




Original research

Design thinking to improve rational use of oral rehydration salts: lessons from an innovative co-packaged diarrhoea treatment kit

Rohit Ramchandani ^{1,2,3} Simon Berry,^{4,5} Jane Berry,⁴ Beth Anne Pratt,⁶ Albert Saka,⁷ Robert E Black¹

¹Department of International Health, Johns Hopkins University Bloomberg School of Public Health, Baltimore, Maryland, USA

²School of Public Health Sciences, University of Waterloo, Waterloo, Ontario, Canada

³Balsillie School of International Affairs, Waterloo, Ontario, Canada

⁴ColaLife, London, UK

⁵The ORS & Zinc Co-pack Alliance, London, UK

⁶Global Health Insights, Nairobi, Kenya

⁷Keepers Zambia Foundation, Lusaka, Zambia

Correspondence to

Dr Rohit Ramchandani, International Health, Johns Hopkins University Bloomberg School of Public Health, Baltimore, Maryland, USA; rramchandani@jhu.edu

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ABSTRACT

Introduction We explored whether greater consideration of product design, informed by end users' opinions, led to improved utilisation (ie, rational use) of oral rehydration salts (ORS) in home settings. We tested whether a 'design thinking' approach, focusing on product acceptability, functionality and ease of use, contributed to an increased likelihood of appropriate ORS use, specifically dosing and preparation of ORS in the correct concentration.

Methods Intervention design decisions were used to develop a co-packaged diarrhoea treatment kit containing ORS and zinc, branded as 'Kit Yamoyo'. In addition to co-packaging, key product design features were the inclusion of 200 mL ORS sachets and a water measurement function incorporated in the packaging design. Cross-sectional data from household surveys of caregivers in rural Zambia were then used to compare ORS preparation and use for diarrhoea patients aged <5 years, who used either the novel co-pack or standard 1 L sachets of ORS. Design benefits were demonstrated to caregivers from two rural areas by trained community health workers (CHWs).

Results Odds of correct ORS preparation were 10.93 times greater ($p < 0.001$; 95% CI 5.74 to 20.78) among Kit Yamoyo users versus individuals who used 1 L sachets. Co-pack users prepared ORS to the correct concentration 93% (95% CI 0.89% to 0.96%) of the time, while non-users prepared it in the correct concentration just 60% (95% CI 0.54% to 0.66%) of the time.

Conclusion Application of design thinking to the development of a co-packaged ORS and zinc diarrhoea treatment kit, coupled with demonstrations by CHWs, can improve rational use of ORS.

INTRODUCTION

This study formed part of a broader trial¹ that focused on increasing coverage of oral rehydration salts (ORS) and zinc for the treatment of childhood diarrhoea in remote rural areas of Zambia.¹ Here, we explore how a design thinking process, including consultation with end users, influenced design elements that facilitated rational use of ORS. Rational use was defined as preparing ORS to the correct concentration. While co-packaging of ORS with zinc, based on WHO recommendations,^{2,3} was a core design focus of the overall intervention and led to improved uptake of the recommended combination therapy,¹ here we focus on how design thinking improved the rational use of ORS.

ORS are typically considered to be any packaged rehydration solution containing a balanced mixture of glucose and electrolytes (eg, sodium, potassium) that stimulates fluid absorption and counteracts dehydration. ORS are fundamental for the treatment of acute diarrhoea in children, restoring electrolyte balance by stimulating the intestinal sodium/glucose transporter SGLT1 and inducing fluid absorption.⁴ This discovery was described as potentially the most important medical advance of the 20th century and has helped save millions of lives.^{5,6}

Diarrhoea remains the second-leading cause of infectious disease-related childhood mortality. Taken together correctly, ORS and zinc can reduce diarrhoea-related morbidity and mortality and are safe and effective in both home and facility settings when properly prepared and

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ The successful treatment of diarrhoea is measured and globally tracked based on the reported use of the combination therapy of oral rehydration salts (ORS) and zinc, as published in national surveys such as the Demographic and Health Surveys. However, this approach provides no indication of how appropriately (ie, rationally) the ORS or zinc were used. The few studies undertaken in this area, combined with behavioural observations, suggest home preparation of oral rehydration solution from 1 L sachets of ORS (the de facto global standard) may be suboptimal.

