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Control of konzo by detoxification of cassava flour in three villages in the Democratic Republic of Congo

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ABSTRACT

Three villages in Boko Health Zone, Bandundu Province, Democratic Republic of Congo (DRC), had 61 konzo cases and konzo prevalences of 2.5%, 4.1% and 7.5% respectively. Konzo cases occurred every year for 10 years and every month, peaking in July. The high mean cyanide content of cassava flour of 50 ppm was due to short soaking of cassava roots for 1–2 days instead of 3–4 days. Konzo cases were examined and village women taught the wetting method that removes cyanogens from flour. The villages were visited every month for 1 year following previous methodology. No new konzo cases occurred during the intervention, mean flour cyanide levels reduced from 50 to 14 ppm and mean urinary thiocyanate levels of school children reduced from 930 to 150 μmole/L. The percentage of children with urinary thiocyanate levels of >350 μmole/L was reduced from a maximum of 80 in Ikialala before the intervention to 0 in Ikusama, Ikialala and 3 in Imboso Mwanga 1 year later. This is the second time that konzo has been controlled and success depends on regular use of the wetting method by village women. The methodology is now being used in other villages in DRC with financial support of AusAID.

1. Introduction

Konzo is an upper motor neuron disease that causes irreversible paralysis of the legs and occurs mainly in children and young women of child bearing age (Ministry of Health, 1984; Howlett et al., 1990). It is associated with the consumption of a monotonous diet of high cyanide cassava by poor rural people in Africa, many of whom have only one meal per day and suffer from malnutrition. It has been proposed that konzo is associated with (1) a high cyanide diet of bitter cassava over a period of several weeks, (2) a low intake of protein, in particular a shortfall of the essential S-containing amino acids methionine and cysteine/cystine, that are needed to detoxify cyanide to thiocyanate (Cliff et al., 1985; Nzwalo and Cliff, 2011).

The evidence for and against this hypothesis was summarised by Tylleskar (1994), who proposed that if it is correct, it should be possible to prevent konzo by using improved methods of processing, to reduce the cyanide intake of people at risk of getting konzo. This has now been achieved by educating the women of Kay Kalenge village in Bandundu Province, DRC to use the simple wetting method (Bradbury, 2006; Cumbana et al., 2007; Bradbury and Denton, 2010) that removes nearly all cyanogens from cassava flour, which prevented the occurrence of any new cases of konzo for 18 months, including two dry seasons when konzo peaks (M. Banea et al., 2012).

The second requirement for konzo to occur (see above) is a low protein intake. Another way to prevent konzo should therefore be to increase the supply of protein, particularly S-containing amino acids that are required for detoxification of cyanide to thiocyanate in the body, catalysed by the liver enzyme rhodanese. A shortfall of S-containing amino acids would result in reduced ability to detoxify cyanide and increased cyanide concentration in the blood, which could trigger konzo (Cliff et al., 1985; Cardoso et al., 2004), perhaps by formation of the neurotoxin cyanate (Tor-Agbidye et al., 1999). In three unrelated konzo epidemics in different countries, which resulted from drought and insufficient processing of bitter cassava roots, it was found that people of the same ethnic group consuming bitter cassava, located only about 5 km away had a konzo prevalence close to zero. Those with near zero prevalence in Mozambique lived near the sea (Ministry of Health, 1984), in DRC they lived in the forest (Banea Mayambu, 1993) and in Tanzania they lived close to Lake Victoria (Howlett et al., 1992). These people had a better supply of protein, including fish from the sea or lake Victoria or animals from the forest that had protected them from contracting konzo, compared with those living nearby

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who had contracted konzo, because they had no access to animal protein. This evidence supports the hypothesis that konzo is prevented by an adequate supply of animal protein.

In this paper we report an intervention in three villages in Boko Health Zone, adjacent to Popokabaka Health Zone in Bandundu Province, where konzo was first discovered by Trolli (1938). Using methods similar to those used successfully in Kay Kalenge village in Popokabaka Health Zone (M. Banea et al., 2012), we have been able to prevent the occurrence of new konzo cases over 1 year.

2. Materials and methods

2.1. Study area

Based on an Action Against Hunger survey (Kasonga and Calo, 2011) and after discussion with the central office of Boko Health Zone, we decided to visit two adjacent health areas. Three villages in these health areas were identified as having high konzo prevalence and they were visited in June 2011 to establish contact. The location of the three Boko villages (Imboso Mwanga, Ikusama and Ikialala) is shown in Fig. 1, fairly close to Kay Kalenge village, where the previous intervention was made (M. Banea et al., 2012). They are in the savannah 10–20 km from the main road, but the roads into Imboso Mwanga and Ikusama became unserviceable in 2008 and are no longer usable. No cassava can be sold from these two villages. No village has a market. Imboso Mwanga has a health centre and Ikialala a health post. Ikusama has a primary/secondary school and Ikialala has a primary school. Sources of water including rivers are available 2–4 km from the villages. Cassava, peanuts, maize, cowpea, squash, pepper and pineapple are grown and there are goats, pigs and chicken.

