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Reasons for Inconsistent Condom Use among Female Sex Workers: Need for Integrated Reproductive and Prevention Services

Reasons for Persistence of Dwelling Vulnerability to Chagas Disease (American Trypanosomiasis): A Qualitative Study in Northeastern Brazil

Resource Allocation in Pakistan's Health Sector: A Critical Appraisal and a Path toward the Millennium Development Goals

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From the Editor-in-Chief

This issue of *World Health & Population* presents three original research papers that should be of great interest to our readers, in addition to a high-quality paper reprinted from the *International Journal of Environmental Research and Public Health (IJERPH)*. The original papers have all been published online by *WHP* during the last quarter and are selected here as representative of recent outstanding contributions to the journal.

The first paper in this issue, "Reasons for Inconsistent Condom Use among Female Sex Workers: Need for Integrated Reproductive and Prevention Services," reports on an HIV prevention study in Conakry, Guinea. Authors Josephine Aho and colleagues examine the regularity of use of condoms by females sex workers (FSWs), both with paying clients and with their regular non-client sex partners. There was a large discrepancy in condom usage – nearly 100% with commercial clients but only 80% with regular non-client partners. The study identified a desire to have children, not lack of knowledge about HIV transmission, as a primary driver of inconsistent condom use. The authors hypothesize that marriage and children may be seen as means for the FSW to escape sex work. The study recommended that HIV prevention activities with FSWs consider the individual holistically, and not just focus narrowly on prevention behaviours such as condom use. Involvement of FSW's regular, non-client partners was also seen as critical.

In our second paper, Taís Gomes and colleagues examine the relationship between traditional and improved housing and the transmission of Chagas disease in Northeastern Brazil. Using qualitative methods and structured interviews, the authors examine the interplay between humans, their domiciles and the disease vector – triatomine bugs – which are well adapted to the typical mud structures people live in. Notably, the triatomines are responsible not only for Chagas disease but also for widespread food-borne illnesses. A simple answer is better housing. However, beyond the impact of poverty alone, government land policy and traditional housing preferences (e.g., mud huts) continue the link between disease victims, where they live and insect vectors. Even though the cost of improved housing is currently on par with the cost of mud huts, because of the need to buy the necessary wood, cultural, economic, and policy barriers remain. Again, a more holistic approach is needed to address the vicious circle of disease, poverty and counterproductive government policy.

"Resource Allocation in Pakistan's Health Sector: A Critical Appraisal and a Path toward the Millennium Development Goals" is the third paper in this issue. In the context of the Millennium Development Goals (MDGs), Babar Sheikh and colleagues analyze financing mechanisms prevalent in Pakistan's healthcare delivery system. Largely due to persistent poverty and long-standing political turmoil, Pakistan ranks very low among lower- and middle-income countries in government per capita healthcare expenditure. The healthcare delivery infrastructure, however, is equally weak and would be inadequate, at least in the short run, to absorb increased investment and improve health outcomes. Those who can afford care from the private sector obtain it, thus increasing the equity and access gap between the poor and the not-so-poor. The authors present health financing challenges and opportunities in the context of political "devolution" in Pakistan – the return of making policy and financial decisions to the provinces and away from the traditional highly centralized approach in the country. They conclude that although a myriad of factors are holding back progress toward meeting the MDGs in Pakistan, the devolution initiative empowers provinces to develop innovative, locally relevant and feasible approaches, in particular in the healthcare financing arena.

The final paper in this issue is the reprint from *IJERPH*, "Global Access to Safe Water: Accounting for Water Quality and the Resulting Impact on MDG Progress," by Onda, LoBuglio and Bartram. Onda and his colleagues are at The Water Institute, Gillings School of Global Public Health, University of North Carolina at Chapel Hill. They propose that adequate monitoring of progress toward the MDG drinking water target (MDG 7c) must include measures of water quality and protection, not just counted as

"improved" on the basis of construction or installation alone. When adjusted, the measures show a shortfall of 10% in the achievement of the MDG, contradicting the widely heralded achievement of this MDG target.* Measurement issues matter, and the public, policy makers and politicians alike need to be careful not to "declare victory and leave" too soon. As a side note, Figure 1 in this paper, "World population by water contamination status and sanitary risk, 2010," is a particularly illuminating categorization of the status of the world's population in terms of access to safe drinking water.

In conclusion, the world is rapidly approaching the target date of 2015 for achieving the MDGs, and studies are proliferating about progress, lack of progress, and the need for greater progress toward achievement. Although many MDGs appear less and less likely to be realized, in particular in the most needy areas of the world, the attention the MDGs are still receiving is welcome and needed. The work we have to do will be ongoing.

In summary, we hope that you find the papers in this issue interesting and worthwhile, and that you will also consult others recently released online at www.worldhealthandpopulation.com. WHP remains committed to its mission to provide a forum for researchers and policy makers worldwide to publish and disseminate health- and population-related research, and to encourage applied research and policy analysis from diverse global and resource-constrained settings. *WHP* is indexed on MEDLINE and is accessible through PubMed.

We look forward to continued enthusiastic submission of manuscripts for consideration, peer review and publication. Finally, the editors and publishers of WHP are always interested in any comments or suggestions you might have on the papers or about the journal and our mission. Please feel free to write or e-mail us.

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* For example, Wijeseker, S. 2012, March 6. "MDG Drinking Water Target Being Met Is Cause for Celebration." *The Guardian (UK) Policy Matters Blog*. Retrieved June 5, 2013. < http://www.guardian.co.uk/global-development/poverty-matters/2012/mar/06/mdg-drinking-water-target-met>.

Reasons for Inconsistent Condom Use among Female Sex Workers: Need for Integrated Reproductive and Prevention Services

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Abstract

Background: Interventions for condom use promotion have been undertaken for HIV prevention among female sex workers (FSWs). Our aims are to (1) assess the frequency of inconsistent condom use with clients and with the main regular non-client sex partner (RNCP); and (2) investigate factors associated with inconsistent condom use with the RNCP, particularly the desire to have children and links of the RNCP with commercial sex work.

Methods: A cross-sectional study was conducted in Conakry, Guinea, among 223 FSWs. A questionnaire on socio-demographic characteristics, behaviours and desire for children was administered. Descriptive statistics and logistic regression were performed.

Results: Inconsistent condom use was frequent with the RNCP but rare with the clients (80.4% vs. 1.3%). FSWs' desire for children was strongly associated with inconsistent condom use with the RNCP.

Conclusion: Interventions that take into account reproductive health are needed to prevent HIV among FSWs and their children.

Introduction

Female sex workers (FSWs) are a vulnerable population with a high risk of HIV infection in several developing countries that have primarily heterosexual epidemics. Prevention of HIV in this population, which has an extended sexual network, is of paramount importance, particularly in countries of low general population prevalence where this high-risk group may contribute greatly to the national incidence (Boily et al. 2002; Godin et al. 2008).

Apart from structural ones, interventions aimed at preventing HIV among this high-risk population are threefold: (1) condom use promotion, (2) screening and treating sexually transmitted infections (STIs), and (3) voluntary counselling and testing (VCT) promotion (Shahmanesh et al. 2008). Condom use promotion includes, in particular, the distribution of condoms and condom use negotiation (Feldblum et al. 2005; Foss et al. 2007).

Interventions aimed at increasing condom use among FSWs have targeted mainly FSWs and their male clients and have been successful at increasing condom use in commercial partnerships (Foss et al. 2007; Lowndes et al. 2000). However, risky sexual behaviour among FSWs may differ according to partner type. For example, while some studies have reported high rates of condom use ranging from 80 to 100% when considering FSWs and their client partners, (Alary et al. 2002; Cote et al. 2004), others have shown that FSWs tend to use condoms less frequently with their regular non-client sex partners (RNCPs) (Ulibarri et al. 2012; Wong et al. 2003). One factor contributing to non–condom use that has been extensively examined among HIV-positive individuals is the desire for children (Myer et al. 2007; Nattabi et al. 2009). However, this factor has not been studied in high-risk populations such as FSWs. Moreover, literature is scarce on the extent of RNCP participation in commercial sex and the impact of participation on the frequency of condom use between an FSW and her RNCP.

