ORIGINAL ARTICLE

SMS-based intervention in type 2 diabetes: clinical trial in Senegal

Matthieu Wargny,[1,2] Line Kleinebreil,[3] Said Norou Diop,[4] Maïmouna Ndour-Mbaye,[4] Mady Ba,[5] Beverley Balkau,[6,7] Dominique Simon[8]

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[1]CIC d'Endocrinologie, Maladies Métaboliques et Nutrition, CHU de Nantes, Nantes, France
[2]L'Institut du Thorax, INSERM UMR 1087, UNIV Nantes, CHU de Nantes, Nantes, France
[3]Université Numérique Francophone Mondiale, Hôpital national de Saint Maurice, Saint-Maurice, France
[4]Centre du Diabète Marc Sankalé, Centre hospitalier Abass Ndao, Dakar, Sénégal
[5]Bureau du représentant de l'OMS pour le Sénégal Almadies, Lotissement Ngor-Extension, Dakar, Sénégal
[6]INSERM U-1018, CESP, Team 5, Villejuif, Villejuif
[7]Université Paris-Saclay, Université Paris-Sud, Université Versailles Saint-Quentin en Yvelines, Versailles, France
[8]ICAN, Hôpital de la Pitié-Salpêtrière, Paris, France

Correspondence to
Dr Matthieu Wargny, CIC d'Endocrinologie, Maladies Métaboliques et Nutrition, CHU de Nantes, Nantes 44000, France; matthieu.wargny@gmail.com

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ABSTRACT

Objective Since 2014 Senegal has benefited from regular awareness-raising Short Message Service (SMS) campaigns (Be He@lthy, Be Mobile initiative) directed at people who have signed up, for free, to the 'mDiabète' programme. We report on an evaluation of its impact on diabetes control.

Design The clinical trial was designed to send daily SMS during 3 months to people with type 2 diabetes. Due to centre randomisation, SMS were sent from inclusion (M0) to month 3 (M3) to people in centre S and from M3 to month 6 (M6) to people in centre P.

Setting Medical centre S in the northwestern suburbs of Dakar; centre P in Popenguine, 70 km south of Dakar.

Participants In February 2017, people with type 2 diabetes were consecutively recruited in the two centres. Complete data were available from 186 of these people.

Main outcome measures HbA1c was measured in the two centres with the same assay throughout the study. The primary end point was the difference between centres for the change in HbA1c from M0 to M3. Secondary end points were the evolution of HbA1c in centres S and P between M3 and M6.

Results The HbA1c change from M0 to M3 in centre S was better than in centre P, with a median difference of −0.4%, quartiles (−1.0; 0.3) versus 0.2% (-0.5; 0.8), respectively (p=0.0038). HbA1c decreased over the 3 months after having stopped SMS in centre S and was confirmed in centre P. The campaign cost was €2.5 (US$3.1) per person.

Conclusions In Senegal, SMS sending was associated with an improved glycaemic control in people with type 2 diabetes. As SMS has a high penetration in low-income, middle-income countries where medical resources are scarce, health interventions using mobile telephones should be developed to facilitate exchanges between people with diabetes and medical teams; this may reduce diabetes-related complications.

INTRODUCTION

From the beginning of the 21st century, the prevalence of diabetes has grown rapidly around the world, including in low-income, middle-income countries where diabetes was a rare disease in the 1980s.[1] According to the International Diabetes Federation estimates, in 2017, 425 million adults have diabetes around the world and >90% of them, type 2 diabetes; in Africa >15.5 million adults have diabetes, including 135 600 in Senegal.[2] Further, 4 million deaths were due to diabetes, mainly because of cardiovascular and renal complications, while diabetic retinopathy was the leading cause of vision loss in working-age adults (20–65 years). Global diabetes-related healthcare expenditure in adults aged 20–79 years reached US$700 billion.[2]

Several studies, most notably the UKPDS (United Kingdom Prospective Diabetes Study),[3] showed that optimal glycaemic control is effective in delaying the onset of diabetes-related complications, including cardiovascular disease, kidney disease, blindness and limb amputation. To improve glycaemic control in people with diabetes, a multifaceted diabetes management is needed. Diabetes educational programmes are proposed by care providers in many countries, most often in hospitals. They provide an education about diet, the use of glucose-lowering drugs, glucose monitoring and the risk factors associated with diabetes-related complications, and they encourage physical activity.[4] Unfortunately, these education programmes are time-consuming and expensive, and health systems in low-income, middle-income countries are short of health professionals and resources. Mobile technology, particularly text messaging via the Short Message Service (SMS), has a high penetration in

these countries. Thus, mobile Health (mHealth) interventions could provide a support to facilitate communication between people with diabetes and medical teams.