WHAT THIS STUDY ADDS

⇒ This study, conducted in Zambia, validates and provides updated evidence to support the notion that 1 L sachets are associated with the incorrect preparation of ORS and that design thinking can be used to facilitate improved rational use. Zambian caregivers either used too little or too much water and/or only part of a sachet's contents, thereby limiting treatment efficacy. Caregivers using an ORS/zinc co-pack containing 200 mL sachets of ORS, shipped in packaging that can be used to measure 200 mL of water, were more likely to mix ORS correctly (93% of the time) compared with caregivers who were given standard issue, 1 L ORS sachets alone (60% of the time).

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Our findings highlight the benefits of focusing on better product design to improve caregivers' rational use of ORS, with the approach also likely to benefit the use of other therapeutics.

⇒ This work also highlights the limitations of using population coverage of ORS as an indicator of progress against childhood diarrhoea, as stated use by household survey respondents does not necessarily equate to correct preparation and proper utilisation. Furthermore, our findings cast some doubt on the appropriateness of using 1 L sachets of ORS as the standard for home-based treatment of diarrhoea.

administered.^{7–14} By 2030, scaling up both medicines to 90% coverage could reduce diarrhoea mortality in children by 51%, compared with 2015 levels.¹⁵ Co-packaging of ORS and zinc currently remains very limited: around 43% of diarrhoea cases globally receive ORS, but only around 7% receive both ORS and zinc.¹⁶ In Zambia, estimates made prior to our intervention demonstrated zinc coverage was <1%, while coverage of sachet-based ORS was 64%.¹⁷ Inclusion of zinc in the novel co-packaged design process was thus essential, to align with international recommendations that children with acute diarrhoea receive both therapies³ and that ORS and zinc be co-packaged in diarrhoea treatment kits.² Coverage estimates of ORS and zinc for diarrhoea treatment in children are typically derived from reported levels of usage from household surveys, for example, Demographic and Health

Surveys (DHS), and do not indicate whether medicines are correctly prepared or administered. Rational use of ORS requires the solution to be prepared in an appropriate quantity at the correct concentration and with safe water.^{18 19}

Inaccuracies during home-mixing of ORS solutions and/or an inappropriate drinking volume can lead to recipients experiencing electrolyte imbalances such as hypernatraemia.^{20 21} Incorrect dilution can result in either high or low concentrations of salts and glucose, decreasing the effectiveness of ORS treatment for dehydration from acute diarrhoea.²²

Few studies have explored whether ORS are correctly prepared at the household level. Barros *et al* found that 44% of Brazilian caregivers used less than 800 mL of water when preparing a sachet intended for dilution in 1 L of water,²³ resulting in solutions with excessive sodium concentrations in 38% of cases. Only 69% of ORS users in that study used the entire sachet, with an average intake of ORS of 354 mL over 24 hours. A Nigerian study reported that just 62% of users at the household level correctly described how to prepare ORS,²⁴ while Zwisler *et al*²⁵ concluded that correct ORS dosing was a challenge for caregivers in India and Kenya. A study in Indonesia demonstrated that only between 59% and 69% of caregivers who administered ORS to their children aged <2 years prepared them correctly.²² Caregivers regularly note a lack of confidence in administering ORS without health provider consultation, often rooted in uncertainty around preparation and the aetiology of diarrhoea.²⁶

The limited research available suggests that 1 L of ORS solution far exceeds the average 400 mL of ORS a child under 5 typically consumes in a day.^{23 27 28} While appropriate for health facility settings, 1 L sachets are inappropriate for home use as, on average, more solution will be discarded after 24 hours (~600 mL) than will be consumed by a child (~400 mL). This problem is often amplified in rural settings, where accessing water and making it safe to drink can be a significant effort.^{25 29} Once ORS are prepared, WHO recommends the solution be discarded within 24 hours³⁰ due to the risk of contamination.^{31–35} In addition, caregivers are reluctant to prepare large volumes of ORS because they dislike discarding unused portions,^{25 36} indicating that 1 L sachets for household use may promote incorrect or even risky health behaviour.