In the context of a cross-sectional study on VCT among FSWs in Conakry, Guinea, we examined the frequency of inconsistent condom use with clients and with RNCPs among the participants, and we investigated factors associated with inconsistent condom use with RNCPs.

Methods

Study Population

In 2005–2006, we conducted an investigation of the acceptability and consequences of VCT of HIV in a cohort of 421 FSWs in Conakry, Guinea (Aho et al. 2012). Participants in this study were initially recruited at three private or public health centres with adapted healthcare (AHC) for FSWs in Conakry. To avoid stigma, AHC services offer medical care and assistance adapted to the specific needs of FSWs and are integrated into antenatal clinics or general healthcare. These AHC services were implemented in collaboration with the West Africa AIDS program (AIDS 3), a Canadian program aimed at HIV prevention through syndromic control of STIs for FSWs and their partners, and promoting health in the community (Morin et al. 2008). Any woman practising commercial sex work, defined as self-reported history of sexual relations in exchange for money, in the month preceding her visit to the AHC was eligible for the study. The baseline prevalence of HIV in our study population was 38.1% (Aho et al. 2012). One year after recruitment, a second follow-up visit took place, with further data collection. A total of 223 women participated in this follow-up visit, and the prevalence of HIV was 35.3% at follow-up. We present in this article data drawn from this visit. The study was reviewed and accepted by the Committee for Research Ethics of the University of Montreal and by the National Committee of Ethics of Guinea. All subjects provided informed consent before participating in the study. Participating women received financial compensation for their transport and interview time. Free condoms and lubricants were distributed to them.

Data Collection Procedures

Data collection for the follow-up visits took place from June to December 2006 in the three AHC

centres in Conakry as well as in worksites (bars, brothels and nightclubs). Information on socio-demographic characteristics, variables related to sex work, behavioural variables and variables related to exposure to preventative interventions was collected in face-to-face interviews. All interviewers, most of whom were health agents, were specifically trained for this study. Characteristics of participants in the follow-up visit did not differ significantly from those who participated at initial enrolment (Aho et al. 2012).

Variables and Variables Definitions

Our questionnaire included the questions (1) "How often did you use condoms for sex with your main RNCP in the past three months?" and (2) "How often did you use condoms fox sex with your clients in the last week?" Using this data, we defined two variables: (1) consistency of condom use with the RNCP, defined as having always used a condom in sexual encounters with the RNCP in the preceding three months, and (2) consistency of condom use with clients, defined as having always used a condom in sexual encounters with clients during the preceding one week. We analyzed inconsistent condom use with the RNCP or with clients as dichotomous (yes vs. no) variables.

In addition to examining frequency of inconsistent condom use, we also investigated factors associated with inconsistent condom use with the RNCP in the preceding three months. Independent variables that were investigated included age (continuous), current attempts toward pregnancy (dichotomous: yes or already pregnant vs. no), the FSW's desire for children (dichotomous: yes vs. no), the RNCP's desire for children (dichotomous: yes vs. no), parity (dichotomous: 0 vs. 1), duration of the relationship with the RNCP (categorical: ≤12 months, >12 months), awareness by the RNCP that his partner is an FSW, as reported by the FSW (dichotomous: yes vs. no), RNCP being a client at his partner's worksite (dichotomous: yes vs. no), self-perception of HIV risk (dichotomous: low to intermediate vs. high or already HIV-positive). All of these variables were measured in the questionnaire administered to the FSW.

Analyses

To describe the study population, proportions, means and standard deviations (SD) were calculated. For the first objective, prevalence estimates of inconsistent condom use with the RNCP and with clients were calculated. For the second objective, variables associated with inconsistent condom use with the RNCP among participants who had one were explored using logistic regression. Crude prevalence odds ratios (PORs) and their 95% confidence intervals (CIs) were calculated. All variables associated with inconsistent condom use at $p<0.25$ in the bivariate analyses were included in a multivariate logistic regression analysis. Adjusted PORs and their 95% CI were determined. SPSS 17.0 was used for statistical analysis.

Results

Characteristics of the Study Population

A total of 223 subjects participated in the study. Participants' age ranged from 16 to 46 years (mean: 27.1 years, SD: 6.1 years). Most of the women (109/223, 48.9%) were divorced, separated or widowed; 7.2% were married and 43.9% single. Mean duration of sex work was 30 months, and FSWs reported a mean of 25.0 clients in the week preceding their interview (SD = 12.1). The mean monthly income of FSWs was 88.9 US dollars (SD = $32.6). A majority of participants (168/223, 75.3%) currently had one or more RNCPs (Table 1). Other characteristics of the population are presented in Table I.

Table 1. Characteristics of the study population

Variables	N (%)[a]	
	All participants (*n* = 223)	Participants with an RNCP (*n* = 168)
Socio-demographic variables		
Age, mean (SD)	27.1 (6.1)	26.2 (5.5)
Marital status		
Single	98 (43.9)	85 (50.6)
Divorced, separated, widowed	109 (48.9)	69 (41.1)
Married	16 (7.2)	14 (8.3)
Monthly income in USD, mean (SD)	88.9 (32.6)	86.2 (32.4)
Number of regular non-client partners		
0	55 (24.7)	–
≥1	168 (75.3)	168 (100.0)
Parity		
0	50 (22.4)	139 (23.2)
≥1	173 (77.6)	129 (76.8)
Prior abortion		
No	176 (78.9)	132 (78.6)
Yes	47 (21.1)	36 (21.4)
Sex work and behaviour		
Duration of sex work		
≤ 24 months	142 (64.8)	105 (64.0)
> 24 months	77 (35.2)	59 (36.0)
Number of clients in the preceding week, mean (SD)	25.0 (12.1)	24.6 (12.1)
Violence episode from a client in the preceding three months		
No	169 (76.1)	124 (74.3)
Yes	53 (23.9)	43 (25.7)
Inconsistent condom use with clients in the preceding week		
No	220 (98.7)	166 (98.8)
Yes	3 (1.3)	2 (1.2)
Alcohol consumption		
No	118 (52.9)	84 (50.0)
Yes	105 (47.1)	84 (50.0)
Perceived HIV risk and HIV serostatus		
Self-perceived risk of HIV infection		
Low to intermediary	136 (61.0)	106 (63.1)
High or HIV positive	87 (39.0)	62 (36.9)
HIV serostatus		
Negative	143 (64.7)	113 (68.1)
Positive	78 (35.3)	53 (31.9)
RNCP is a customer in the FSW's worksite		
Yes	–	7 (4.2)
No		161 (95.8)

Table 1. Continued

Variables	N (%)[a]	
	All participants (*n* = 223)	Participants with an RNCP (*n* = 168)
RNCP works at the FSW's worksite		
Yes	–	32 (19.0)
No		136 (81.0)
FSW's desire for children with her RNCP		
No	–	118 (70.7)
Yes		49 (29.3)
RNCP's desire for children with the FSW		
No	–	69 (41.3)
Yes		98 (58.7)
Current attempts toward pregnancy		
No	179 (80.3)	126 (75.0)
Yes or already pregnant	44 (19.7)	42 (25.0)
Inconsistent condom use with the RNCP in the preceding three months		
No	–	32 (19.2)
Yes		135 (80.4)

FSW = female sex worker; RNCP = regular non-client sex partner; SD = standard deviation; USD = US dollars.
[a] Except for continuous variables (age, monthly income, number of clients) for which means and standard deviations are presented.

