<sup>8,9</sup> and, therefore, treatment success.<sup>10</sup> Despite simple guidelines for the management of febrile children, non-adherent prescription, dosing, and dispensing of drugs, and counselling practices that do not conform to these established guidelines have been widely reported at outpatient facilities across the continent.<sup>11–14</sup> Complex interventions such as high quality in-service training, supervision,

audit with feedback, and quality improvement schemes have been suggested as interventions to improve the use of drugs and adherence to guidelines in low-resource settings.<sup>15,16</sup> However, little information exists about the cost-effectiveness of such interventions and about the possible existence of simple, inexpensive, and effective interventions that could be easily replicated in similar settings.<sup>16</sup>

Notwithstanding poor health indicators, restricted resources, poor infrastructure, and weak health systems, many African countries have overcome communication problems with the widespread use of mobile phone technology.<sup>2,17</sup> In this study, we report a randomised controlled trial in Kenya designed to test whether text-message reminders sent to health workers' mobile phones could improve and maintain health-workers' adherence to national guidelines for the management of outpatient paediatric malaria with the recommended artemisinin-based combination treatment in Kenya—artemether-lumefantrine.

## Methods

### Study population

This cluster randomised controlled trial was done at all 107 rural government health facilities (dispensaries and

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health centres) in 11 districts in two malaria endemic areas in Kenya: Greater Kwale, located along the Indian Ocean coast with a population of 650 000 people; and Greater Kisii and Gucha, located in the western highlands with a population of 1 030 000 people. In both areas, artemether-lumefantrine was deployed to health facilities in August, 2006. Between September, 2006, and July, 2009, the main artemether-lumefantrine implementation activities in study districts consisted of three rounds of malaria case-management training sessions for health workers and dissemination of national guideline documents and drug management wall charts.

Written informed consent was obtained from all interviewed carers and health workers. The study protocol was approved by the University of Oxford (OXTREC No 3808) and Kenya Medical Research Institute (SSC No 1329). The trial is registered with Current Controlled Trials, ISRCTN72328636.

#### Randomisation and masking

All health facilities (study clusters), stratified by study area, were randomly allocated to either the intervention or control group, with a computer-generated sequence (generated by the research team). Researchers and health workers were not masked to intervention although patients and carers were unaware whether they were in an intervention or control group.

#### Procedures

The intervention was a one-way communication of text-message reminders about paediatric malaria case-management sent to health workers' personal mobile phones. All health workers doing outpatient consultations in the intervention group received text messages about malaria case-management for 6 months. The intervention did not include the provision of a mobile phone. The key messages addressed recommendations from the Kenyan national malaria guidelines<sup>18</sup> and training manuals.<sup>19</sup> The messages were in English, the language of pre-service and in-service training of Kenyan health workers.<sup>19</sup> We created ten different text-messages (panel 1) to communicate the content and order of the key aspects of the outpatient clinical process with respect to paediatric malaria case management. For 5 working days (Monday to Friday), two text messages (one at 9 am and one at 2 pm) were sent daily (excluding public holidays) to every health worker's mobile phone. The same process was repeated every week for 6 months. This long intervention period was selected to ensure high exposure to the intervention to show proof of concept. Each case-management message was up to 120 characters long. To increase the probability that health workers would read the messages, each message was complemented with a quote that was up to 40 characters long and unrelated to malaria case-management but designed to be motivating, entertaining, or merely attention-getting.<sup>20</sup> The quotes were unique to each message sent to health workers.

#### Panel 1: Verbatim content and schedule of text-messages (ten examples)

##### Message one (Monday morning):

Check ALL sick children <5yrs for any severe signs! Also check for fever, cough, diarrhea, pallor & any other problem.  
Quote: "Persistent work triumphs"

##### Message two (Monday afternoon):

Child has FEVER when complained by mother or child is hot or Temp is  $\geq 37.5$  - Pls ask mother, touch child & take Temp!  
Quote: "Actions speak louder than words"

##### Message three (Tuesday morning):

TREAT with AL all children under 5yrs weighing  $\geq 5$ kg coming with FEVER for first visit & without severe signs.  
Quote: "Opportunity seldom knocks twice"