Since 1978, just one sachet size (1 L) has been generally available; health centres usually prescribe one or two 1 L sachets. Thus, if directions are followed and the prepared ORS solution is consumed within 24 hours, most patients only receive sachets sufficient for 1 or 2 days. However, mild and severe diarrhoeal episodes last on average 4.3 and 8.4 days, respectively.³⁷ Home-based treatment under such scenarios is inadequate in terms of administered quantity for both rehydration and maintenance therapy of diarrhoea,³⁸ and it has been proposed that innovations should include sachets

smaller than the traditional 1L for home use.² In India and Kenya, caregivers preferred 200 mL sachets to 1L sachets for use at home²⁵; further evidence that multiple, smaller sachets of ORS would be more appropriate for home use.

While there is evidence that inaccuracies in home preparation of ORS can be reversed with appropriate education and health promotion,²⁰ an additional strategy, explored here, would be to design an ORS product that encourages and facilitates correct quantities and dilution of ORS, while continuing to reinforce rational use through health promotion activities.

A systematic review of barriers and facilitators to the implementation of oral rehydration therapy in low-income and middle-income countries identified ‘design to enhance acceptability’ as a core thematic outcome.³⁹ While various strategic approaches to increasing the use of ORS have been identified in the literature, there is a paucity of quality research investigating the effectiveness of interventions to promote the correct use of ORS.^{40 41}

METHODS

Setting

This study formed part of a broader trial and was conducted across four remote, rural districts in the Southern and Eastern Provinces of Zambia. Two districts served as intervention arms (Kalomo and Katete); each had a matched comparator district (Monze and Petauke, respectively), based on various relevant criteria (rurality, caregiver’s age/education, diarrhoea burden and access to treatment).¹

Patient and public involvement: the product design process

We used four methods to gather insights into the needs and desires of caregivers with respect to childhood diarrhoea treatment with ORS and zinc in the home:

1. Caregiver focus groups.⁴²
2. Ad hoc informal discussions with caregivers.
3. Stakeholder consultations (including insights from commercial partners).⁴³
4. Literature review.

The product design focus groups comprised 8 groups of 9–12 caregivers (n=82), from remote rural areas of Katete and Kalomo districts. Discussions aimed to capture qualitative information to understand challenges in appropriately treating diarrhoea at home in children aged <5 years. Feedback was solicited on an early prototype of the co-pack under development for the project. Focus group members were also asked to indicate how much they would be willing to pay for the co-pack.

Focus group insights were synthesised with findings from the ad hoc informal discussions with caregivers, stakeholder consultations and the literature review to inform the design of the kit. Key themes that emerged included:

1. Challenges at the household level in preparing conventional 1L sachets of ORS obtained from health centres, related to measuring the correct volume of water.
 2. The large quantity of solution produced (1L) compared with what a child will consume in 24 hours.
 3. Poor flavour of ORS obtained from health centres, contributing to reluctance of children to drink the solution.
 4. Preferences relating to branding and co-pack components.
 5. Willingness to pay (WTP) for a commercially available, co-packaged ORS and zinc product.
 6. Long distances to public sector treatment access points.
 7. Regular stock-outs at public sector rural health centres.
- The design of our co-packaged ORS/zinc product sought to address these themes as follows:
1. Offer an ORS sachet size better suited to a child’s consumption (ie, 200 mL).
 2. Use orange-flavoured ORS.
 3. Provide a measuring functionality through packaging design (figure 1).
 4. Enhance ease of use and facilitate improved adherence (eg, instructions, 200 mL measurement mark, transportability).
 5. Ensure attractiveness (eg, colour, images, brand name).⁶
 6. Establish a value-chain, to local retail outlets, for the co-packaged ORS/zinc product based on a retail price of ZMK5000 (US\$0.97) (ZMK, Zambian kwacha prior to 31 December 2012; USD value=average exchange rate in 2012.)

Intervention

The final co-packaged ORS/zinc product, branded Kit Yamoyo,¹ was assembled locally by Pharmanova, Zambia, using their own low-osmolarity ORS, based on the WHO formula. The salts were packaged in 200 mL sachets; during the trial, each kit contained eight sachets, a blister pack of ten zinc tablets and a small bar of soap (20 g). The contents were packaged in a lidded, plastic container, originally designed to ‘piggyback’ on Coca-Cola’s supply chain by fitting in the unused spaces between crated bottles of Coke. This container, dubbed the ‘Aidpod’ by the British Broadcasting Corporation, was designed to double as a measurement vessel for the volume of water required to correctly prepare the ORS. A measurement line was scored onto the container to denote the 200 mL mark. Reuse of the container in the home was promoted.