Prevalence of Inconsistent Condom Use

The prevalence of inconsistent condom use with clients was rare (3/223, 1.3%). Conversely, among participants who reported having an RNCP, the prevalence of inconsistent condom use was frequent (135/168, 80.4%). All women stated that consistent condom use can prevent HIV acquisition (223/223, 100%). The majority of FSWs said that women can protect themselves from acquiring an STI from an infected partner by asking for condom use during the infection (203/223, 91.0%).

Factors Associated with Inconsistent Condom Use with the RNCP

Almost half of RNCPs were reportedly aware that their partner was a sex worker (72/167, 43.1%, Table 1). A fifth of RNCPs were regular clients in their partner's worksite (32/168, 19.0%) (Table 1). However, neither of these variables, nor age, was associated with inconsistent condom use in bivariate analysis (Table 2). On the other hand, current attempts toward pregnancy and desire for children from the FSW or her RNCP, as well as self-perception of HIV risk, were strongly associated with inconsistent condom use (Table 2). In multivariate analysis, we did not include current attempts toward pregnancy because of its co-linearity with the FSW's desire for children. In the multivariate model, only the FSW's desire for children remained statistically significantly associated with inconsistent condom use with the RNCP (OR = 13.60, 95% CI = 1.66–111.37).

Table 2. Factors associated with inconsistent condom use with the RNCP among FSWs who have one (*n* = 167)

Variables	Inconsistent condom use N (%)[a]	Crude OR (95% CI)	*P*-value	Adjusted OR (95% CI)
Age, mean (SD)	26.0 (5.2)	0.97 (0.91–1.04)	0.429	–
Monthly income in USD, mean (SD)	87.7 (22.3)	1.13 (0.88–1.46)[b]	0.339	–
Current attempts toward pregnancy				
No	95 (75.4)	1.00 (reference)		–
Yes or currently pregnant	40 (98.0)	6.32 (1.44–27.70)	0.015	
FSW's desire for children with her RNCP				
No	86 (72.9)	1.00 (reference)		.00 (reference)
Yes	48 (98.0)	17.30 (2.29–130.74)	0.006	13.60 (1.66–111.37)*
RNCP's desire for children with the FSW				
No	47 (68.1)	1.00 (reference)		1.00 (reference)
Yes	87 (88.8)	3.53 (1.57–7.95)	0.002	1.36 (0.55–3.41)
Parity				
≥ 1	103 (79.8)	1.00 (reference)		
0	32 (82.0)	1.11 (0.44–2.80)	0.826	–
Prior abortion				
No	104 (79.4)	1.00 (reference)		
Yes	31 (86.1)	1.61 (0.57–4.53)	0.367	–
Duration of the relationship with the main RNCP				
≤ 12 months	44 (73.3)	1.00 (reference)		1.00 (reference)
> 12 months	91 (84.3)	2.07 (0.95–4.51)	0.068	2.19 (0.94–5.10)
Main RNCP's awareness of his partner FSW's sex-worker status				
Yes	57 (79.2)	1.00 (reference)		
No	78 (82.1)	1.28 (0.59–2.81)	0.533	–
RNCP is a customer in the FSW worksite				
Yes	24 (75.0)	1.00 (reference)		
No	111 (81.6)	1.54 (0.62–3.84)	0.353	–
Self-perceived risk of HIV infection				
Low to intermediary	80 (75.5)	1.00 (reference)		1.00 (reference)
High or HIV positive	55 (90.2)	2.98 (1.15–7.72)	0.020	2.45 (0.87–6.95)
HIV serostatus				
Negative	93 (83.0)	1.00 (reference)	0.383	–
Positive	41 (77.4)	0.70 (0.31–1.57)		

CI = confidence interval; FSW = female sex worker; OR = odds ratio; RNCP = regular non-client sex partner; SD = standard deviation; USD = US dollar.

[a] Except for continuous variables (age, monthly income, number of clients) for which means and standard deviations are presented.

[b] OR calculated for an increase of 20 dollars in income (approximately corresponding to the income SD).

[c] Current attempts toward pregnancy were not included in the multivariate analysis because of a strong co-linearity with desire for children.

* $p < 0.05$.

Discussion

Our study aimed to explore factors associated with condom use. We found that the FSW's desire for children was strongly associated with inconsistent condom use.

This study has shown that a high number of clients as well as a high desire to have children are both part of the reality of this population of FSWs. RNCPs can work or be a client in the sex worksite. Getting married and motherhood could be seen as a means to escape sex work (Mantoura et al. 2003).

As reported elsewhere in the literature (Alary et al. 2002; Cote et al. 2004; Ulibarri et al. 2012; Wong et al. 2003), condom use by FSWs was more frequent with clients than with RNCPs in our study. Generally, RNCPs of FSWs have been less studied or targeted by HIV/STI interventions than clients of FSWs. However, Lowndes et al. (2002) reported that almost half of RNCPs were involved in their girlfriend's work, and 66% had other regular sex partners besides their FSW partner, 11% of whom were also FSWs. In fact, our study showed that almost half of RNCPs were aware of the FSW status of their partner and more than one fifth of RNCPs were either regular customers in their partner's worksite or worked at the bars. This may lead to a higher risk of HIV infection among RNCPs. A study has shown that HIV prevalence among RNCPs was twice that of the clients' (Lowndes et al. 2002).

Our findings highlight the fact that commercial and non-commercial sex relations are not two separate worlds. Stoebenau (2009) reported from an ethnographic study conducted in Madagascar that the distinction between RNCPs and clients did not exist for some FSWs. The relationship between clients and FSWs is dynamic, and when affective ties appear in the relationship, condom use may be less appealing. In our study, the association between longer duration of the relationship with the partner and reporting less condom use almost reached statistical significance. Ties of the RNCP with the FSW worksite had no impact on consistency of condom use. More importantly, the FSW's desire to have children was strongly associated with inconsistent condom use with the RNCP. However, despite the high baseline prevalence of HIV of 38.1%, only one fourth of the enrolment sample had undergone an HIV test before the study and only 12% of seropositive FSWs were on antiretroviral therapy (Aho et al. 2012). These results show the importance of taking reproductive health into account while designing HIV preventive interventions, as has been the case in positive prevention programs. In studies of serodiscordant couples, it has been shown that despite recommendations to use condoms to avoid HIV transmission, the desire for children was an important factor to take into account (Myer et al. 2007; Nattabi et al. 2009; Oladapo et al. 2005). Reproductive health services aimed at FSWs may also be useful as part of prevention of HIV transmission from mother to child in this highly infected population at child-bearing age.

The intertwining relationship between sex work and non–sex work makes prevention particularly challenging when it comes to promoting condom use and reproductive health, including prevention of mother-to-child HIV transmission. As the high STI burden experienced by FSWs can impair their fertility (Westrom 1994), the duration of attempts toward pregnancy by non–condom use could be long, increasing risks of HIV transmission. Thus, condom use promotion should be a part of a comprehensive strategy for sexual and reproductive health in FSWs. Such a holistic approach should integrate STI/HIV prevention and reproductive health matters, including relationships with an RNCP. This strategy, which could take place in settings already attended by FSWs, such as the AHC, should be implemented for this population and their sexual partners to deal with sex-work and non-sex-work issues as those two worlds are frequently not easy to demarcate. It should be aimed at RNCPs as well as at FSWs.

This study has several limitations. First, the cross-sectional data collection may have prevented us from capturing the temporality for some associations such as condom use and desire for children. Second, the recall of some variables may be inaccurate, but the relatively short period of recall (less than three months) required for most variables may have contributed to minimizing recall error. Third, some data on RNCPs, such as their desire for children, was collected from FSWs and not from the partner himself. This indirect reporting may be inaccurate and may

overestimate the desire, especially when the FSW herself has a desire for children. Last, the limited sample size of this study led to low precision of some estimates and may have led to a failure to detect some associations.

However, our study is one of the first, to our knowledge, to assess associations between condom use, desire for children and participation of the RNCP in the sex work.