Indeed, 45 years ago in the USA, regular phone contacts between people with type 1 diabetes and care providers were shown to reduce emergency hospitalisations and keto-acidosis episodes,[5] but whether mobile phone applications improve glycaemic control in diabetes has been poorly investigated up to now,[6] with questionable results, particularly in resource-poor settings.[7] The single study from Africa[8] included only 40 people with type 2 diabetes and showed an unexpectedly large 1.7% reduction in HbA1c in the intervention group. However, because of several flawed methodological aspects, this African study was considered to be of poor quality, providing unreliable data, in the meta-analysis.[6]

The dramatic increase in mobile phone use worldwide, from 1 billion subscribers in 2002 to 6 billion in 2012 (86% of the world's population), made mHealth one of the most attractive areas of public health intervention for WHO, even though evidence of effectiveness has not yet been proven.[9] One-way push mobile text messaging, where the receiver cannot respond, could be considered as the least advanced but the most widely used tool for mHealth.[10] In 2012, the *Be He@lthy, Be Mobile* initiative was founded as a joint partnership between WHO and the International Telecommunications Union (ITU).[11] It aims to design, deploy and scale-up non-communicable disease prevention and management services that can be promoted using mobile phones. It is currently working with governments in 10 countries across a range of income groups and disease areas. As of early 2017, programmes have been fully launched in India, Senegal, Zambia, Egypt and the Philippines, and are under preparation in Tunisia. Since 2014, Senegal has promoted *Be He@lthy, Be Mobile*, with regular awareness-raising SMS campaigns directed at people who have signed up for free access to the 'mDiabète' programme. They receive during 3 months a series of SMS that are different according to whether they say they are 'interested in diabetes', 'have diabetes' or 'work as healthcare professionals'. The voluntary registrations increased from 1000 in 2014 to 12 000 in 2015, 51 000 in 2016 and 117 000 in 2017. Indeed, to evaluate the programme's capacity to improve diabetes management, any quantitative improvement in glycaemic control requires documentation.

Thus, in 2017, WHO and ITU initiated in Senegal the study reported here, which assessed the SMS campaign's efficacity, comparing HbA1c changes for people in one centre who received SMS with those in a second centre who did not receive such messages.

METHODS

Study design

A controlled open, two-centre, clinical trial with a randomised time allocation of the intervention was designed. Two medical centres, the 'Centre Philippe Maguilène Senghor' (S) located in Yoff, in the north-western suburbs of Dakar, and the 'Centre Médical de Popenguine' (P), 70 km south of Dakar, were involved. They included consecutively, from 13 February 2017, all adults (≥18 years) with type 2 diabetes who had a mobile-cellular telephone that was able to receive SMS every day, and who gave informed consent to participate. Patients suffering from sickle-cell disease were not included. By time randomisation at the centre level, the S centre participants received SMS during the first three months (M_0 to M_3) then no SMS during the three following months (M_3 to M_6), while it was the reverse for P centre participants (no SMS from M_0 to M_3 then SMS from M_3 to M_6). The same SMS series (50 SMS overall) were sent to participants in each centre, with a daily SMS on weeks 1, 2, 4, 5, 7, 9 and 11 and no SMS in weeks 3, 6, 8, 10 and 12 (see online supplementary file 1 for the content of the SMS in French). Usual diabetes care was provided throughout the study, and one diabetologist in each centre was in charge of the participants. The type of glucose-lowering treatments was not modified, but doses could be changed if needed. Informed consent was obtained from all included patients.

Outcomes

The primary study outcome was the difference between the S and the P centres for the change of HbA1c level between M_0 and M_3, to assess the impact of the SMS programme on glycaemic control.