The 200 mL sachet size was approved by Zambia’s Pharmaceutical Regulatory Authority. The co-pack included an instruction leaflet, describing how to use the packaging to measure, mix and administer the ORS, along with dosage and regimen instructions for the zinc tablets. The leaflet carried the Kit Yamoyo branding and was held in place with a heat-sealed, breathable film; this sealed the entire kit, rendered it waterproof and performed a tamper evidencing function.

Caregivers involved in focus groups were presented with various options for images on the packaging. The most popular image, and the one adopted for the Kit Yamoyo branding, was that of a caring mother holding



Figure 1 Kit Yamoyo in use — using the packaging as a measuring device for the water needed to mix 200 mL of ORS. ORS, oral rehydration solution.

her smiling child. This image was reminiscent of the logo depicting a seated mother feeding her small child that was used in a very successful ORS campaign conducted in Egypt in the 1980s (figure 2).⁴⁴

Kit Yamoyo was made available through small, community shops in the two intervention districts.¹ With support from the Ministry of Health, approximately 30 community health workers from the two intervention districts were trained in the product's benefits, in giving product demonstrations, and tasked with sign-posting caregivers to participating shops.

Staff in 50 and 46 village shops in Kalomo and Katete, respectively, were similarly trained.¹

No co-packs were made available in the comparator districts. Baseline studies showed that Government of the Republic of Zambia (GRZ) health centres were the only alternative source of ORS and zinc in both the intervention and comparator districts, with very limited private-sector supply. In health centres, ORS were dispensed in sachets for the conventional 1 L of solution. GRZ-branded ORS were not flavoured and were not co-packaged with zinc. Caregivers typically



Figure 2 Kit Yamoyo (Zambia, 2013) and Mahloul Moalgett et Gaffaff (Egypt, 1985).

Table 1 Sample characteristics, including proportion of rational use*

Characteristic	Kit Yamoyo users (n=174)	1 L sachet users (n=233)
Mean age (years)	27 SD=7.9	29 SD=9.6
Proportion of caregivers with higher than primary education (%)	5 SD=22.5	9 SD=28.4
Proportion of caregivers who heard information relating to ORS in the previous 3 months (%)	71 SD=46	42 SD=50
Proportion of caregivers who prepared ORS to the correct concentration (%)	93 SD=26.4	60 SD=49.1

*The sample is based on those ORS users who prepared the entire contents of either Kit Yamoyo or the conventional 1 L sachets. ORS, oral rehydration salts.

received two 1 L sachets, depending on stock availability. Zinc was rarely dispensed with ORS, contributing to coverage rates of less than 1% at the beginning of the broader trial.¹

Study design, sample size and statistical analysis

The outcome for the analysis was rational use of ORS, defined as preparing ORS in the correct concentration, based on a WHO core determinant of rational use by consumers.¹⁸ The main outcome indicator was correct preparation of ORS given to children under 5 with diarrhoea in the 2 weeks preceding the survey. Diarrhoea was defined as experiencing three or more loose or watery stools in the previous 24 hours. This study used cross-sectional data gathered through household surveys in each district at the endline of the broader trial.¹ Kit Yamoyo users from intervention districts (children under 5 with diarrhoea in the two preceding weeks and who used ORS) were compared with non-users (ie, 1 L GRZ ORS sachet users), to investigate whether ORS was prepared in the correct concentration (table 1). To increase power, the sample of non-users was drawn from those using 1 L GRZ ORS sachets in both the intervention and comparator districts. Intervention and comparator district data were pooled after confirming similar outcomes within each arm.

An a priori sample size estimation was made prior to baseline to provide 80% power to detect a 30% difference in correct ORS preparation, with a two-tailed alpha of 0.05. Calculation assumptions, based on previous evidence, included that 60% of caregivers were able to correctly prepare ORS,^{22 24 45 46} 60% of children with diarrhoea received ORS,⁴⁷ and there was a 25% period prevalence for diarrhoea among children under 5 in Zambia.⁴⁷ This resulted in a sample size estimation of 420 children aged <5 years in each of the intervention and comparator groups. Given that the sample size used was based on the broader study, with more than 600 households with children under

5 per group, the sample size achieved was well within the required estimate for this study.