2.2. Cassava processing and storage

Cassava is the staple food and is grown in the woods and in the valleys, mainly bitter cassava, except for a few families who grow some sweet cassava. Cassava is processed by each woman by soaking it in her hollow in the river for two nights or even less especially in the rainy season, and then drying for 1–2 days. The dried cassava cossettes are stored in large baskets. There is a shortage of cassava during October and November, because people are working in the fields.

2.3. Extended intervention in the villages

In July 2011 the full team visited Imboso Mwanga, Ikusama and Ikialala to examine and rehabilitate konzo cases with antiinflammatory drugs and multivitamins. Suspected konzo cases were examined in their homes following a standardised WHO protocol (WHO, 1996) and results are in Table 1. The type, month and year of onset of the disease was registered. A population census was taken of the three villages which showed 652 males and 663 females totalling 1315. To obtain baseline data the total cyanide content of cassava flour samples and the thiocyanate content of urine samples from school children were measured, before the introduction of the wetting method. The women were trained in use of the wetting method to remove cyanogens from flour. The intervention took place over 1 year from July 2011 to July 2012. Visits of the full team were made in July and November 2011, February and July 2012 and at each of these visits a check was made for new konzo cases. There were also focus group discussions on the continued use of the wetting

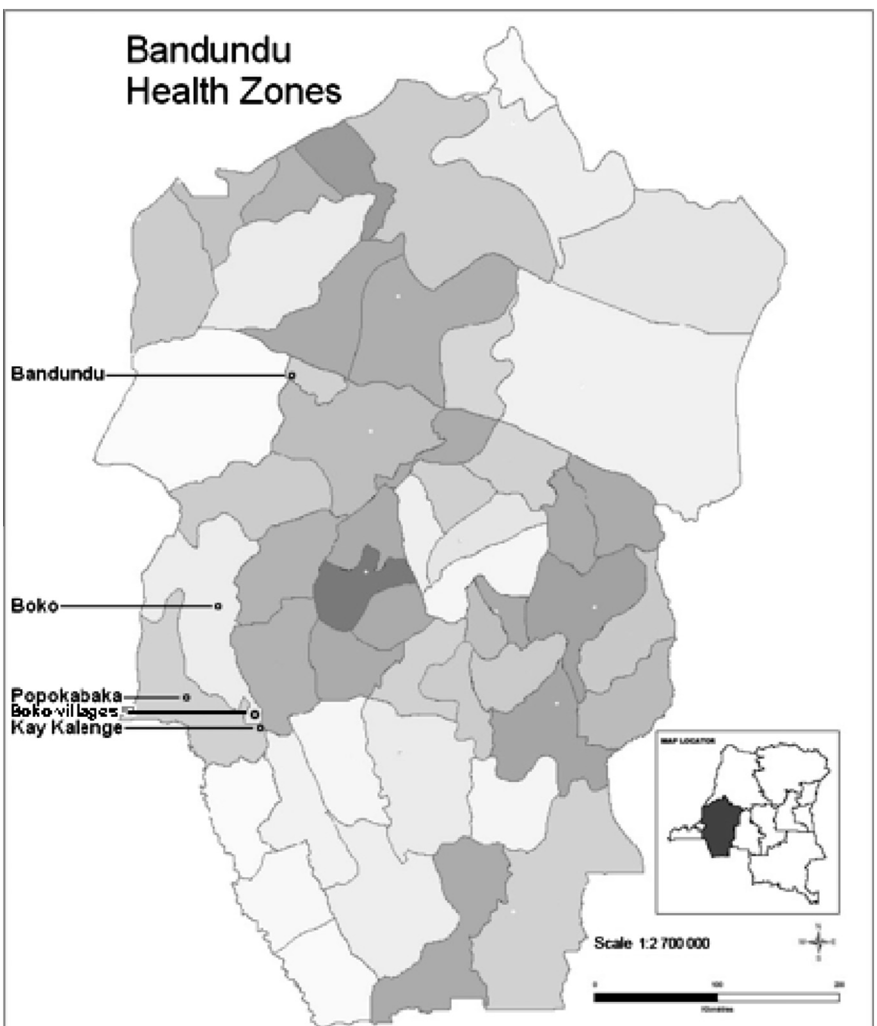

Fig. 1. Map showing the Health Zones of Bandundu Province, DRC modified from http://reliefweb.int/sites/reliefweb.int/files/resources/3A4632031B94F342852572DC006BFC2Eocha_REF_cod070508.pdf), and including the location of the Boko villages and of the previous intervention in Kay Kalenge village (Banea et al., 2012a).

Table 1
Population, number of konzo cases and % konzo prevalence in three Boko villages.