The secondary outcomes were (1) the evolution of HbA1c between M_3 and M_6 in the S centre in order to check whether there was a residual effect of SMS on glycaemic control and (2) the evolution of HbA1c between M_3 and M_6 in the P centre in order to confirm the benefit, if any, of the SMS programme on glycaemic control.

HbA1c was measured locally in each medical centre, and the same HbA1c assay (Siemens DCA Vintage HbA1c) was used in both centres during the entire study period.

Statistical analysis

We compared baseline (first day of follow-up), M_3 and M_6 characteristics between centres S and P. The differences in participants' characteristics between the centres were analysed using Fisher's exact tests for categorical variables, and Student's t-tests or Wilcoxon rank-sum tests for continuous variables, according to their distribution. After-before comparisons were performed using Wilcoxon signed-rank tests.

Study size was originally calculated according to the main outcome. Assuming a 0.25% difference between the centres S and P for the evolution of HbA1c between inclusion and M_3, and a common SD of 0.5%, we had a power of 90% to reject the null hypothesis (H_0: S=P) with a bilateral α risk of 0.05 if we included

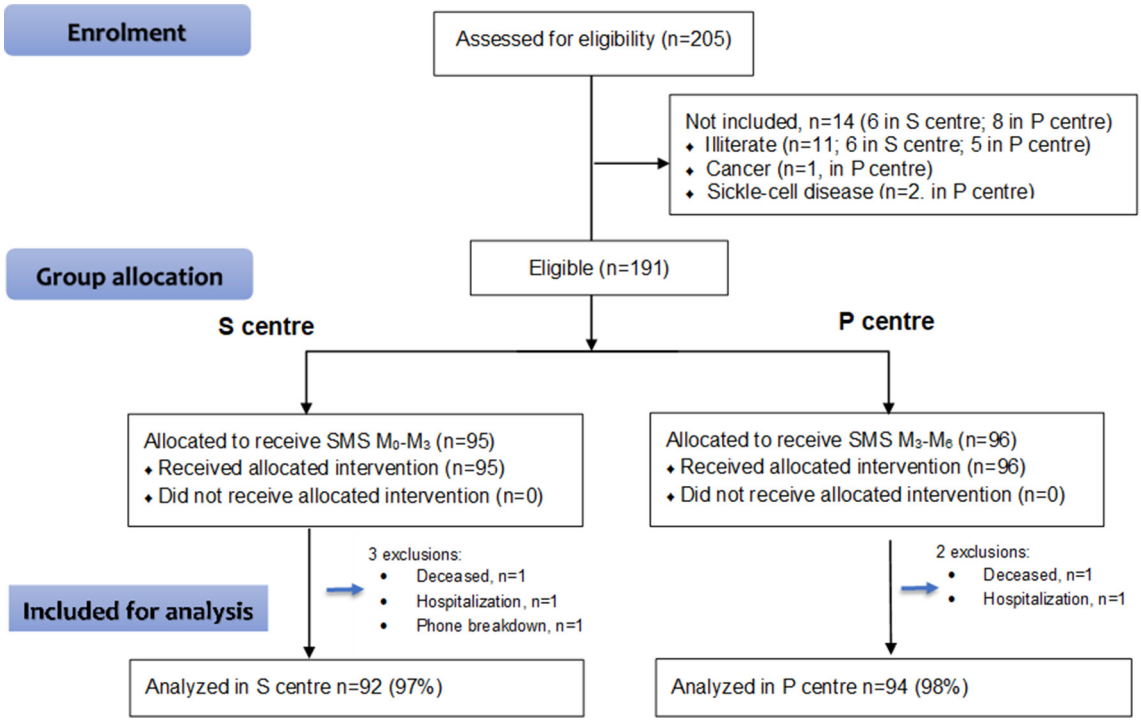

Figure 1 Flow diagram of the Dakar study. P, Centre Médical de Popenguine; S, Centre Philippe Maguilène Senghor; SMS, Short Message Service.

85 participants per centre. Thus, the inclusion of a total of 180 participants was planned to anticipate a possible loss of follow-up for 10 patients. However, as the distribution of HbA1c and its 3-month changes were not Gaussian (see online supplementary file 2), we used a non-parametric approach for the analyses.