Conclusions

In conclusion, our results show that condom use by FSWs is a complex sexual health matter that relates not only to HIV prevention but also to reproductive health. Thus, condom use should be approached in a holistic manner to achieve a comprehensive and effective strategy to fight HIV in populations most at risk.

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Reasons for Persistence of Dwelling Vulnerability to Chagas Disease (American Trypanosomiasis): A Qualitative Study in Northeastern Brazil

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Abstract

Interaction between Chagas disease vectors and man is continuous in vulnerable dwellings, in which the vectors feed on man and find conditions for reproduction. This study explores factors that affect the choice of home construction methods in a rural community in Brazil, emphasizing the rationale for the persistence of dwelling vulnerability. Information on local resident perspectives regarding safety and home construction methods was gathered through domiciliary interviews with open questionnaires. The study revealed a large proportion of vulnerable mud huts, with others under construction.

Insecurity over land tenure inhibits the construction of definitive houses. Mud homes are associated with greater structural stability. Cultural and economic factors have clearly been linked to the choice of method for home construction. The economic evolution of family conflicts with traditional aspects as well as the relative increased cost of the materials needed for mud house construction has not completely inhibited building with mud.

Introduction

Endemic Chagas disease, discovered at the beginning of the twentieth century, is the result of the close interaction between hematophagous insect vectors that transmit the protozoa *Trypanosoma cruzi* (the etiological agent) and man (Coura and Borges-Pereira 2012; Coura and Junqueira 2012; Neiva 1910, 1913). This vector–man interaction emerged from the establishment of propitious conditions for the triatomine colonization of human dwellings, that is, the development of a new habitat for these insects, an ecotope affording conditions for survival and reproduction (Dias 1946, 1954; Gurevitz et al. 2012; Hashimoto et al. 2012).

This process introduced man into the ancestral enzootic cycle of the parasite in nature (Guhl et al. 2009; Kirchhoff 2011; Prata et al. 2011; Roque et al. 2013). The socioeconomic characteristics of the settling process throughout the outback of northeastern, central, southeastern and southern Brazil were responsible for the demographic phenomena resulting in the establishment of the basic man–insect interaction unit – the mud hut, a primitive and particular kind of dwelling. In this context, characteristics of the Brazilian colonization process, such as landlordism, the enslavement of Africans, the imposition of European culture on the Amerindians, assimilation of mono cultivation and an export-oriented economy have produced poverty in vast rural regions (Prado Junior 1979; Wegenast 2010).

… contamination of food with T. cruzi–infected triatomine feces … has led to many food-borne outbreaks.

Recently, the transmission of Chagas disease in Brazil is shifting to the northern (Amazon) region and is associated with contact between man and non-domiciled wildlife vectors (Monteiro et al. 2012; Ricardo-Silva et al. 2012). The contamination of food with *T. cruzi*–infected triatomine feces is an example of such contact and has led to many food-borne outbreaks (Beltrão et al. 2009; Nóbrega et al. 2009), even outside the Amazonian region (Shikanai-Yasuda and Carvalho 2012). In addition, transmission of Chagas disease through blood transfusion has become an ever-increasing concern in non-endemic countries in Europe and North America as a result of emigration from Central and South America (Agapova et al. 2010; Jackson et al. 2009).

As the first step to a current comprehension of social and economic determinants of insect-borne transmission in northeastern Brazil, we have been studying the rationale for the persistence of dwelling vulnerability into the twenty-first century. In this paper we discuss some aspects that may be associated with the maintenance of vector-borne transmission of Chagas disease.

Population and Methods

In 2012, we visited rural localities in the semi-arid region of northeastern Brazil, within the Caatinga biome on the shore of Santo Antonio, an artificial lake created in 1927 and expanded in 1958. Chagas disease is considered endemic in this region (Alencar 1987). The lake is strategic for the irrigation projects carried out by the national anti-drought department (DNOCS, Portuguese acronym) in the lower Jaguaribe River region. Timbaúba do Pitingão, together with the localities of Riacho do Barro, Lagoa do Mato, São Pedro de Cima, Capim Grosso and Tabuleirinho, all located on the perimeter of the Santo Antonio reservoir, will be further studied in this research project.

We approached thirty-seven families to take part in our research. One occupant in each residence was interviewed in a qualitative study through semi-structured questionnaires. The survey axes were

organized into four spheres: (i) characteristics of the local landownership structure, (ii) activities involving household maintenance and income, including the characterization of extreme poverty defined by a per capita family income below 30 US dollars, (iii) perceptions concerning household safety regarding the transmission of Chagas disease, and (iv) possibilities and options for home building methods. The interviews addressed the four main spheres of qualitative observation, leaving respondents free to express their knowledge and insights on each topic. Responses were recorded for subsequent analysis.

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Thus, descriptive data were obtained through direct, interactive contact between researchers and interviewees. The methodological design employed was the case study, in which we sought a detailed examination of an environment, together with its inhabitants. All responses on each main study topic were systematically reorganized into a comprehensive framework, synthesizing residents' beliefs and perceptions with respect to the persistence of housing vulnerable to Chagas disease in the region.

Results

Our observations in the Timbaúba do Pitingão locality confirmed a large proportion of mud hut dwellings, with more under construction. Of the 37 families we visited, 51% (19) had decided to build their houses with mud and wood (Figure 1).

Figure 1. Dwellings in Timbaúba do Pitingão, State of Ceará, northeastern Brazil

A A mud hut in which the outer surface of mud has collapsed, exposing the wooden frame.
B A mud house partially damaged, although part of the coating of clay, painted white, is preserved.
C A clay block house, newly built, beside a mud house.

D An improved clay block house.

Interviewees' responses led us to realize that almost all inhabitants leased the land from the Brazilian federal government, in an irrigation and colonization program administered by DNOCS. Participants in the program pay low fees for the land – approximately 30 dollars per year for seven hectares. More fertile land is available during the six-month drought than in the rainy season, which causes flooding. People mainly plant corn and beans, but squash, cucumber, papaya and guava are also grown. Most of these crops, as well as goats, sheep, chickens and pigs that are reared, are for home consumption.

Our observations in the Timbaúba do Pitingão locality confirmed a large proportion of mud hut dwellings, with more under construction.

In our study we also strive to characterize activities associated with household maintenance and income for the definition of extreme poverty. Most families do not receive government income assistance (Family Financial Aid, a federal income transfer program to mitigate extreme poverty), as there is usually at least one family member receiving retirement social security. For example, in one family, the sum of the monthly value of two benefits reached 620 dollars, which, divided by the five family members, gave a per capita monthly income of 124 dollars. This amount disqualified the family from the classification of extreme poverty, which is the case for the majority of households in the region. The poorest families we interviewed had a per capita family income of 40 dollars per month (10 dollars above the limit). Therefore, we did not identify any households in Timbaúba do Pitingão eligible for extreme poverty classification.

There are a few families in the Timbaúba do Pitingão community with members working in the urban heart of Russas, in the large local shoe industry. We observed that the houses of these families were built of masonry. Instead of paying rent in the city, they choose to live in Timbaúba do Pitingão, where the cost of living is cheaper and life is more serene.

Concerning dwelling security, residents' perceptions and beliefs through systematization of information from interviews disclosed that for most of the community, the mud houses are safer, as "they are bound" and "anchored to the ground," whereas the clay brick structures have no pillars. In Timbaúba do Pitingão, we encountered mud houses built recently (five months ago), so this construction technique is still under way in the area. Some residents refused to modernize their mud houses, although they knew of association between the mud huts and insect vectors that transmit Chagas disease. Interestingly, there have been reports of mild earthquakes in the area, according to one family of fishermen. These natural phenomena would also explain the anxiety about and avoidance of clay brick construction, reinforcing the belief that the mud housing is more secure.