Village	Population	Number of konzo cases	% Prevalence
Imboso Mwanga	550	14	2.5
Ikusama	316	13	4.1
Ikialala	449	34	7.6
Total	1315	61	4.6

method and other matters. Cassava flour samples and urine samples were collected randomly and analysed for total cyanide content and urinary thiocyanate respectively. Between these visits, monthly visits were made by the Caritas Popokabaka team to support the women in the Boko villages, following the pattern used previously (M. Banea et al., 2012).

The wetting method to remove cyanogens from cassava flour involves adding dry flour to a bowl and marking the level on the inside of the bowl. Water is then added with mixing, the volume of the damp flour initially decreases and then increases as more water is added. No more water is added when the level of the wet flour comes up to the mark. The wet flour is then placed in a thin layer not greater than 1 cm thick on a mat and allowed to stand for 2 h in the sun or 5 h in the shade for the hydrogen cyanide gas to escape (Bradbury, 2006; Cumbana et al., 2007; Bradbury and Denton, 2010). The damp flour is mixed with boiling water in the traditional way to make the thick porridge (fufu) which is eaten with pounded, boiled cassava leaves (saka saka) or some other food to give it flavour. Women leaders were identified in each village, 20 in each of Imboso Mwanga and Ikusama and 10 in Ikialala. They were trained in the use of the wetting method to detoxify the cassava flour. The women leaders then trained 10–15 other women in the village. Small training sessions were also carried out in the villages and in this way about 200 women (72%) were trained in Imboso Mwanga, 120 (75%) at Ikusama and 180 (79%) at Ikialala. In each village a committee was set up to ensure good follow up. Use of the wetting method requires a knife, a plastic basin and a mat and these were supplied to each family. Illustrated, laminated posters in Kiyaka that describe the wetting method, were supplied from Australia (Bradbury et al., 2011).

2.4. Urinary thiocyanate analysis

In July 2011 before the introduction of the wetting method, 40–80 samples of urine were collected randomly in each village from school age children and a record made of their age, sex and whether or not they were living in a family with a case of konzo. This gave baseline data on the situation before the introduction of the wetting method. The same procedure was followed for urine collections in subsequent visits of the full team. The samples were analysed in the village using the urinary thiocyanate picrate kit D1 (Haque and Bradbury, 1999) which had been field tested in Mozambique (Ernesto et al., 2002; http://biology.anu.edu.au/hosted_sites/CCDN/). A colour chart was used with 10 shades of colour from yellow to brown, corresponding to 0–100 mg thiocyanate/L urine (ppm). The results in ppm are multiplied by 17.2 to convert them to μmole thiocyanate/L urine. The percentage of entries in each of the 10 levels from 0 to 1720 μmole/L was calculated from the raw data for each village over the four visits of the full team, see Tables 4–6.

2.5. Total cyanide analysis of cassava flour

In July 2011 about 30 samples of cassava flour were obtained randomly from each village to obtain baseline data before the introduction of the wetting method. In subsequent visits of the full team in each village cassava flour samples, which were ready to be used for production of fufu, were obtained randomly. The analyses were carried out using the simple picrate kit B2 to determine the total cyanide content of cassava flour (Egan et al., 1998; Bradbury et al., 1999; http://biology.anu.edu.au/hosted_sites/CCDN/). A colour chart was used with 10 shades of colour corresponding to 0–800 mg HCN equivalents/kg cassava flour (ppm).

Table 2
Mean total cyanide content (ppm) of cassava flour in the Boko villages in July 2011 (baeline value, before introduction of the wetting method) and during the intervention.[a]

Village	Mean total cyanide (ppm) of cassava flour in			
	Jul 2011[b]	Nov 2011	Feb 2012	Jul 2012
Imboso Mwanga	44(38)	18(19)	21(19)[d]	15(15)
Ikusama	74(75)[c]	31(26)	20(16)	18(16)
Ikialala	43(50)	38(38)	14(16)	9(11)
Mean over all villages	50(53)	29(30)	18(17)	14(15)

[a] Mean values are from 30 samples of flour unless stated otherwise. Standard deviations are in brackets.
[b] Baseline value, before introduction of the wetting method.
[c] Mean of 18 samples.
[d] Mean of 27 samples.

3. Results

As shown in Table 1 there were a total of 61 konzo cases in a population of 1315 giving an average prevalence rate of 4.6%. The % prevalence of konzo is 2.5% for Imboso Mwanga, 4.1% for Ikusama and 7.5% for Ikialala. Nearly one half of the patients (44%) had at least one person (living or dead) from their family with konzo. Of the 61 konzo cases, 82% experienced an abrupt onset of <1 day, 15% said that it took 2–7 days and 3% found a slow occurrence over several weeks. About one half (49%) of patients immediately contacted the health authorities, 38% went to traditional healers and the remainder did not consult anyone. A large percentage (89%) of the population reported that the paraparesis remained stable over years, while11% said that it became worse over time. With regard to walking, 5% were unable to walk, 32% used two sticks, 17% a single stick and 46% did not need a stick. Speech problems affected 15% of patients and 39% had vision problems. Two konzo patients also had goitre. Nearly all patients (98%) exhibited exaggerated knee jerk and ankle reflexes. A continuous clonus was observed with 29 patients and the Babinski sign was found in 57 patients. Women as well as children who were above the age of 5 years were most affected. In total 72% were female and 28% male. The monthly distribution of konzo cases is shown in Fig. 2, while the annual distribution of konzo cases since 1985 is shown in Fig. 3.