All statistical analyses were performed using R software.[12]

RESULTS

Enrolment

As shown in the flow diagram (figure 1), 191 consecutive people fulfilled the inclusion criteria and were enrolled in February 2017. Final data were not available for five individuals: three in the S centre (one death, one hospitalisation, one failure of the mobile device) and two in the P centre (one death, one hospitalisation). Complete data were thus obtained for 186 people, 92 in the S centre who received SMS from M_0 to M_3, and 94 in the P centre who received SMS from M_3 to M_6.

Baseline characteristics

At baseline, participants in the two centres did not differ in age, sex, weight and body mass index, diabetes duration, frequency of insulin treatment or HbA1c level (table 1).

Table 1 Baseline characteristics of the population, by study centre

	Senghor (n=92)	Popenguine (n=94)	P values
Women	78 (85%)	70 (75%)	0.10
Age (years)	55±10	54±12	0.42
Weight (kg)	72 (63; 81)	70 (62; 80)	0.51
Body mass index (kg/m²)	25.5 (22.5; 28.6)	25.4 (23.3; 29.3)	0.96
HbA1c (%)	8.1 (6.8; 10.8)	8.4 (6.3; 11.2)	0.91
Treated with insulin	26 (28 %)	23 (25 %)	0.62
Diabetes duration (years)	n=92	n=92 (2 values missing)	0.21
<1	19 (21%)	15 (16%)	
1–5	28 (30%)	42 (46%)	
5–10	24 (26%)	19 (21%)	
>10	21 (23%)	16 (17%)	

For categorical variables, figures and percentages are given by n (%).
For quantitative parameters, m±SD are given when the distribution was considered as Gaussian, or median (quartile 1; quartile 3) in case of skewed distribution.

Table 2 Change in HbA1c (%), between study centres and between visits

HbA1c change (raw %) over time between groups	Senghor (n=92)	Popenguine (n=94)	P values
M_0 and M_3	−0.4 (-1.0; 0.3)	0.2 (-0.5; 0.8)	**0.0038**
M_0 and M_6	−0.6 (-1.4; 0.2)	0.0 (-1.1; 0.5)	0.061
M_3 and M_6	−0.2 (-0.7; 0.2)	−0.1 (-0.8; 0.2)	0.91
HbA1c before vs after intervention (pooled analysis)	**Before intervention M_0 Senghor and M_3 Popenguine**	**After intervention M_3 Senghor and M_6 Popenguine**	
HbA1c (%)	8.3 (6.7; 10.9)	8.0 (6.4; 9.9)	**0.00014**

Results are shown as median (quartile 1; quartile 3) of the values of interest. P values are given using Wilcoxon rank-test for non-paired series, or Wilcoxon rank-sum test for paired series. P-value < 0.05 are marked in bold.

Outcomes

For the primary outcome, the decrease in HbA1c from M_0 to M_3 was significantly higher in the S than in the P centre (median difference: −0.4%, quartiles (−1.0; 0.3) vs 0.2% (-0.5; 0.8), respectively, p=0.0038) (table 2).

The improvement in glycaemic control in the S centre persisted 3 months after the end of the SMS sending period, with a slight but statistically significant lower HbA1c between M_3 versus M_6 (7.5% (6.3; 10.1) vs 7.4% (6.3; 9.7), p=0.036) (table 3). In addition, the favourable impact of SMS on glycaemic control was confirmed in the P centre with a significantly lower HbA1c at the end of the intervention period, that is, between M_3 and M_6 (8.4% (6.4; 10.9) vs 8.3% (6.6; 9.8), p=0.015) (table 3). Overall, in a post-hoc analysis, when pooling the S and P centres to compare HbA1c just before versus at the end of the SMS intervention, a positive effect was observed with a significantly lower HbA1c: 8.3% (6.7; 10.9) versus 8.0% (6.4; 9.9), respectively, p<0.001 (table 2).

DISCUSSION

This randomised clinical trial shows that SMS were associated with an improvement in glycaemic control in people with type 2 diabetes. Furthermore, this favourable effect was observed in both centres, and persisted and even increased during the 3 months after the SMS were stopped.

Limitations of the study

The positive effect of SMS on the primary outcome can be challenged as our hypothesis on difference of HbA1c change between groups was not confirmed in parametric analysis (p=0.18) although the differences between S and P groups after the first 3 months was larger than expected (0.4% for the mean value) but with a much broader dispersion (SD 1.8%). Indeed, as the difference in HbA1c change did not have a Gaussian distribution (see online supplementary file 2), it was necessary to use a non-parametric approach.