Regarding the *bicudos*, the name people use for the insects that transmit Chagas disease in northeastern Brazil, some residents understood about the relocation of the vectors from the wild to dwellings and told us that these insects are brought in from the forest with firewood. A 52-year-old woman said, "If the *bicudos* have the opportunity, they hide in the cracks of the mud hut walls, come out at night and use us as a food [blood] source while we are sleeping."

With respect to residential construction in the region, a clay brick house costs between 2,000 and 2,500 dollars, while a mud dwelling costs around 1,500 dollars, with most of the manual labour provided by the family. Analyses of the interviews confirm that many of the residents were born and raised in mud houses and resist accepting an alternative. For example, a woman living in the same mud hut for over 30 years declared that her cousin, living in another location, had built his mud house just six months ago. Intriguingly, after purchasing all the wood needed, the home ended up being almost as expensive as a clay brick house and more complicated to build, possibly because instead of gathering wood directly from the forest, people now have to

buy it from local dealers.

Nevertheless, many people still base their building preference for mud on financial resources, even though, as described above, the construction costs are now comparable. Therefore, for some inhabitants, the justification for retaining mud houses must be more cultural than economic. A 72-year-old resident was a subsistence farmer who had lived most of his life in mud houses.

He related that in the past, clay brick dwellings were virtually non-existent because of the difficulty and expense of construction. Now, he states his preference for clay brick houses with the misconception that people do not build them for financial reasons. As a boy, he lived in mud houses and never saw *bicudos*, probably because the houses were always sprayed with insecticides.

Discussion

Results of this qualitative study demonstrate that mud houses represent not only the present but also the future, as well as the past. Furthermore, the absence of land property deeds discourages housing upgrades to more durable structures such as the clay brick.

… mud dwellings still seem to be the preference, regardless of their high depreciation factor.

The interviews revealed that most of the families have traditionally lived for many years in these triatomine-susceptible dwellings and probably will continue to do so. Contrastingly, residents' life stories suggest that building a mud house now can be almost as expensive as a brick house, because the good-quality wood essential for mud hut construction is no longer freely available. To build a mud dwelling, different species of wood are required, including aroeira (*Schinus terebinthifolius*), pau-branco (*Auxemma oncocalyx*), marmeleiro (*Cydonia oblonga*) and carnauba (*Copernicia prunifera*). These trees, now scarce because of deforestation of the region, are sold by the owners of ranches and farms at prices residents consider exorbitant. For example, carnauba trunks are necessary for the roof's supporting beams but can no longer be cut locally. As these palm trees are the source of carnauba wax, an important natural resource, their maintenance is closely regulated by the government. Currently, mud dwellings are still being constructed in the location. However, most of the older mud structures undergoing the natural process of degradation are now being replaced by more modern masonry houses.In the study area, some mud house residents have recently built masonry houses because of a raw material shortage for mud walls, which in some cases is critical for the choice of construction technique. Nevertheless, despite a rise in raw material prices, mud dwellings still seem to be the preference, regardless of their high depreciation factor in contrast to masonry. For example, some mud houses are now worth only about 200 dollars, while clay brick structures have maintained their value of between 2,500 and 3,000 dollars.

Building a mud house consists of the following steps. First, you dig deep into the ground to install the "forks," which are the main support beams. These beams are made of aroeira tree trunks. Centre columns are higher, for roof support. Subsequently, carnauba beams are secured on top, either inclined or horizontally, according to the length of the forks, to support the roof. Pau-branco vertical sticks are inserted from the ground and attached to the horizontal carnauba beams for the wall structure. The next step is to complete the wall, nailing horizontal quince sticks to the vertical pau-branco sticks, forming a grid to sustain the mud filling. Then, the gaps in the grid are manually filled with clay. Afterwards, the irregular surface is smoothed with a thin and homogeneous mixture of soil, sand and, optionally, cement, thus concluding the construction of the walls. The roof construction is the final step, traditionally completed with rafters, joists and ceramic tile. In our research we witnessed, in some homes, every aspect of construction.

The farmer who described the mud house construction technique had wished to build his house with clay bricks when he was getting married, thirteen years earlier. However, at that time, clay brick dwellings were forbidden because residents did not have legal land ownership, and permission to establish permanent dwellings would automatically entitle them to the land (squatters' rights). An additional problem was the possibility of the Santo Antonio dam expansion causing flooding in the area and forcing evacuation. At that time, even ceramic tile roofing of mud houses was prohibited, only straw roofing being permitted. The dwellings had to be temporary so that they could be moved and rebuilt in other locations in case of expropriation. Such a measure would not result in mandatory compensation for the relocated family.

We attested to the weaknesses of clay brick houses constructed in Timbaúba do Pitingão, due to simplified techniques and poor masonry which have been adapted for building with clay brick at minimum cost, compatible with the relative poverty of the region. This justifies the safety concerns of the interviewees.

… firewood serves as a vehicle for T. pseudomaculata to invade and colonize the dwelling, linking wild and domestic cycles of T. cruzi transmission.

There are no pillars or foundations in these houses, just fragile columns of clay bricks bonded with mortar that support the vertical clay brick walls. There are no concrete columns reinforced with steel, and the walls are attached to one another directly. They are seldom plastered and usually spackled in the attempt to increase strength and waterproofing.

Nowadays, inhabitants are authorized to build clay brick homes in Timbaúba do Pitingão, which is exactly what some retired local farmers do. Retirees have fixed monthly incomes of 310 dollars and the possibility of bank loans with automatic paycheque deductions. Two to three thousand dollars affords construction of a clay brick house, especially if the residents can save on manual labour, using family members to help. If any family member is a bricklayer, a bank loan of less than 1,500 dollars may be enough. In our observations, we found that many clay brick houses were built after the retirement of a family member, with funds raised in the form of loans. More clay brick constructions are imminent, awaiting the retirement of one of the future inhabitants.

The local vegetation is characterized by the presence of the black jurema bush (*Mimosa tenuiflora*). The initial entomological surveys we conducted in Timbaúba do Pitingão established the presence of *Triatoma pseudomaculata* (another formidable Chagas disease vector) in some sylvatic and peridomestic areas, the association of black jurema with this species of triatomine already having been confirmed (Freitas et al. 2004). The black jurema is an important source of firewood for cooking. Brought for storage in the domestic and peridomestic environments, the firewood serves as a vehicle for *T. pseudomaculata* to invade and colonize the dwelling, linking wild and domestic cycles of *T. cruzi* transmission. Our entomological survey did not identify bug colonies in the home environment, demonstrating that, despite the vulnerability of mud houses, the entomological surveillance system conducted by the authorities for the control of Chagas disease in the city has been effective.

According to Pisani (2004), the soil has been used as a raw material for buildings since the prehistoric period. It is an ancient construction technique that has benefits such as regulating the internal temperature of the environment and the possibility of easy relocation with minimal economic loss. We realized that a key feature of the mud structures was the need for regular maintenance. The wooden frame of mud houses, although able to endure for many decades, is subject to annual cycles of rain and drought, suffering dilations after the rainy season. This expansion of the wood frame induces cracks and blisters in the plastered walls, generating numerous crevices that serve as shelter for the insects that transmit American trypanosomiasis, which affords

the process of colonization by the bugs. The mud houses, therefore, require annual maintenance in order not to become susceptible to triatomine colonization.

In conclusion, Timbaúba do Pitingão is still a locality with a large proportion of vulnerable mud dwellings. Cultural and economic factors have clearly been linked to the choice of method for home construction. While some masonry houses are replacing the old mud huts, mud dwellings are still being built, exhibiting the dilemmas associated with beliefs and perceptions about the safety of mud houses and the possibility of building clay brick houses. In this context, the economic evolution of family conflicts over traditions, as well as the relative increased cost of the materials needed for mud house construction, has not completely inhibited building with mud. It may be that a housing alternative with higher quality and safety has, as yet, not been offered in the region.