##### Message four (Tuesday afternoon):

For first visit of child <5yrs malaria test IS NOT NEEDED - Treat fever with AL & treat any other present illness!  
Quote: "Better be safe than sorry"

##### Message five (Wednesday morning):

Prescribe AL based on WEIGHT: 6 tab for 5-14kg; 12 tab for 15-24 kg; 18 tab for 25-34kg; 24 tab for  $\geq 35$ kg.  
Quote: "A goal without a plan is just a wish"

##### Message six (Wednesday afternoon):

If WEIGHT suitable AL pack is out of stock, IMPROVISE with available AL - don't give other antimalarial if you have AL!  
Quote: "Little by little one walks far"

##### Message seven (Thursday morning):

Give FIRST AL DOSE under observation at facility even if no food is available - if vomited within 30min REPEAT dose.  
Quote: "Two wrongs do not make a right"

##### Message eight (Thursday afternoon):

Advise mother to give SECOND DOSE of AL after 8hrs, then to give dose every 12hrs until all doses are finished.  
Quote: "Failing to plan is planning to fail"

##### Message nine (Friday morning):

Advise mother to FINISH all AL doses over 3 days even if the child feels better after few doses!  
Quote: "A smile you sent, will always return"

##### Message ten (Friday afternoon):

Advise mother to give AL AFTER FEEDING child & if VOMITED within 30min to REPEAT dose & return for replacement dose.  
Quote: "The greatest wealth is health"

AL= artemether-lumefantrine. Pls=please. Tab=tablet. Temp=temperature.

The maximum number of characters in each message was 160, which is the maximum amount of text that can be sent in a text message to most mobile phones in Kenya. Before the trial, the text messages were pretested in neighbouring study districts during two rounds of individual interviews with 20 health workers who had

similar roles to health workers in the study areas. This pretesting showed that most messages were understood—some messages needed further simplification and refinement before being finalised and eventually used.

We programmed the computerised text-message distribution system on a desktop server interfaced with the network of a local cellular-service provider through a global system for mobile communication modem. The system ensured automated delivery of text-message content at predefined transmission times to a list of mobile phone numbers. The performance of the distribution system was tested in two rounds: first on 40 mobile phone numbers during 6 weeks from Oct 01, 2008, to Nov 11, 2008, and then on 120 recipients from Feb 02, 2009, to Feb 06, 2009.

To assess the intervention, we did three health facility surveys: one before the intervention began (March 6, 2009, to April 3, 2009) to establish a baseline; one at 6 months, just after the end of the intervention (Nov 12, 2009, to Dec 10, 2009), to assess immediate post-intervention effects; and one 6 months after the intervention (May 5, 2010, to May 31, 2010) to assess retained effects.

During the baseline survey, we explained the purpose of the text-message intervention and health-facility surveys to all health workers in the intervention and control facilities who did consultations for sick children on the day of the survey. On completion of the baseline survey, study nurses visited all 120 outpatient health workers at intervention facilities and invited them to participate in the study. One health worker did not have a mobile phone and was excluded from the study. The remaining 119 health workers agreed to participate and provided written informed consent. All health workers in intervention facilities were told that messages would include quotes unrelated to malaria; therefore the possibility of quotes having a distracting or confusing effect was presumably minimised. Intervention delivery ran from May 4, 2009, to Oct 30, 2009. 33 361 text messages were sent to 119 health workers on 150 phone numbers (31 health workers had more than one number). For those health workers who had more than one phone number (usually two), the intervention was sent to both numbers to increase likelihood that the message would be delivered to the health worker, irrespective of the number they used at the time of delivery.

During each survey, health facilities were visited for 1 day and all sick children younger than 5 years who presented to outpatient departments underwent rapid screening by study nurses when they were ready to leave the facility. Screening consisted of the collection of the following information: age, weight, temperature, history of fever, absence of routine negative malaria test, signs of severe disease, and whether the visit was for an initial or follow-up consultation. For children meeting the criteria for artemether-lumefantrine management (panel 2), study nurses did a structured interview with carers,

### Panel 2: National recommendations and definition of the primary outcome

#### National recommendations for the management of uncomplicated malaria in children younger than 5 years

- In areas with high risk of malaria, any child with fever or history of fever and no severe signs should be presumptively classified and treated as malaria. The use of parasitological diagnosis is not a prerequisite for treatment.
- The recommended first-line treatment for uncomplicated malaria in children who weigh 5 kg or more is AL, in a weight-specific six-dose regimen given over 3 days.
- The second dose of AL should be taken after 8 h.
- AL should preferably be taken with a meal.
- The first dose of AL should be given at a health facility under the observation of the health worker even if the patient has not eaten.
- Carers should have the AL dosing schedule explained to them.
- If vomiting occurs within 30 min of taking the drug, the AL dose should be repeated.
- The health worker should emphasise that all six doses should be taken over 3 days, even if a patient feels better after a few doses.