There have been no new cases of konzo even amongst the 25 mothers who have given birth in Imboso Mwanga, 15 in Ikusama and 10 in Ikialala. Focus groups in February and July 2012 found that in the three Boko villages the women and their children did not become sick any more (no dizziness, stomach aches, vomiting, diarrhoea), nor did they get muscle pain and hurting legs. The children did not lose weight and women and children were healthy.

The quality of the fufu is much improved compared with fufu made from untreated flour. It is very good to eat, like a mixture of corn flour and (old) cassava flour. It does not stick in the pot. It stores better than fufu from old cassava flour and so can be used for several days, as previously noted by M. Banea et al. (2012). The major disadvantage is that, particularly in the wet season when it must be left inside the house because of the rain, the wetting method takes a longer time (5 h). Some families do not have a table to put the mat on, and left on the ground it sometimes gets rainwater or dust into the flour.

3.1. Extent of use of wetting method by women

In July 2011 the training of the women in use of the wetting method to remove cyanogens from cassava flour reached about 117 women at Imboso Mwanga, 70 at Ikusama and 95 at Ikialala. In each village the women accepted the wetting method spontaneously. In November 2011, as a result of focus group meetings, there were an additional 22 women trained in the three villages. In February 2012, it was found through focus group meetings that 19% of households in Imboso Mwanga did not use the wetting method, compared with 6% in Ikusama and 8% in Ikialala. The highest amount of non-use of the wetting method occurred in Imboso Mwanga, due to a personal conflict between those in charge of the training of women and follow up. Non-use occurred particularly with families of divorced people or very poor families who did not have cassava fields and were forced to buy cassava every day. In July 2012 two focus groups were held in each village and it was found that there were still some families that only occasionally used the wetting method. The people of surrounding villages are willing to use the wetting method but want to be trained first.

Table 3
Mean urinary thiocyanate content (μmole/L) of school children in Boko villages in July 2011 before introducing the wetting method and during the intervention.[a]

Village	Mean urinary thiocyanate content (μmole/L) in			
	Jul 2011[b]	Nov 2011	Feb 2012	Jul 2012
Imboso Mwanga	780(610)	260(260)	260(230)	190(150)
Ikusama	950(620)	290(250)	210(110)	150(64)
Ikialala	1050(560)	360(300)	210(200)	104(86)
Mean over all villages	930(610)	300(260)	230(190)	150(110)

[a] Mean values based on sample sizes ranging from 43 to 80 with most sample sizes of 60. Standard deviations shown in brackets.
[b] Baseline value, just before introduction of the wetting method.

Table 4
% Of children from Imboso Mwanga with urinary thiocyanate contents in each of 10 levels from 0 to 1720 μmole/L.

Urinary thiocyanate (μmole/L)	% Of school children in			
	Jul 2011[a]	Nov 2011	Feb 2012	Jul 2012
0	0	3	2	10
17.2	4	4	4	10
34.4	2	5	0	0
68.8	0	7	18	0
103	8	6	7	7
172	10	38	34	47
344	24	26	22	23
688	6	7	9	3
1030	24	4	4	0
1720	22	0	0	0

[a] Baseline results obtained just before the introduction of the wetting method.

3.2. Cyanide in flour and urinary thiocyanate results

The total cyanide content of cassava flour samples is given in Table 2 for the three villages, a baseline value before the introduction of the wetting method in July 2011, and during the intervention in the three visits of the full team in November 2011 and in February and July 2012. Similarly the urinary thiocyanate results were obtained for the three Boko villages, a baseline value in July 2011 and three results during the intervention, see Table 3. For any particular visit the results for the three villages were combined and it was found that there were no significant differences between the results for girls and boys, or between the two age groups 3–9 years and 10–14 years. However for July 2011, just before the introduction of the wetting method, there was a significant difference ($P = 0.04$) between the mean urinary thiocyanate content of children who lived in a household with a case of konzo, 1110(630) μmole/L, $n = 37$, compared with the mean value of those who lived in a household with no konzo case 880(590) μmole/L, $n = 116$. In the three later visits during the intervention, November 2011 to July 2012, there were no differences between the urinary thiocyanate results of children whether they lived in a household with a case of konzo or not. The % of children with urinary thiocyanate contents in each of the 10 levels from 0 to 1720 μmole/L before the introduction of the wetting method, in July 2011 and on the subsequent three visits of the full team are shown in Tables 4–6 for Imboso Mwanga, Ikusama and Ikialala.