The population in Senegal is predominantly Muslim. Ramadan occurred during the second period (between M_3 and M_6) and may have interfered with glycaemic control because of modifications in nutritional habits.[13] However, the period between inclusion and M_3 was chosen so that there was no interference with the primary end point.

Strengths of the study

One diabetologist in each centre followed the patients and recorded the HbA1c data; this was probably a key factor, as very few patients were lost to follow-up, all of them for serious medical reasons (death or hospitalisation). The same HbA1c assay method was used at each visit, so the data are reliable.

The choice of the two centres, 70 km apart but also far from the local reference centre, the Abass Ndao hospital, was crucial to eliminate the risk of 'pollution' of the SMS intervention. It is unlikely that the people in the P centre would be aware of the content of the SMS received by those in the S centre during the first three months of the study. Also, it should be noted that these centres had similar resources and cared for similar populations in terms of socioeconomic status.

Table 3 Changes in HbA1c within study centres

	HbA1c (%)			
	M_0	M_3	M_6	P values
Senghor	8.1 (6.8; 10.8)	7.5 (6.3; 10.1)	7.4 (6.3; 9.7)	**(M_3/M_0), p=0.0025** **(M_6/M_0), p=0.0003** **(M_6/M_3), p=0.036**
Popenguine	8.4 (6.3; 11.2)	8.4 (6.4; 10.9)	8.3 (6.6; 9.8)	(M_3/M_0), p=0.25 (M_6/M_0), p=0.25 **(M_6/M_3), p=0.015**

Results are shown as median (quartile 1; quartile 3) of HbA1c at visit. P values are given using Wilcoxon rank-sum test for paired series.

The local physician's practices may have differed slightly.

Generalisability

The results observed in Senegal can probably be extrapolated to other countries, but the SMS approach may be more valuable in low-income, middle-income countries where it is difficult to organise educational groups to improve knowledge and motivation of people with diabetes for a better empowerment of daily care.[4] The worldwide diffusion of mobile phone use makes it very convenient for low-resource countries. In addition, the financial aspect is a major argument to develop mHealth: the mean cost of sending one SMS was €0.05 (US$0.061) in Senegal. Thus, the campaign reported here cost €2.5 (US$3.1) per person.

Illiteracy can probably be considered as the main limitation to generalise mHealth procedures in some low-income, middle-income countries as 5.4% of the patients assessed for eligibility were not included because of illiteracy. However, some illiterate patients were able to be included in the study thanks to the support of family or friends who explained to them the content of the SMSs.

Interpretation

The positive results obtained in this controlled study lead us to conclude that mHealth is both a cheap and effective tool for the therapeutic education of people with diabetes. Its use should be extended to the other fields of chronic diseases, to reduce complications in people with diagnosed diseases as well as to prevent the occurrence of diseases, for instance, by promoting a healthy lifestyle in populations that are less and less physically active and are exposed to 'coca-colonisation'.[14]

CONCLUSIONS

In Senegal, sending diabetes education messages via SMS was associated with an improvement in glycaemic control in people with type 2 diabetes. As text messaging has a high penetration in low-income, middle-income countries where medical resources are scarce, this kind of mHealth intervention should be developed to facilitate exchanges between people with diabetes and medical teams, and so reduce the risk of diabetes-related complications.

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Contributors SND and MN-M brought their field experience and chose the two study centres. MN-M and LK wrote the original protocol and submitted it to the ethics committee, with the support of MB from WHO local office. SND and LK supervised the local investigators' training and the progress of the study. BB, DS and MW performed the statistical analysis. DS and MW wrote the original draft. All authors participated in the correction of the draft and the final writing of the manuscript.

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Competing interests MW and DS received personal fees from the WHO for the analysis and writing of the submitted manuscript. MB is a current employee of WHO. SND received fees from ITU as a temporary consultant in the m.Diabète project Sénégal, and from SANOFI Afrique as a member of the African advisory board. MN-M received consultant fees from ITU.

Patient consent Informed consent was obtained from all included patients.

Ethics approval Senegal National Ethics Committee for Scientific Research.

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