#### Study definition of children who needed AL according to the guidelines included children with all of the following attributes:

- Child presenting to a study health facility for an initial visit.
- Younger than 5 years old.
- Weight of 5 kg or more.
- Absence of general danger signs (inability to drink or breastfeed, history of convulsions, lethargy or unconsciousness, and vomiting), neck stiffness, and severe pallor.
- History of fever during present illness or a temperature of 37.5°C or more.
- Absence of previous use of AL during this illness.
- Absence of routine negative malaria test.

#### Primary outcome\*—% of children needing AL who were correctly managed

Correct AL management included children whose carer did task one to four:

- 1 Antimalarial prescribed—proxy for malaria diagnosis.
- 2 AL prescribed.
- 3 AL prescribed in recommended weight-specific dose.
- 4 AL prescribed tablets dispensed to patients to take home.

And at least four of the following six dispensing and counselling tasks:

- 5 First AL dose given at a health facility.
- 6 Carer advised on number of tablets per dose, number of doses per day, and number of days of treatment.
- 7 Carer advised to give second dose after 8 h.
- 8 Carer advised to give AL after a meal.
- 9 Carer advised what to do if a child vomits everything.†
- 10 Carer advised to give all doses even if child feels better.

AL=artemether-lumefantrine. \*Prespecified primary protocol outcome which included all components from one to six was expanded because the intervention also included components seven to ten, no evidence exists that completion of dispensing and counselling components five to six results in better outcomes than completion of tasks seven to ten, and the expanded outcome based on ten criteria in combination with individual component outcomes in patient subsets was deemed more informative to assess all aspects of the intervention. †A child who cannot hold down food, fluids, or oral drugs.

during which information about previous use of antimalarial treatment, routine diagnostic results, drugs prescribed, and dispensing and counselling tasks done during the facility visit was recorded. At the end of the survey, all health workers who saw recruited children were interviewed. Basic information about health-worker demographics, access to guidelines, exposure to in-service

training, supervision, and intervention text messages received was recorded. Finally, each facility was assessed to find out the availability of drugs, malaria diagnostics, wall charts, and retrospective malaria morbidity in the previous 6 months.

We used recommendations specified in national malaria guidelines and training materials for the management of uncomplicated malaria in children younger than 5 years to identify children who needed treatment and drug management tasks that should be done (panel 2). Kenyan guidelines valid at the time of the study recommend that in areas with high risk of malaria all children who weigh 5 kg or more with fever or a history of fever, and who present for an initial outpatient visit without signs of severe disease should be presumptively treated with artemether-lumefantrine. Because of some ambiguity in the guidelines for the use of malaria testing in this age group, which do not provide recommendation on how to treat test-negative children, children who were tested and had a negative result were excluded from the definition. The primary outcome was a composite indicator for correct artemether-lumefantrine management; this consisted of completion of all four treatment tasks that were deemed mandatory for correct management of malaria and at least four of six dispensing and counselling tasks (panel 2). We also did exploratory analyses to assess quality of care with two additional composite definitions: completion of all four treatment tasks and at least five of six dispensing and counselling tasks, and completion of all ten tasks. Finally, completion of each of ten individual tasks was assessed in subsets of children.

### Statistical analysis

We calculated the sample size with unpublished data collected in study districts during health-facility surveys undertaken in 2006.<sup>21</sup> We hypothesised that the intervention would improve correct artemether-lumefantrine management by at least 25% (from an assumed 9% correctly managed children at baseline to at least 34% at both follow-up surveys). Therefore, assuming a level of confidence of 95%, power of 90%, baseline prevalence of 9%, an effect size of 25%,

intracluster correlation coefficient of 0.79, and average cluster size of six children, the minimum number of clusters or facilities was 52, with 312 eligible children in each group of the trial. To account for the possibility of complete artemether-lumefantrine stock-out at a facility on a survey day, which would preclude assessment of drug management at such facilities, all 107 functional facilities in the study area were included.