To assess the association between co-pack use and correct ORS preparation, we used a logistic regression analysis and calculated the odds ratio (OR) of correct ORS preparation among co-pack users versus 1 L GRZ ORS sachet users. A robust variance estimate was used to account for within-site correlation of outcomes.⁴⁸ Testing for confounding variables found that age of the respondent and having heard information relating to ORS in the previous 3 months were significantly associated with the main predictor of Kit Yamoyo use and were included in the model. We controlled for confounders by calculating the adjusted OR using a multivariable logistic regression model. All analyses were conducted using STATA V.13 (StataCorp).

Study instruments and sampling

The data used for this study came from an endline household survey that formed part of a larger study.¹ The survey was administered to independent, cross-sectional samples of caregivers of children under 5 in rural areas (>10 km from district towns) of four districts. Households were selected using a random-walk technique,⁴⁹ modified to avoid potential clustering effects and selection bias, with probability proportional to population size within each site. Population size was determined based on standard enumeration area (SEA) data provided by the GRZ Central Statistics Office.⁴⁷

Respondents were primary caregivers (aged >15 years) of a child under 5 with diarrhoea in the 2 weeks preceding the survey, to minimise recall bias and align with global standards (eg, DHS). To eliminate intra-household correlation, only a single reference child per household was selected, alphabetically when more than two children with diarrhoea were in the home. Respondents were asked to recall the episode of diarrhoea and about related treatment-seeking behaviour and knowledge.

Caregivers were questioned about how they prepared the ORS solution, the specific ORS product used, its source, the quantity from the sachet used during a single preparation, and the volume of water used. Correct ORS preparation was defined as preparing the solution to the correct concentration. The reported volume of water used was cross-referenced with information reported about the container used to measure the water, as well as to where it was filled. Interviewers were trained in advance on standard measurements (200 mL, 500 mL, 1 cup, 1 L, etc), as well as common containers (and their associated volumes) found at the rural household level. In cases where the container used to measure the water was available, interviewers asked for visual verification and were trained to take a photograph on the Samsung tablets used for data collection (figure 3), the first pictorial data of their kind.



Figure 3 Small selection of representative images, captured during this research, of the variety of containers used to measure water for the preparation of ORS from standard, 1 L commercial sachets. ORS, oral rehydration salts.

Accurate preparation of the correct concentration was determined by cross-tabulating the quantity of ORS used with the volume of water used. To maximise confidence in this accuracy, the analysis focused only on those caregivers who used an entire sachet of ORS. Those who used part of a sachet were excluded from the analysis ($n=68$, 29%), as there was no reliable mechanism for assessing the quantity of ORS they had used.

Experienced local staff from an external data collection agency were trained by the project team to pretest and subsequently administer all surveys in the local language. Surveys (20–60 min, depending

on responses) were conducted during August 2013, with data entered into Open Data Kit software on the Samsung tablets. Consistency checks to avoid data entry errors were automated. All data were cross-checked daily by trained field supervisors and uploaded each evening to a central server, checked by a data specialist for completeness and consistency, and coded or flagged for inconsistency and follow-up with interviewers.

Informed consent was obtained from all respondents prior to survey administration, through a signature or other marking. In Zambia, the age of consent is 16 years. Assent was obtained for caregivers under the age

of 16, with consent provided by their spouse or legal guardian.

RESULTS

Among the 2477 households with at least one child under 5 years, surveyed at endline, the prevalence of diarrhoea during the 2 weeks preceding the survey was 28.4% (n=704). Of those children with diarrhoea, 67.4% (n=475) used ORS across the intervention and comparator districts. We compared those who used Kit Yamoyo (n=174) versus those who used conventional 1 L sachets (n=233) with regard to preparing the ORS to the correct concentration (deemed as being accurate within 25 mL).

The variety of measuring vessels used by respondents to prepare ORS solutions could potentially be unsafe in terms of the volumes they measure or even by facilitating contamination of ORS (figure 3).