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Resource Allocation in Pakistan's Health Sector: A Critical Appraisal and a Path toward the Millennium Development Goals

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Abstract

Pakistan is trying hard to sustain its progress toward the Millennium Development Goals. However, because of a lack of political commitment to innovative solutions to improve its financing mechanism, the health system is unable to provide even essential and basic services to the people. The country, with more than 70% of the population living on less than two US dollars a day, largely depends on direct taxes for its revenue. Because of inadequate financing, the quality of government services is inexcusably poor; therefore, a majority of people seek healthcare in the private sector. This has led to a horde of issues pertaining to equity, accessibility and fairness. High out-of-pocket expenses on health jeopardize a family's livelihood, pushing it into a vicious circle of poverty. In the wake of recent devolution, this paper presents options for future health financing that enables the provinces to exert their autonomy to safeguard the health of the most vulnerable in the country. Our recommendations follow the vision of the World Health Organization and the Commission on Macroeconomics and Health, to achieve universal health coverage and social protection for the poor.

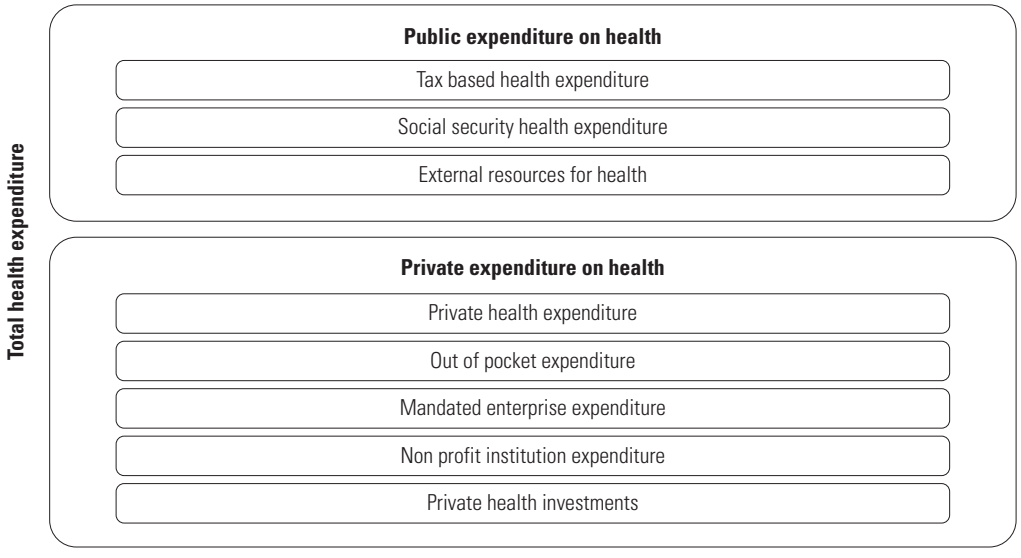
Background

Healthcare embraces all the goods and services designed to promote health through promotive, curative and palliative care, whether directed to individuals or to populations. Providing a mix of services to a huge population is a challenge for most middle- and low-income countries with low budget allocations for health. Social and economic deprivation, compounded by issues such as gender, education, women's status, nutrition and sanitation, put immense pressure on the poor to seek medical care. Under such circumstances, the key milestones of a robust health system should encompass improving the health status of the population as well as cover the financial cost of treating illness. A well-functioning health system aims to lessen the financial burden on healthcare users (World Health Organization 2000). The widening coverage gap between rich and poor has decelerated the progress of health indicators under the Millennium Development Goals (MDGs). Communities must not experience financial hardship in accessing health services. To achieve this goal, the World Health Organization (WHO) also urged member states to modify healthcare financing systems within the sociocultural, macroeconomic and political context of the country and to develop sustainable financing mechanisms to manage their health systems (World health Organization 2000).

The total healthcare expenditure in a country is usually sourced through a mix of public and private spending, as shown in Figure 1 (Poullier et al. 2002). More reliance on private health expenditures without a mechanism to enforce regulations is likely to promote inequity, inaccessibility and financial hardship in healthcare seeking. Every year, 11% of the population in African and South Asian countries suffers severe financial hardship, and 5% falls below the poverty line. Inappropriate and inadequate financial mechanisms for public health expenditures and low income add an enormous burden on low-income quintiles. Coverage for social security protection in middle-income countries varies from 20% to 60%, compared with 5% to 10% in African and South Asian countries (World health Organization 2005). Since most low-income countries are not on track to achieve MDG targets, the developing an impetus to identify health financing mechanisms that address the coverage gaps for universally accessible health services is critical.

With this background and state of affairs, we performed a critical appraisal of financing in Pakistan's health sector. Furthermore, in this paper we attempt to shed light on feasible options of improving health sector financing and allocations in the post-devolution period, wherein provinces are autonomous in making their own strategic decisions.

Figure 1. Sources of public and private expenditure in a health sector



Source: Poullier et al. 2002.

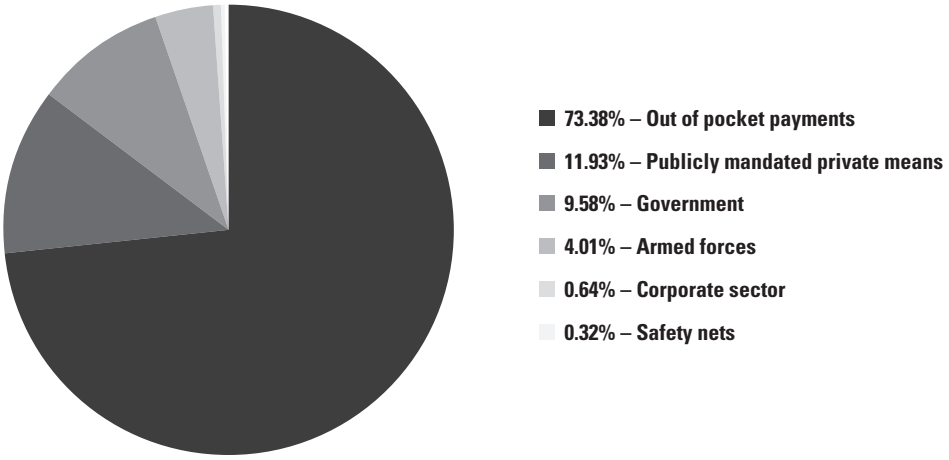
Health Financing in Pakistan

Pakistanis a low-income country in South Asia with a slow progression on the Human Development Index, where it currently stands 125th among 169 countries (United Nations Development Program 2010). Population growth, with an epidemiological transition i.e. changing disease patterns during the last decade, did not allow policy makers to develop mechanisms for financing health, therefore rendering a larger segment of population bereft of essential healthcare packages. About 0.6% of GDP and 5.1% to 11.6% of development expenditure on health is financed by the Government of Pakistan (Ahmed and Shaikh 2008; Nishtar 2006), contrary to the WHO recommendation to allocate at least 5% of GDP spending on health (World health Organization 2000). Notably, member countries of the Organisation of Economic Cooperation & Development (OECD) spend more than 8% of their GDP on health (OECD 2011). The health sector in Pakistan has received increments in budgetary allocations over the last few years, but they were not adjusted for inflation, population growth and burden of disease, leading to unresolved issues for social protection and health for all. Moreover, three-fifths of budgetary allocations are consumed by non-development purposes such as salaries, thus leaving a meagre share to deliver efficient, equitable and quality service. The public sector in Pakistan has shown weak capacity in the context of delivery and management of health services, resulting in a number of quality, competence and coverage issues (Nishtar 2010). The need to develop appropriate systems for allocating resources from the central to lower administrative levels has always been critically felt at the policy level.