Data were double-entered and verified with Microsoft Access 2007. Analyses were done at the patient level and were restricted to children seen at facilities where artemether-lumefantrine was in stock on survey days. Only one facility in the control group during the immediate post-intervention survey did not have the drug. First, we did an intention-to-treat-analysis. Second, we did a per-protocol analysis in which analyses during the follow-up surveys were restricted to children seen by health workers who were fully exposed to the intervention in intervention facilities or not exposed to the intervention in control facilities.

The intervention effect was assessed at two timepoints: immediately after the end of the intervention to assess short-term effects on malaria case-management, and 6 months after the end of the intervention to establish whether there was sustained improvement of the quality of care given to children with malaria. The effect size of the intervention was measured with difference-of-differences analysis—ie,  $(\text{follow-up} - \text{baseline})_{\text{intervention}} - (\text{follow-up} - \text{baseline})_{\text{control}}$ .

We used STATA (version 11) for descriptive analyses and SAS (version 9.2) for analyses to estimate difference-of-differences effect sizes, corresponding 95% CIs and p values, and confounding. We used the SAS Genmod procedure with an identify link function and binomial distribution so that the parameter estimates of the model were risk differences.<sup>22</sup> The model contained variables for study group (intervention vs control), time one (baseline vs follow-up survey 1), time two (baseline vs follow-up survey two), a group-time-one interaction term, and a group-time-two interaction term. The model parameter estimates that correspond to the interaction terms are the difference-of-differences effect sizes. The model used generalised estimating equations with an

	Intervention group				Control group			
	Baseline	Follow-up one	Follow-up two	Total	Baseline	Follow-up one	Follow-up two	Total
Enrolled (n)	549	482	436	1467	528	456	401	1385
Met artemether-lumefantrine management criteria and included in intention-to-treat analysis (n)	439	391	327	1157	422	358*	332	1112
Met artemether-lumefantrine management criteria and included in per-protocol analysis (n)	439	299	285	1023	422	354	320	1096

\*Seven children from one facility met AL management criteria but were excluded from analysis because the facility had no artemether-lumefantrine.

**Table 1: Number of children enrolled and analysed, by study group and survey time**

independent working correlation structure to account for the correlated nature of the data. We examined the effects of 13 factors (eg, study area, preservice and in-service training, supervision, wall charts, guidelines, and drug availability) on the main study effects by entering factors into models one at a time. Any factor that changed either of the two difference-of-differences effect sizes by more than 20% was regarded as a confounder and retained in the final model. Because no factor changed an effect size by more than 16% in either the intention-to-treat or per-protocol analyses, the final model contained no confounders. Statistical significance was defined as  $p < 0.05$ .

### Role of the funding source

The sponsor of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

### Results

Table 1 shows the number of children enrolled into the study at each survey, and the number of children included in intention-to-treat and per-protocol analyses. No carer of a sick child refused to participate in the study. Characteristics of health facilities and children needing