4. Discussion

The largest village Imboso Mwanga has a % prevalence slightly less than that of Kay Kalenge at 2.7% (M. Banea et al., 2012). 82% of the 61 konzo cases occurred abruptly in less than 1 day. There were no cases in which there was an improvement over time and in 11% of cases the konzo became worse over time: 5% were severely disabled (unable to walk), 49% moderately disabled (one or two sticks needed), and 46% mildly disabled (visible spasticity but no stick needed). This fits the pattern of results from four previous studies, see M. Banea et al., 2012). Averaging the data over five studies gives severely disabled 9(5)%, moderately disabled 29(14)%, and mildly disabled 62(11)%. As in the previous study (M. Banea et al., 2012), 72% of konzo cases were female and 28% male, but there is a great deal of variability in the ratio of females to males, probably due to local unknown factors (Howlett, 1994).

The monthly distribution of konzo cases is shown in Fig. 2 with maximum incidence in July, the peak time of cassava consumption in the dry season and a smaller konzo incidence peak in March–April. With the Boko villages konzo cases occur every month of the year, whereas with the four villages including Kay Kalenge there were no cases between September and December (M. Banea et al., 2012). The distribution of konzo cases over the years is shown in Fig. 3, with a peak in 2010 whereas the Kay Kalenge villages gave a large peak in 2009 and a smaller one in 1992. The incidence of konzo over the years is very dependent on local factors (M. Banea et al., 2012) and also depends on the accuracy of the memory of the individuals affected by konzo. There is an unbroken incidence of konzo every year for 10 years from 2002 to 2011, com-

Table 5
% Of children from Ikusama with urinary thiocyanate contents in each of 10 levels from 0 to 1720 μmole/L.

Urinary thiocyanate	% Of school children in (μmole/L)			
	Jul 2011[a]	Nov 2011	Feb 2012	Jul 2012
0	0	4	2	7
17.2	0	1	0	2
34.4	0	3	2	0
68.8	0	9	6	0
103	5	1	16	23
172	9	38	37	65
344	18	30	37	3
688	21	9	0	0
1030	12	5	0	0
1720	35	0	0	0

[a] Base line results obtained just before the introduction of the wetting method.

Table 6
% Of children from Ikialala with urinary thiocyanate contents in each of 10 levels from 0 to 1720 μmole/L.

Urinary thiocyanate	% Of school children in (μmole/L)			
	Jul 2011[a]	Nov 2011	Feb 2012	Jul 2012
0	0	3	3	28
17.2	3	2	5	7
34.4	0	6	7	0
68.8	0	2	2	0
103	0	11	25	22
172	5	21	33	40
344	12	32	16	3
688	23	14	7	0
1030	20	9	2	0
1720	37	0	0	0

[a] Base line results obtained just before the introduction of the wetting method.

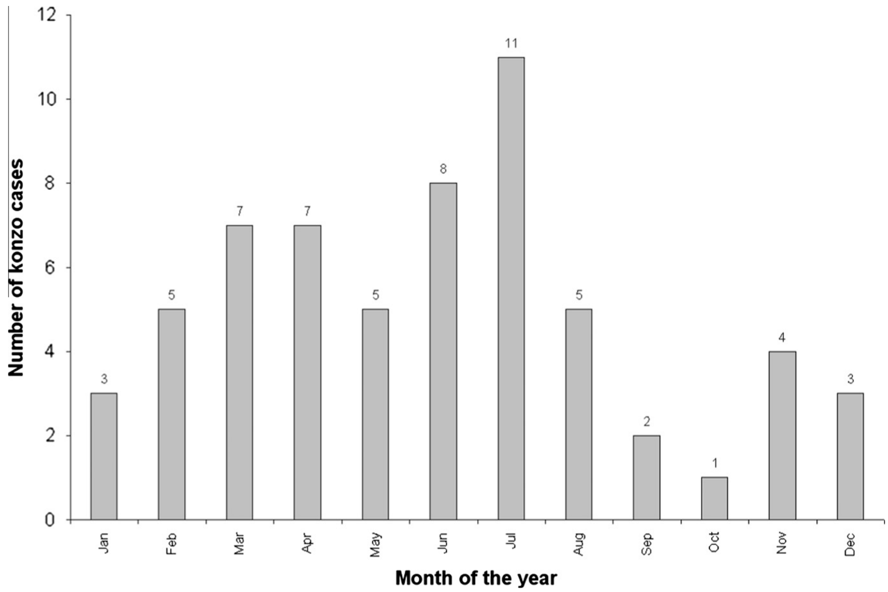

Fig. 2. Monthly distribution of onset of konzo in the three Boko villages.