We found that just 60% (95% CI 0.54% to 0.66%) of 1 L sachet users prepared ORS to the correct concentration when preparing them at home. Of those who used Kit Yamoyo, using the packaging as a measurement vessel, 93% (95% CI 0.89% to 0.96%) prepared ORS solution to the correct concentration. The unadjusted OR of correct preparation, comparing Kit Yamoyo with 1 L sachet users, was 10.7 (95% CI 5.44 to 20.97, $p<0.001$). After adjusting for age and exposure to ORS messaging during the previous 3 months, the odds of correct ORS preparation were found to be 10.93 times greater (95% CI 5.74 to 20.78, $p<0.001$) in Kit Yamoyo users versus those who used 1 L sachets (table 2).

The reported number of 200 mL ORS sachets administered by caregivers who used the co-pack (containing eight sachets) is shown in figure 4. Among caregivers, 75% reported that they used four sachets or fewer, with just 10% reporting that they used all eight sachets provided. The caregivers who used four sachets or fewer treated their children over an average of 2.78 days, which was not significantly different from the duration of 2.75 days reported by caregivers using two 1 L sachets. It should be noted that dispensing two 1 L sachets permits a maximum treatment duration

of 2 days if caregivers follow instructions to mix one entire sachet with 1 L of water, discarding any unused solution after 24 hours.

Of the 100% of Kit Yamoyo users who said they would use ORS the next time their child had diarrhoea (n=173), 99% (95% CI 97.2% to 1.0%) of them specifically stated they would use Kit Yamoyo.

DISCUSSION

Our design thinking approach revealed several issues in relation to the use of ORS that could potentially be addressed through product design. Kit Yamoyo was thus designed based on caregivers' opinions, in contrast with many health products, which are often designed based on providers' opinions.

We found that 40% of caregivers in rural Zambia incorrectly prepared standard issue 1 L sachets of ORS. This was, at least in part, due to an inability to measure effectively the required volume of water to prepare the solution to the correct concentration. In addition, user and stakeholder consultations identified a key insight explored in this study: 1 L sachets produce too much oral rehydration solution to be consumed by a child in a single day in a home setting.

Accordingly, the Kit Yamoyo co-pack was designed to include 200 mL ORS sachets. Although this sachet size was novel and remains uncommon, it is one of the sizes listed in the WHO Essential Medicines List.⁵⁰ This design decision allowed the co-pack's packaging to serve as a vessel for measuring the correct volume of water to make up the ORS solution from the sachets provided. This standardised the home-based ORS preparation process and led to improved rational use by enabling ORS to be mixed to the correct concentration. The measurement vessel, combined with the smaller, 200 mL ORS sachets, empowered caregivers by removing uncertainty, enabling correct health behaviour and instilling confidence in their ability to effectively treat their children at home. In 2019, supported by evidence from research related to the work described here, WHO changed their Model Essential Medicines Lists to recommend that ORS and zinc be co-packaged.^{51 52}

Table 2 Odds of correct ORS solution preparation*†

Characteristic	Unadjusted, simple logistic model		Multivariable logistic regression model	
	OR (95% CI)	P value	OR (95% CI)	P value
Kit Yamoyo (n=174) vs 1 L ORS sachet (n=233)	10.7 (5.44 to 20.97)	<0.001	10.93 (5.74 to 20.78)	<0.001
Age of caregiver (for every additional year) (n=174 for Kit Yamoyo users and n=233 for 1 L sachet users)	0.98 (0.96 to 0.99)	0.007	0.98 (0.97 to 1.00)	0.089
Heard information relating to ORS in previous 3 months vs heard no such message (n=174 for Kit Yamoyo users and n=233 for 1 L sachet users)	1.48 (1.07 to 2.06)	0.019	0.84 (0.54 to 1.32)	0.456

Figures in bold font denote statistically significant values.
 *Based on those who prepared the entire contents of the sachet.
 †Adjusted for within-site correlation using robust variance estimate.
 ORS, oral rehydration salts.