	Baseline		Follow-up one		Follow-up two	
	Control	Intervention	Control	Intervention	Control	Intervention
<b>Health facilities</b>						
Total number of facilities (n)	53	54	53	54	53	54
Health facilities in Greater Kwale area	26 (49%)	26 (48%)	26 (49%)	26 (48%)	26 (49%)	26 (48%)
Dispensary level	46 (87%)	46 (85%)	46 (87%)	46 (85%)	46 (87%)	46 (85%)
Malaria microscopy available	12 (23%)	17 (32%)	13 (25%)	16 (30%)	12 (23%)	17 (32%)
Any AL pack in stock	53 (100%)	54 (100%)	52 (98%)	54 (100%)	53 (100%)	54 (100%)
All weight-specific AL packs in stock	33 (62%)	33 (61%)	9 (17%)	7 (13%)	5 (9%)	10 (19%)
At least one AL management wall chart exposed	33 (62%)	33 (61%)	39 (74%)	34 (63%)	43 (81%)	41 (76%)
<b>Characteristics of children needing AL management</b>						
Total number of children (n)	422	439	358	391	332	327
Child level characteristics						
Age (months)	23 (21–24)	22 (21–23)	24 (22–25)	24 (23–26)	25 (23–26)	23 (22–25)
Weight (kg)	10.2 (9.9–10.4)	10.1 (9.8–10.4)	10.3 (10–10.6)	10.5 (10.2–10.7)	10.6 (10.3–10.9)	10.3 (10–10.6)
Temperature (°C)	37.2	37.2	37.3	37.4	37.3	37.4
Previous use of antimalarial treatment	10 (2%)	13 (3%)	4 (1%)	3 (1%)	2 (1%)	4 (1%)
Positive malaria test	9 (2%)	15 (3%)	16 (5%)	9 (2%)	11 (3%)	14 (4%)
Health-facility level characteristics						
Seen at dispensary	372 (88%)	367 (84%)	314 (88%)	333 (85%)	293 (88%)	273 (84%)
Seen at health facility with malaria microscopy	67 (16%)	121 (28%)	79 (22%)	119 (30%)	73 (22%)	105 (32%)
Seen at health facility with at least one AL management wall chart	274 (65%)	284 (65%)	272 (76%)	274 (70%)	252 (76%)	252 (77%)
Seen at health facility with all weight-specific AL packs in stock	232 (55%)	265 (60%)	50 (14%)	51 (13%)	30 (9%)	63 (19%)
Seen at health facility with sulfadoxine-pyrimethamine tablets in stock	413 (98%)	439 (100%)	354 (99%)	378 (97%)	332 (100%)	327 (100%)
Health-worker level characteristics						
Exposure to AL management interventions						
Seen by health worker trained on AL use	239 (57%)	261 (60%)	248 (69%)	256 (66%)	219 (66%)	232 (71%)
Seen by health worker with access to AL guidelines	366 (87%)	370 (84%)	293 (82%)	336 (86%)	308 (93%)	288 (88%)
Seen by health worker who received AL supervisory visit	95 (23%)	146 (33%)	126 (35%)	158 (40%)	147 (44%)	130 (40%)
Exposure to text-message intervention						
Seen by health worker without exposure	422 (100%)	439 (100%)	354 (99%)	38 (10%)*	320 (96%)	16 (5%)†
Seen by health worker with only 1–5 months' exposure	0	0	4 (1%)‡	54 (14%)§	0	26 (8%)¶
Seen by health worker with complete exposure	0	0	0	299 (77%)	12 (4%)	285 (87%)

Data are n (%) or mean (95% CI) unless otherwise stated. AL=artemether-lumefantrine. \*Seen by four health workers transferred to intervention facilities after recruitment (29 children), one health worker on sick leave during the recruitment (six children), and one health worker who reported not receiving any messages (three children). †Seen by two health workers transferred to intervention facilities after recruitment (ten children), one health worker who was newly posted (four children), and one health worker who reported not receiving any messages (two children). ‡Seen by one health worker exposed for 1 month who was transferred from intervention to control facility after recruitment. §Seen by three health workers who reported receiving text messages for 1, 1.5, and 5 months, respectively (33 children), one health worker who changed phone number after 3–5 months (17 children), and one health worker who requested to stop receiving text messages after 1 month because their facility was temporarily closed (four children). ¶Seen by four health workers who reported receiving text messages for 2 months and 5 months, respectively (18 children) and one health worker who lost their phone after 1 month (eight children). ||Seen by one health worker who was transferred from intervention to control facility immediately after recruitment.

**Table 2: Characteristics of health facilities and children needing artemether-lumefantrine management, by study group and survey time**

artemether-lumefantrine management were much the same between study groups and study times (table 2). However, more children were seen at baseline surveys than they were at follow-up surveys at facilities where all four weight-specific artemether-lumefantrine packs were in stock on survey days (table 2). During the follow-up surveys at intervention facilities, 81% (584) of children were seen by health workers who received the complete 6-month intervention and 2% (16) of children at control facilities were seen by health workers either partly or fully exposed to the intervention.