Resource generation can be from taxes, employee contributions, the community, private insurance and out-of-pocket expenditures. In Pakistan, the most common modes of health financing are through general taxation and out-of-pocket payments. The Government of Pakistan is responsible for health spending in the public sector, where the capital investment through general taxation is channelled in annual development plans, inclusive of external funding from bilateral and multilateral donors (Ghaffar et al. 2000). Most revenue is collected by the central finance ministry and then redistributed vertically between the federal and provincial governments and horizontally among the provinces. A positive note is that about 80% of the financial resources in the public sector are provided by the Government of Pakistan. Pakistan's per capita spending on health is around 22 US dollars, of which the government's share is 6.4 dollars and 1.3 dollars are contributed by development partners. Obviously, the dependency factor is not very worrisome, as Official Developmental Assistance has been quite variable over the past few years and has depended on international and local political priorities. Of total health expenditures, out-of-pocket expenses constitute the largest share and have to be borne mostly by the poor, even when seeking care at government facilities, for instance, while purchasing medicine. Provincial governments' allocations have been even more skewed toward the non-development side, with a considerable share given to tertiary hospitals in all the provinces (Mohammad et al. 2007).

Current health insurance schemes in Pakistan cover only 5% of the population (Asian Development Bank 2005). Likewise, Zakat (the Islamic concept of a luxury tax on 2.5% of dormant wealth over a certain amount unused for a year, collected and used in specified categories), Bait-ul-Maal (a treasury of an Islamic government, used to provide income for the needy, including the poor, elderly, orphans, widows and the disabled) and private health insurance are the other financing mechanisms, catering to a very small proportion of the population.

Figure 2. Health expenditure coverage in Pakistan.



Source: Nishtar 2010

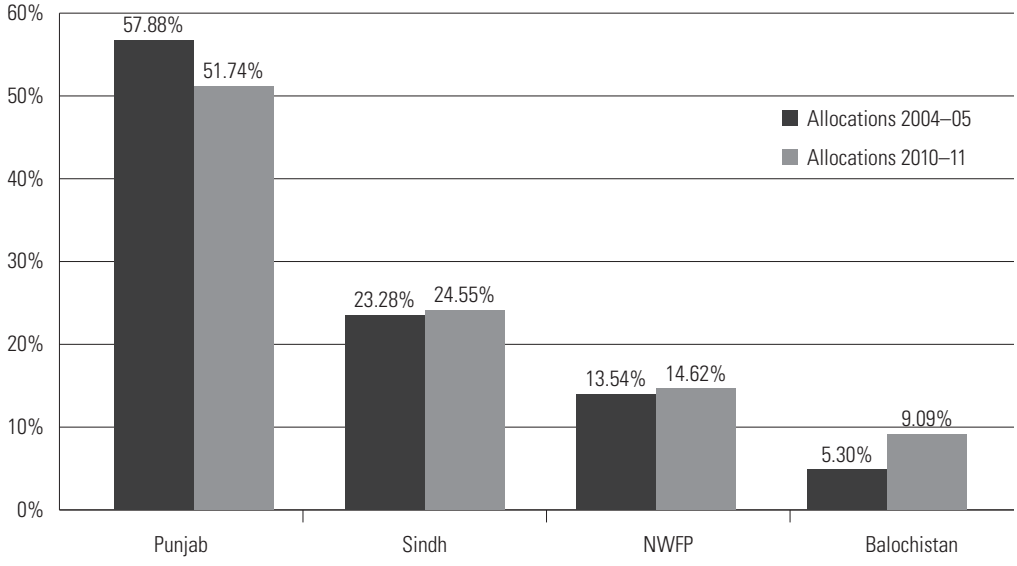
Alarmingly, private (out-of-pocket) expenditures on health have increased to as high as 80%, thus pushing more people below the poverty line (World Health Organization 2011). Local evidence shows this expense as high as 73% as shown in Figure 2. Because of these high costs, the gap in access to health services by the poorest and wealthiest quintiles has been growing for years. Soaring healthcare costs have burdened poor households with crushing expenditures, aggravating their poverty. Therefore, there is an urgent need to provide them with protection against the impoverishing blows of ill-health (Belay et al. 2010).

Resource allocation is the distribution of resources among competing groups of people, programs or geographical areas. It refers to fair financing, one of the six building blocks of health systems (World Health Organization 1996). Resource allocation formulas have an essential role to play in the public sector in directing resources to underserved geographic areas, underprivileged population groups and underfunded programs. It is imperative that resource allocation to developmental and non-developmental health plans is evenly distributed across the federation and provinces. Low spending on health is not the only impeding factor in the provision of equitable, accessible and efficient services; there is also an issue of imbalance in allocation of resources to developmental and non-developmental annual plans. Over the years, non-developmental health spending has remained high, compared to the developmental projects' budget. Notably, the provinces spend 70% to 80% of their health expenditures on non-developmental and recurrent expenses, including salaries (Government of Pakistan 2005). Expansion of developmental health plans in the provinces has not factored in population growth, leading to unsatisfactory coverage and substandard quality of public health services, particularly in rural Pakistan. At present, financing mechanisms to reduce out-of-pocket payments and increase the pooling of general taxation are missing. Yet there are opportunities to plan and promote various modes of health system financing.

There are federal, provincial and district levels for generation and allocation of public health expenditures in Pakistan. While total funding for the health sector is important, it is instructive to see how it is spent by the respective tiers of government. From the federal level, resources include revenue shares, grants, straight transfers and loans that are transferred to the provincial level, based on a resource allocation formula. The National Finance Commission (NFC) recommends distribution of specified taxes and duties between the federation and provinces and disbursement of grants to provincial governments, and decides on the borrowing powers to be exercised by the

federation and provinces (Ahmed et al. 2007). The provincial divisible pool consists of federal tax assignments, straight transfers and provincial tax receipts. Priority expenditures comprise pensions, subsidies, debt servicing and priority programs and are subtracted from the gross divisible pool to arrive at a net divisible pool. The provincial divisible pool is then further divided into a provincial retained amount and a provincial allocable amount, which are 45% and 55%, respectively (Government of Sindh 2004). Population had been the sole criterion for the NFC's formula for distribution to the provinces since the inception of the federation, in 1947. However, in 2010 the NFC adopted a more equitable and fair allocation formula, considering the relative weight of population, level of development, provincial revenue and inverse population density. Consequently, shares were more responsive to the provinces' population needs, as shown in Figure 3 (Government of Pakistan 2010).

Figure 3. Provincial allocations by the National Finance Commission Award in 2004-05 and 2010-11. Ministry of Finance, Islamabad



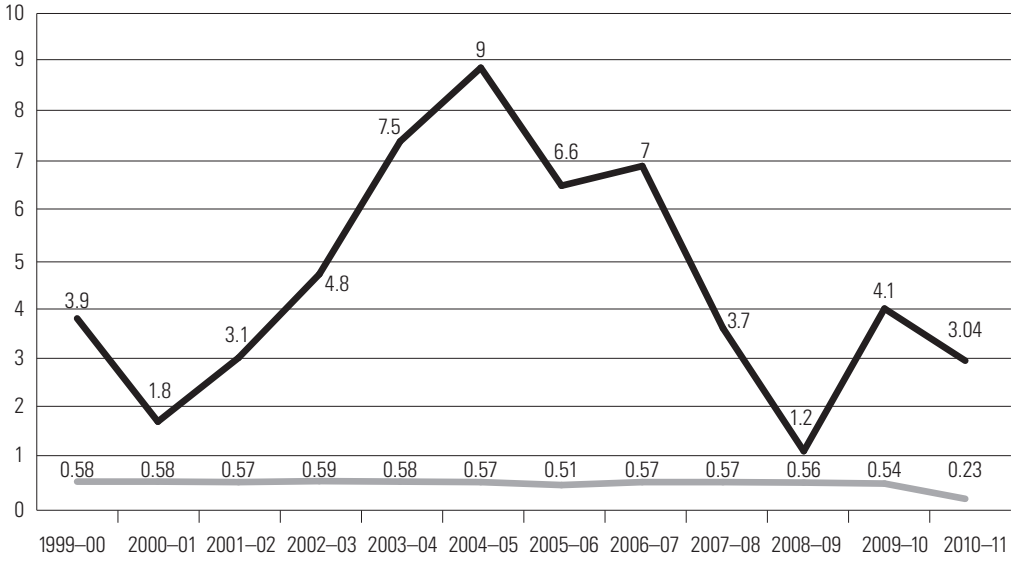
NWFP = Northwest Frontier Province.
Source: Government of Pakistan 2010.