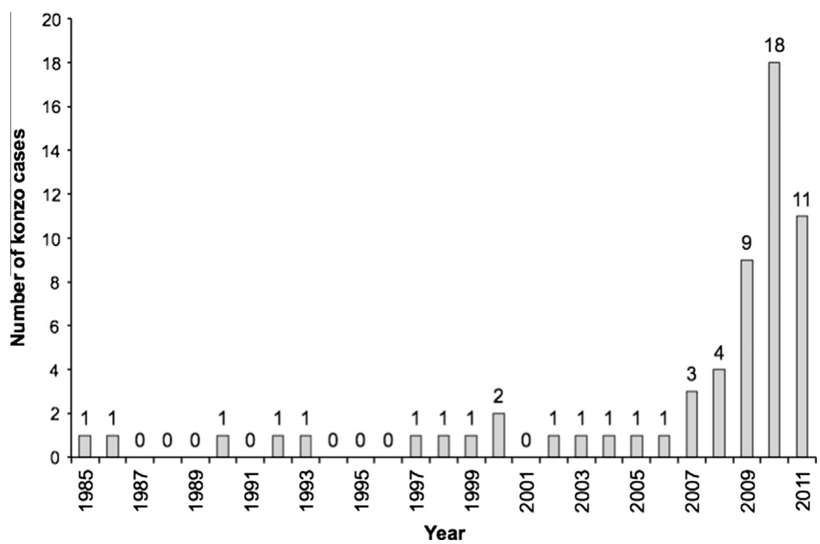

Fig. 3. Annual distribution of onset of konzo in the three Boko villages from 1985 to 2011.

pared with only 5 years for the Kay Kalenge villages. This result, together with the greater % prevalence of konzo in the Boko villages than in Kay Kalenge and its occurrence every month of the year, all show that the konzo situation is worse than in the Kay Kalenge villages (M. Banea et al., 2012).

Our claim that by use of the wetting method we prevented konzo in Kay Kalenge (M. Banea et al, 2012), has recently been questioned (Adamolekun, 2012), partly on the grounds that new cases of konzo had only occurred for 5 years before the intervention. We were aware of this possible line of argument (J.P. Banea et al., 2012). There had been new konzo cases in the Boko villages every year for the preceding 10 years (Fig. 3), so the absence of new konzo cases after introduction of the wetting method in July 2011, further strengthens our case that we have in fact prevented konzo. This great improvement compared with the previous 10 years, shows that regular use of the wetting method by the women to remove cyanogens from cassava flour is an effective preventive treatment against konzo. This result confirms the claims made in our first study in Kay Kalenge (M. Banea et al, 2012). Through focus group discussions it was found that the women and children did not get sick anymore due to cyanide poisoning and did not lose weight. As discussed previously by M. Banea et al. (2012), the fufu made from untreated flour has a bitter flavour due to the presence of linamarin that itself has a bitter taste (King and Bradbury, 1995), but that made from treated flour is sweet and also stores longer (for 2 days) than that from untreated flour.

The training of the women to use the wetting method occurred mainly at the July 2011 visit and they accepted the method spontaneously. More women were trained in November 2011, but it was found in focus groups during the subsequent visit in February 2012 that 19% of households in Imboso Mwanga still did not use the wetting method, compared with 6–8% in the two smaller villages. This was traced to a personal conflict between trainers in Imboso Mwanga. Also non-use occurred amongst the very poor who did not have cassava fields. The effect of non-use of the wetting method in Imboso Mwanga is seen in Tables 4–6, where there is a larger number of urinary thiocyanate values of >350 µmole/L in February and July 2012 for Imboso Mwanga than for the other two villages. The success of the intervention in preventing konzo is critically dependent on the acceptance and use by all the women of the wetting method.

4.1. Total cyanide content of cassava flour

There is a decrease over the intervention in the total mean cyanide content of cassava flour samples from its baseline value before introduction of the wetting method of 50–29 ppm in November 2011 and 14 ppm in July 2012 (see Table 2 and Fig. 4). By the end of the intervention in July 2012 the total mean cyanide content was less than the FAO/WHO safe limit of 10 ppm (FAO/WHO, 1991) in Ikialala village, but higher in the other villages. This result is not as good as that obtained in the longer 1.5 y intervention in Kay Kalenge, where flour total cyanide results were <10 ppm over the final half of the intervention (M. Banea et al., 2012).

The high total cyanide content before the intervention results from reduced times of immersion of cassava roots of only 2 days or sometimes only 1 day, compared with the 4 days needed to effectively remove cyanogens (Banea et al., 1992). A return of the soaking (retting) processing method to 4 days instead of 1–2 days, would greatly reduce the total cyanide content of flour and prevent konzo, and hence there may be no need to introduce the wetting method. But the problems associated with increasing the time of immersion from 1–2 to 4 days are (1) pressure from the family to produce the food more quickly and (2) the increased likelihood that the roots may be stolen from the hollow in the river where they are soaking. The advantages of introducing the wetting method are that it is (1) an additional processing method to greatly reduce cyanide content, (2) fast (2–5 h) compared with several days and (3) located inside the house or in the sun outside and is hence much more secure from thieves than the river.