In the intention-to-treat analysis, correct artemether-lumefantrine management was improved immediately after intervention and at 6 months after intervention compared with baseline (table 3). We recorded improvements of similar effect size when the performance indicator was all four treatment tasks and at least five of six dispensing and counselling tasks; a 21.4 percentage-point (95% CI 9.0–33.7, p=0.0007) improvement immediately after the intervention and a 23.7 percentage-point (11.6–35.7, p=0.0001) improvement 6 months after the intervention. We also recorded improved performance when carers did all ten tasks, but the effect sizes were smaller than they were when carers did the four treatment tasks and five of six

dispensing and counselling tasks; 10.3 percentage-point (4.0–16.6, p=0.0013) immediately after the intervention and 11.3 percentage-point (5.1–17.6, p=0.0004) 6 months after the intervention ended.

Analysis of individual artemether-lumefantrine management components showed that the biggest improvements were achieved when the following four dispensing and counselling tasks were completed (all of which were rarely done before the intervention began): giving of the first dose at the health facility, counselling to give the second dose after 8 h, counselling to give the drug after a meal, and counselling on what to do in case of vomiting (table 3). We recorded little change in the completion of the remaining six tasks at 6 months after intervention compared with baseline (table 3), but these tasks were done for most patients before the intervention began. All improvements recorded in the intention-to-treat analysis were also recorded in the per-protocol analysis, but effect sizes were larger in that analysis—correct artemether-lumefantrine management improved by 31.7 percentage-points (95% CI 15.6–47.8) during the immediate post-intervention survey and 28.6% percentage-points (12.7–44.6) during the late post-intervention survey (webappendix p 1).

See Online for webappendix

	Baseline		Follow-up one		Follow-up two		Effect size (difference of differences)			
	Control	Intervention	Control	Intervention	Control	Intervention	Immediately after end of intervention		6 months after end of intervention	
							% change (95% CI)	p value	% change (95% CI)	p value
<b>Composite performance</b>										
Correctly managed	422/47 (11.1%)	439/90 (20.5%)	358/59 (16.5%)	391/194 (49.6%)	332/58 (17.5%)	327/168 (51.4%)	23.7% (7.6 to 40.0)	0.0040	24.5% (8.1 to 41.0)	0.0034
<b>Individual components</b>										
1. Antimalarial treatment prescribed	422/347 (82.2%)	439/358 (81.6%)	358/302 (84.4%)	391/336 (85.9%)	332/271 (81.6%)	327/273 (83.5%)	2.1% (-8.3 to 12.8)	0.6759	2.5% (-9.1 to 14.1)	0.6676
2. AL treatment prescribed	347/303 (87.3)	358/312 (87.2)	302/239 (79.1)	336/320 (95.2)	271/234 (86.4)	273/255 (93.4)	16.2% (1.1 to 31.5)	0.0361	7.1% (-4.8 to 19.2)	0.2382
3. AL prescribed in recommended dose	303/291 (96.0)	312/297 (95.2)	239/225 (94.1)	320/307 (95.9)	234/218 (93.2)	255/247 (96.9)	2.6% (-2.2 to 7.4)	0.2799	4.5% (-1.2 to 10.3)	0.1196
4. AL dispensed to take home	303/302 (99.7%)	312/309 (99.0%)	239/239 (100%)	320/319 (99.7%)	234/234 (100%)	255/255 (100%)	0.4% ND	ND	0.7% ND	ND
5. First AL dose given at health facility	302/45 (14.9%)	309/79 (25.6%)	239/42 (17.6%)	319/191 (59.9%)	234/49 (20.9%)	255/142 (55.7%)	31.6% (7.4 to 55.9)	0.0105	24.1% (1.5 to 46.6)	0.0364
6. Explained how to take AL dose	302/287 (95.0%)	309/282 (91.3%)	239/233 (97.5%)	319/316 (99.1%)	234/219 (93.6%)	255/250 (98.0%)	5.3% (-1.9 to 12.6)	0.1469	8.1% (0.1 to 16.4)	0.0478
7. Advised to take second dose after 8 h	302/114 (37.8%)	309/131 (42.4%)	239/96 (40.2%)	319/245 (76.8%)	234/92 (39.3%)	255/182 (71.4%)	32.0% (9.4 to 54.6)	0.0056	27.5% (4.4 to 50.5)	0.0198
8. Advised to take AL after meal	302/103 (34.1%)	309/107 (34.6%)	239/109 (45.6%)	319/164 (51.4%)	234/108 (46.2%)	255/168 (65.9%)	5.3% (-11.3 to 21.8)	0.5318	19.2% (2.1 to 36.3)	0.0277
9. Advised what to do if vomiting occurs	302/22 (7.3%)	309/17 (5.5%)	239/20 (8.4%)	319/85 (26.7%)	234/12 (5.1%)	255/71 (27.8%)	20.1% (7.5 to 32.6)	0.0017	24.5% (12.6 to 36.4)	<0.0001
10. Advised to complete all doses	183/302 (60.6%)	309/213 (68.9%)	239/148 (61.9%)	319/249 (78.1%)	234/163 (69.7%)	255/220 (86.3%)	7.9% (-9.4 to 25.0)	0.3740	8.3% (-7.6 to 24.1)	0.3067