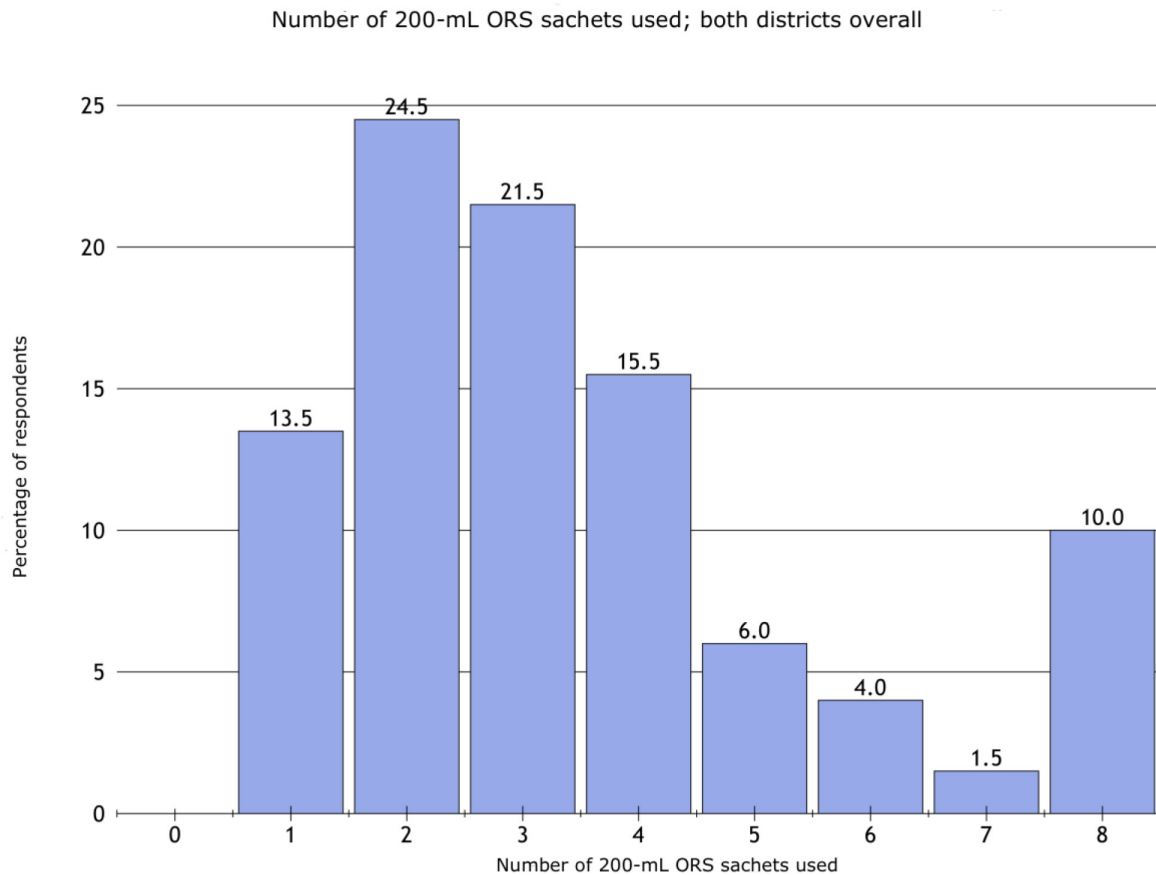


Figure 4 Number of sachets used reported by caregivers using an ORS/zinc co-pack containing 8×200 mL ORS sachets (n=174). ORS, oral rehydration salts.

Our findings beg the question of whether the global health community should be assessing coverage based on the rational use of ORS, rather than reported use alone. There is a need for greater confidence in whether ORS solutions are being prepared correctly. However, as with the current coverage indicator, a practical approach under routine data collection would likely require the indicator to be based on reported rather than observed evidence. Products developed using human-centred design thinking, which can help facilitate correct treatment and health behaviour, may help provide greater confidence in such reported data. Standardised treatment processes that are not dependent on patients' ability to recall information, technical expertise of health workers, or health facility supplies and equipment also offer tremendous potential for business model innovation—one in which patients' expectations and preferences are understood and prioritised.

Our work suggests that a treatment cannot be considered delivered until it is correctly prepared, administered and used by the end user. The global indicator used to assess progress in diarrhoea treatment—that is, coverage—is defined as the proportion of children with diarrhoea in the 2 weeks preceding a household survey who received ORS.⁵³ This is based

on reported administration of ORS by the caregivers being interviewed. However, our study showed that 40% of caregivers who reported giving ORS to their children, using standard 1 L sachets, prepared them to an incorrect concentration. This can have negative consequences for the efficacy of ORS. It was also probably a conservative estimate of incorrect use, given that our analysis focused only on those caregivers who used the entire sachet of ORS; 29% did not. Those who did not prepare the entire sachet were more likely to have prepared a solution of incorrect concentration, thus the proportion of users who prepared the solution incorrectly would likely be higher than shown by our findings. Incorrect preparation of ORS has important implications for global health research and policy, given that coverage figures from DHS and other routine surveys that use the current indicator of ORS coverage are not using an indicator based on rational use.