4.2. Urinary thiocyanate content of school children

It was found that there were no differences between urinary thiocyanate levels for girls and boys or between the two age groups of 3–9 and 10–14 years old. In July 2011 before the introduction of the wetting method, it was found that the mean urinary thiocyanate content of children who lived in a household with a case of konzo was significantly larger [1110(630) μmole/L], compared with those children who lived in a household with no konzo case [880(590) μmole/L]. No such difference was observed with the data from Kay Kalenge (M. Banea et al., 2012), perhaps because the urinary thiocyanate levels before introduction of the wetting method in March before the main cassava season, were so much lower than those found in the present study. In the succeeding three visits in the Boko villages there was no difference between the mean urinary thiocyanate results of those children living in a household with or without a case of konzo. Hence before the intervention, those households in which there were konzo cases were those where cyanide intakes were significantly larger, and caused higher urinary thiocyanate levels of those children. After the introduction of the wetting method by the women, the urinary thiocyanate levels of the children were reduced in all households and the former differences were removed.

The mean urinary thiocyanate results in the three villages in Table 3 and Fig. 4 show a rapid decrease after the intervention and a slower decrease thereafter, with the exception of Imboso Mwanga where there is no decrease between November 2011 and February 2012, because 19% of households in that village did not use the wetting method (see Section 3.1). This effect is also noted in the total cyanide content results for Imboso Mwanga in Table 2. The mean value before the intervention (930 μmole/L) is very much higher than that observed in Kay Kalenge (332 μmole/L) (M. Banea et al., 2012) or in Mozambique (Ernesto et al., 2002). This is because the baseline urinary thiocyanate results before introduction of the wetting method were obtained at the peak of the cassava season in July when cassava consumption peaks, compared with the urinary thiocyanate results before introduction of the wetting method in Kay Kalenge which were obtained in March, when less cassava is being consumed (M. Banea et al., 2012). The reduction in the mean urinary thiocyanate content after the intervention is more pronounced with the Boko villages than in Kay Kalenge, but the mean values in subsequent visits are still higher than in Kay Kalenge. In Kay Kalenge the mean urinary thiocyanate level had stabilised at a lower level after the third visit and remained nearly constant thereafter (M. Banea et al., 2012), whereas the Boko results in Table 3 had not stabilised even after the final visit. The percentage of children with high urinary thiocyanate levels from the three villages (Tables 4–6) highlight the much higher values compared with Kay Kalenge. Thus before the intervention

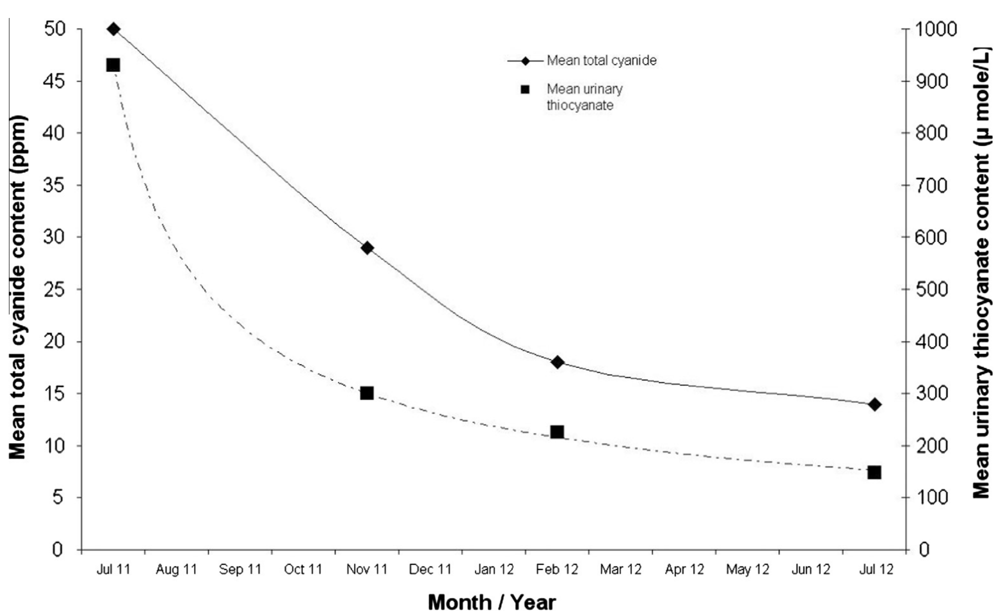

Fig. 4. Comparison of mean total cyanide content of cassava flour (♦) in ppm and mean urinary thiocyanate content (■) in μmole/L before introducing the wetting method (July 2011) and over the 1 year intervention.

there were 52%, 68% and 80% of children in Imboso Mwanga, Ikusama and Ikialala villages respectively with urinary thiocyanate levels above 350 μmole/L compared with 24% of children in Kay Kalenge (M. Banea et al., 2012). We believe that these children are in danger of contracting konzo (J.P. Banea et al., 2012). These large percentages have been progressively reduced over the 1 year intervention to 3% in Imboso Mwanga and 0% in Ikusama and Ikialala.