Data are N/n (%) unless otherwise stated. AL=artemether-lumefantrine; ND=not done (the model did not converge because outcome levels were very close to 100%).

**Table 3: Correctness of artemether-lumefantrine management (intention-to-treat analysis)**

## Discussion

Our findings showed that simple one-way communication of text-message reminders sent to health workers' personal mobile phones improved the quality of artemether-lumefantrine management. We recorded not only a short-term effect of the intervention but also a long-term improvement 6 months afterwards.

We are not aware of any other studies that have assessed text-message reminders on health workers behaviour (panel 3). However, according to early results of a large systematic review of strategies to improve health worker performance in developing countries (213 effect sizes from 172 studies with robust designs and none including text-message interventions), the median improvement was just 9% (IQR 3–23%).<sup>24</sup> Of direct relevance for malaria case-management practices in Kenya, a study that measured case-management indicators similar to those in our study showed only slight (and not statistically significant) positive effects of in-service training and passive distribution of job aids on health workers' adherence to treatment guidelines.<sup>25</sup> In the context of broader health applications of mobile phone technology in developing countries, our results complement the findings of trials in Kenya in which text-message communication between health workers and patients substantially improved patients' adherence to anti-retroviral treatment<sup>34</sup> and HIV treatment outcomes.<sup>3</sup>

The intervention had a substantial effect on the completion of four dispensing and counselling tasks that were rarely done before this study. First, giving of the first artemether-lumefantrine dose at a health facility improved by more than 20%. Completion of this task ensures prompt antimalarial treatment for children presenting to facilities but, as shown in Tanzania,<sup>9</sup> is also associated with better adherence to the full course of artemisinin-based combination treatment. Second, improvements in counselling tasks related to the correct timing of the second artemether-lumefantrine dose (nearly 30%) and the giving of the drug after a meal (nearly 20%) are encouraging findings that are important to ensure successful treatment outcomes in view of the poor oral bioavailability of artemether-lumefantrine and varied absorption between doses.<sup>26–28</sup> Third, febrile children with malaria often vomit after swallowing bitter antimalarial tablets. Therefore, the recorded 24.5% improvement in counselling on what to do if vomiting occurs offers further encouragement.

We do not fully understand why the intervention was successful.<sup>29</sup> Our main assumption is that text-message reminders address health workers' forgetfulness,<sup>30</sup> emphasise the clinical importance of doing tasks described in the messages, and increase the priority of doing the tasks because the text messages represent the voice of authority of the health workers' employer (the Ministry of Health). However, whether the intervention in our setting also involves the communication of new or corrective information, or the enhancement of health

### Panel 3: Research in context

#### Systematic review

On April 1, 2011, we searched a list of references from the Health Care Provider Performance (HCPP) review,<sup>23</sup> a systematic review of studies of health worker performance in low-income and middle-income countries. The HCPP review included more than 105 000 studies that were identified by a search of 15 electronic databases (eg, Medline, CINHL, EPOC specialised register), the bibliographies of 510 previous reviews and other articles, document inventories, and websites of 29 organisations involved with health worker performance (eg, the US Centers for Disease Control and Prevention, World Bank, WHO), the bibliography of the International Network for Rational Use of Drugs, and the WHO Rational Use of Drugs database. Electronic databases were searched without language restrictions in May, 2006, and other sources were searched between 2006 and 2010. Adequate study designs were defined as studies before and after interventions with a control group (with or without randomisation), studies done after intervention with a randomised control group, and interrupted time series. The HCPP review list (dated March 31, 2011) included 2430 references, 852 of which were studies with an adequate study design. To complement the search of electronic databases since 2006, on April 4, 2011 we also searched the Medline database with search terms "text-messaging" and screened 174 citations.