Subsequent work for the scale-up, mainstreaming and commercialisation of Kit Yamoyo in Zambia has moved away from the awkward (yet unique and identifiable) shape of the original co-pack packaging, which had been manufactured in the UK. Eliminating the original packaging allowed the project to refocus on simple, low-cost packaging formats (figure 5) that

A



B



C



Figure 5 New ORS/zinc co-pack post-trial formats designed and used for scale-up. (A) The new ‘flexi-pack’ design used during the scale-up phase. Left: New commercial format (Kit Yamoyo). Right: New government format (GRZ ORS/zinc co-pack). Each format has the same contents: 4x200 mL ORS sachets, one blister pack of 10 zinc tablets and an instruction leaflet that also carries the branding. (B) The new screw-top design used during the scale-up phase. (C) Both scale-up formats use the packaging as a measuring device. Note that the flexi-pack has a 200 mL mark on each side of the bag (only one side is shown here). These enable water to be measured while holding the bag in the hand. The bag has a volume of 200 mL when the water is simultaneously aligned with both marks. GRZ, Government of the Republic of Zambia; ORS, oral rehydration salts.

retained its key features, including the measurement functionality, co-packaging and branding (figure 5c).

Based on the reported number of 200 mL sachets used (figure 4) and the affordability imperative, the co-packs in the scale-up contain four 200 mL sachets of ORS. More research is needed to ascertain the optimum number of 200 mL sachets to include in an ORS/zinc co-pack.

Poor adherence to the 10–14 days zinc regimen is the norm,⁵⁴ so similar design thinking and further study will be required to optimise the effective use of zinc. Future research should focus on how human-centred design might help improve adherence and dosage. Recent WHO recommendations (2019), that ORS and zinc be co-packaged,⁵⁰ should stimulate innovation in packaging design to encourage rational use of both ORS and zinc, with the newly launched ORS/Zinc Co-Pack Alliance⁵⁵ being well placed to disseminate such innovations.

LIMITATIONS

While this study was based on caregivers' reported use of ORS, it could have been strengthened by observing caregivers, to verify the accuracy of reported solution preparation. However, such studies are logistically more difficult and costly to run at the household level. Using a 2-week recall period helped mitigate inaccurate reporting. In addition, there may have been some ambiguity associated with the size of the container used to prepare ORS solutions; however, the interviewers were well trained in asking for descriptions of the containers used, if a specific volume was not clear. Training the interviewers in advance, so they were familiar with standard cup sizes and common containers found in rural households, helped ensure a high degree of confidence in the assessments of correct concentration.

Twitter Rohit Ramchandani @DrRRamchandani

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Contributors RR conceived and designed the study. SB, JB and RR were responsible for the design, coordination and implementation (in collaboration with partners including the Ministry of Health, Pharmanova, UNICEF, Medical Stores, SAB Miller, PI Global, etc) of technical aspects of the trial, including the ORS and zinc co-pack (Kit Yamoyo). AS played a key role in fieldwork and project management on behalf of ColaLife's implementation partner, Keepers Zambia Foundation. RR was the PI and guarantor for the study, led the data-collection team and fieldwork for the household surveys, performed the analyses and wrote the first draft of the manuscript. BAP, SB and JB edited the manuscript. REB reviewed the manuscript and served as an ongoing advisor. All authors contributed to the revision of the manuscript and have approved the final version to be published.

Competing interests ColaLife is an independent UK charity. While it accepts grants and seeks learning from corporate entities it does

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Patient and public involvement Patients and/or the public were involved in the design, or conduct, or reporting, or dissemination plans of this research. Refer to the Methods section for further details.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants and implementation of the project was authorised by national and district government health administrations and through local chiefs. Ethics approval was obtained from ERES Converge in Zambia (IRB No. 00005948; Ref. No. 2012-Jun-002), with approval for secondary analysis from the Johns Hopkins Bloomberg School of Public Health Institutional Review Board. Participants gave informed consent to participate in the study before taking part.

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ORCID iD

Rohit Ramchandani <http://orcid.org/0000-0003-4111-7670>

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