In Fig. 4 there is a comparison between the mean total cyanide content of cassava flour and the mean urinary thiocyanate content of school children. Although both curves trend downwards as the intervention proceeds we note that the mean cyanide levels drop by less than one half from July to November 2011, whereas the mean urinary thiocyanate content falls to less than one third over the same period. This is due to the fact that July is the peak month of both cassava consumption and incidence of konzo (Fig. 2), whereas the amount of cassava eaten is much less in November and hence urinary thiocyanate levels are much lower.

4.3. Relationship between the % konzo prevalence and % of children with high urinary thiocyanate levels, measured before introduction of the wetting method

If the hypothesis is correct that the incidence of konzo is related to high cyanide intake from bitter cassava, then it is reasonable to expect that an increase in cyanide intake is associated with an increase in % konzo prevalence, a dose response relationship (Tylleskar, 1994). A good measure of cyanide intake is the urinary thiocyanate content of school children, but this only measures intake over approximately the previous week and intake is therefore dependent on the season of the year. Thus cassava consumption peaks in July when urinary thiocyanate levels were measured in the Boko villages, but is much less in March, when they were measured in Kay Kalenge (M. Banea et al., 2012). Ideally at a particular location urinary thiocyanate levels should be measured and compared at the same time of the year, as occurred with the three Boko villages. Rather than use the mean urinary thiocyanate content of all children, a better comparison is obtained by separating out those children with high urinary thiocyanate levels (>350 μmoles/L). In Fig. 5 is a graph of the % konzo prevalence obtained from Table 1 vs % of children with urinary thiocyanate levels >350 μmole/L for Imboso Mwanga (52%), Ikusama (62%) and Ikialala (80%), see Tables 4–6. The results for Kay Kalenge obtained in March are 2.7% konzo prevalence and 24% of children with urinary thiocyanate >350 μmole/L (M. Banea et al., 2012). The three Boko points fit a smooth curve and as expected the Kay Kalenge result falls below this curve, because the % children with urinary thiocyanate levels >350 μmole/L was measured in March, before the onset of the main cassava season. For the Boko villages the increasing % of children with urinary thiocyanate levels >350 μmole/L (which is a measure of increasing cyanide intake) is associated with increasing % konzo prevalence, which supports the hypothesis that konzo is associated with high cyanogen intake from a monotonous diet of poorly processed cassava Howlett et al., 1990; Cliff et al., 1985; J.P. Banea et al., 2012).

4.4. Optimum total time of intervention

The total time of the intervention in the Boko villages is 1 year compared with 1.5 years in the earlier intervention in Kay Kalenge village (M. Banea et al., 2012). A disadvantage of the shorter time is that it is insufficient to allow the urinary thiocyanate results to stabilise at low values as at Kay Kalenge, but the shorter intervention is less expensive and allows better use of limited funding.

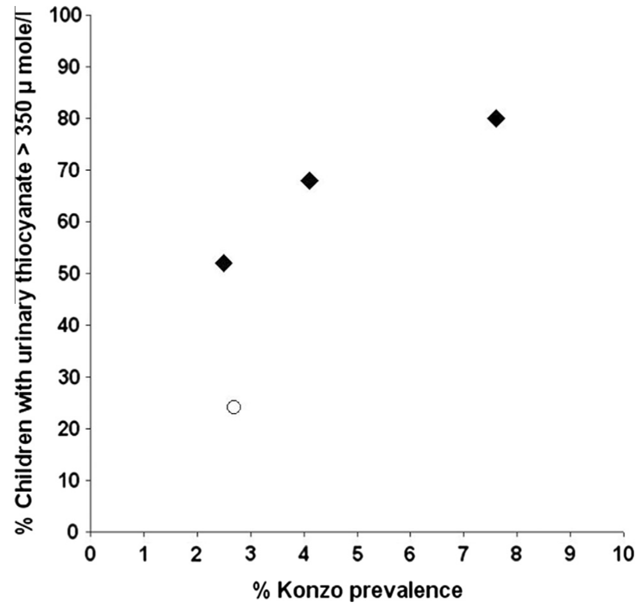

Fig. 5. Graph of % konzo prevalence vs % of school children with urinary thiocyanate content >350 μmole/L, determined before introducing the wetting method in the Boko villages in July (♦) and in Kay Kalenge in March (○) (Banea et al., 2012a).

5. Conclusion

We have now controlled konzo in three villages in Boko Health Zone where konzo had occurred every year for the preceding 10 years, using a 1 year intervention modelled on the previous successful intervention in Kay Kalenge (M. Banea et al., 2012), that involves use of the wetting method by village women to greatly reduce cyanogen intake from cassava flour. We are continuing these interventions to control konzo in other villages of DRC, with the financial support of AusAID.

Conflict of Interest

The authors declare that there are no conflicts of interest.

Acknowledgments

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