#### Interpretation

We know of no other study to examine the effectiveness of mobile phone text-message reminders to improve health worker performance in a developing country. In our study, text-message reminders were associated with substantial improvements in health workers' adherence to national guidelines for the management of outpatient paediatric malaria. In resource-limited settings, malaria control programmes should consider use of text-messaging to improve health workers' case-management practices.

workers' feeling that someone is paying attention to their work (ie, the Hawthorne effect<sup>31</sup>), is not clear. The intervention's effect could have had little to do with the malaria-related content of the messages but with increased motivation from the famous quotes and sayings. We are examining these questions with qualitative research methods, and hope to publish our findings by the end of 2011.

From a programmatic perspective, our findings have important implications for malaria case-management implementers in Kenya and elsewhere in Africa. Despite the encouraging results of our study against frequent reports of unsuccessful interventions to change clinical practices across the continent,<sup>15,16,24</sup> we do not argue that text messaging should replace a traditional package of case-management interventions such as in-service training, supervision, and dissemination of guidelines and job aids. Our intervention provided large and sustained improvements in the quality of care given to children with malaria, but resulted in only about half the children being correctly managed. Therefore, we recommend that text-message reminders should be used to complement existing interventions—which themselves should be qualitatively improved—to target weak points in malaria case-management practices. In the Kenyan context, with 22 million people who subscribe to a mobile phone service<sup>32</sup> and 86% of the population with access to mobile network coverage,<sup>33</sup> and an even

higher likelihood of health facilities having network coverage, the pending large-scale implementation of a universal diagnostic policy for febrile patients<sup>34</sup> offers an opportunity for the government to implement behaviour change through text-messaging.<sup>34</sup> As part of this activity, text-message reminders can be used to strengthen antimalarial treatment and dispensing and counselling practices, but also to reinforce testing of febrile patients, antimalarial treatment for only test-positive patients, and the need to assess children who test negative for malaria for other causes of fever. Across Africa, the network coverage will ultimately establish the feasibility of the intervention. Findings from remote districts in Tanzania suggest that large scale text-message applications in health are feasible.<sup>35</sup>

Because sending text-messages seemed like an insubstantial intervention, we hypothesised that frequent, repetitive reminders during a long period (6 months) would be needed for the intervention to be effective. Moreover, because the study was intended to provide proof of concept, we thought that the testing of the intervention at a high dose would be best. Qualitative research with health workers exposed to the intervention should help reveal how burdensome the intervention was, and whether the intervention could be delivered for a period shorter than 6 months and expanded to other disease areas without losing effectiveness.

The simplicity and low cost of text messaging means that widespread implementation of an intervention that uses this technology can be done quickly and successfully. For example, the cost of a text message in Kenya is about US\$0.01,<sup>36</sup> resulting in the cost of full exposure to our intervention of \$2.6 per health worker, or \$39 000 if scaled up to an estimated 15 000 health workers in all rural facilities nationwide.<sup>37</sup> However, despite the low cost of sending a text message, additional costs and complexities exist in the establishment and maintenance of the distribution systems. We are undertaking a cost-effectiveness analysis under our trial conditions. In collaboration with the Kenyan Ministry of Health, we are also assessing the cost and operational requirements for the deployment and effective maintenance of the text-message distribution system on a national scale. These findings, together with better understanding of health workers' views on the intervention's modalities and underlying motivators that affect their behaviour, will be crucial when considering national scale-up and replication of this intervention elsewhere.

#### Contributors

DZ and RWS had the idea for and designed the study, with contributions from DHH, WSA, and AKR. MN developed the text-message distribution system. DZ, RKS, and MN supervised text-message delivery. DZ and RKS supervised data collection. DZ, RKS, and AKR analysed the data. All authors critically reviewed the paper and approved the final version.

#### Conflicts of interests

DZ and RWS have received a fee for speaking at a meeting organised by Novartis Pharma AG, the manufacturer of artemether-lumefantrine. RKS, WSA, MN, DHH, and AKR declare that they have no conflicts of interest.

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