Devolution and Health Financing

Pakistan's health system has experienced two major political transitions: the local Government Ordinance in 2001 and, recently, the promulgated 18th constitutional amendment. As a result of devolution of the social and health sector under the latter reform, provincial bodies are now autonomous for administrative and financial decisions. This shift in decision making and health services planning to the provincial bodies opens up many prospects for developing effective financing mechanisms for the health sector. Other countries have sustained reforms and faced financial hardships, yet kept health as a national priority; for example, Cuba sustained political transitions and improved its maternal and child health indicators, with an elevated allocation of 7% of GDP for health spending, matching that of the OECD countries (Pan American Health Organization 2011). Under the seventh NFC award in 2011, there are financial increments for the health and the social sector in each province. This opportunity, with amplified benefits to the health sector, makes the case for generation of broader and sustained financing mechanisms in provincial health systems. Nevertheless, the new arrangement must ensure the diminution of inequities in healthcare utilization (Nishtar 2011).

Although the government's health budget has been gradually increasing over the last few years, no absolute increase has been observed in terms of percentage of GDP, which has remained stagnant at or below 1%, as shown in Figure 4 (Ahmed and Shaikh 2008). Devolution has come with many opportunities as well as some risks in the management of heath financing in the provinces.

Figure 4. Health allocation of government as percentage of GDP over the years



GDP = gross domestic product.
Source: Ahmed and Shaikh 2008.

The Government of Pakistan has a history of investing 85% of the health budget for curative care, while primary health services, which cater to 80% of the population, receive only 15% (Nishtar 2010). The provinces' enhanced autonomy after the 18th amendment allows them to manage the pooling and purchasing arrangements for health (World Bank 1998). Now, provinces bear the responsibility of ensuring fair financing in the health system. Accountability mechanisms at the provincial level need to be strengthened to improve performance and transparency in healthcare financing. Another risk is the limited capacity of provinces in managing financing mechanisms. Successful decentralization is critically determined by the local health system's managerial capacity (Spedo et al. 2009). At this time, interim technical support from the federation is desirable not only for swift transfer of financing to the provinces, but also to enable them to build capacity to manage and sustain their own resources.

Health Financing Opportunities with Devolution

It must be ensured that poorer health systems have sufficient funds to scale up the equitable modes of health financing. Low-income countries need to spend at least 35 dollars per capita by 2015 to attain MDGs through universal coverage (World Health Organization 2005). Financial incentives under the last NFC award are well recognized by the provinces, as the new custodians of the health and social sector. Provincial reservations and conflicts over budgetary allocations seem to have been resolved by the 18th amendment. The following recommendations are proposed to create effective health financing mechanisms in the provinces to serve poor segments of the population.

1. Reprioritization of Provincial Budgets

For any health system to function efficiently, it is imperative to set priorities for resource allocation, health services delivery, human resources for health, and a supply of medicine and equipment in various geographical areas. To catch up to MDG targets, provinces must strive to double current health sector allocations (World Health Organization 2011). A transparent and accountable decision-making process is needed to bring evidence-based change. Instead of wasting the already meagre resources, it is high time that we redirect them to high-priority needs. Steps for the health financing decision-making process must include creating a vision and completing a situational analysis, a financial and constraints assessment, development and implementation of proposed strategies, and monitoring and evaluation (World Health Organization 2005). Pakistan's epidemiological and political transition requires that the provinces undertake these steps to revamp health financing mechanisms. The major share of the health budget that is consumed in the non-developmental accounts should be reviewed (Ahmed and Shaikh 2008; World Health Organization 2011). Provinces are now in a position to reallocate finances for developmental and non-developmental sectors, directing an additional benefit to the health and social sector. En route, sufficient allocations will have to be made to incentivize existing human resources as well as fill current vacancies across healthcare delivery levels, from primary to tertiary and across the vertical programs. It may be worthwhile to spend the allocation on public health and essential curative services, leaving the rest to be financed by the private sector perhaps, but mediated through private or social insurance (World Bank 1993). It is an opportune time to give maternal and child health services their due priority, because they serve the most vulnerable segments of the population (Mazhar and Shaikh 2012).

2. Efficient Revenue Collection

Extensive tax and contribution collection capacity is usually observed in the formal economies i.e. having a well structured tax system with registered tax payers, whereas in Pakistan, the informal sector is predominant and accounts for less than 20% of GDP toward general taxation (Nishtar 2010). The federation and provinces must make every effort to collect direct taxation from the formal sector. Likewise, necessary amendments to the present law related to tax collection must be implemented in their true letter and spirit. For broadening the tax collection base, a transparent accountability mechanism must ensure the involvement of the informal sector and other revenue-generating sectors such as agriculture. This will instil greater public confidence in the government's initiatives. The revamped general taxation system of Indonesia, with added benefits to health, accomplished these goals (World Health Organization 2005). Reallocation of a proportion of taxes by the provinces for public health activities would be invaluable for achieving the MDGs by 2015.

3. Social Protection for Health

Social health insurance (SHI) is provided in more than 60 countries around the world (World Bank 2006). Thailand introduced its 30 Baht scheme to promote universal coverage. This novel mode of financing reduced the financial burden on consumers and subsequently discouraged out-of-pocket payments, which occur mostly in the private health sector (Sreshthaputra and Indaratna 2001). Pakistan's current scenario of devolution is ideal for assessing and testing the feasibility of SHI on a small scale (Abrejo and Shaikh 2008). Prepaid vouchers and conditional cash transfers have also been advocated to improve access for the poor to health services and enhance the appropriate service utilization trends (Bellows et al. 2011; Doetinchem et al. 2008). Such modalities have the potential to save households from the health shocks and catastrophic expenditures that push them into the hardships of poverty. Provinces must ensure their stewardship role, which has been defined with multiple facets, from providing a vision for the health of the nation to managing and guaranteeing a just distribution of resources across the health sector

(Saltman and Ferroussier-Davis 2000). Pakistan is facing a double burden of disease i.e. a mix of communicable and non-communicable diseases, and today it reflects almost equal shares of both types of diseases. Chronic diseases, which need expensive treatment and hospitalization, must be covered by safety nets designed for vulnerable segments of the population. Provinces have financial autonomy, following the 2011 reforms, and thus it is an opportune time to devolve these powers further to the districts. At the district level, administration is more manageable and poverty indices more easily calculated to identify the actual population to be covered (Mazhar and Shaikh 2012). With the bureaucratic bottlenecks inherent in a federally run system removed, issues can now be effectively addressed in a devolved system and at the district level. A district social security system has already been proposed as part of the government's policy framework (Planning Commission 2005).

4. Innovative Modes of Financing Health

This is an ideal time to envision innovative ways of financing health and enhancing allocations to the health sector. Globally, there is a dire need to explore options for domestic fundraising through direct and indirect taxation. Indirect taxation can be efficiently channelled through increased taxes, for example, on air fare, foreign exchange transactions and other luxuries (World Health Organization 2005). Higher taxes on products hazardous to health, such as tobacco, would benefit the health system by improving the health of the population as well as increasing tax revenue. However, such innovative health-financing mechanisms demand political commitment from the federation as well as from the provinces. Now that provincial stakeholders have an augmented financial share, they ought to make every effort to test alternative modes of health financing. Furthermore, the federation has a pivotal role in developing the technical and managerial capacity of provinces to lay out innovative health financing strategies that will also create an environment of harmony among provinces. Although cost-sharing programs and co-financing schemes have been tested across the country, serious efforts to scale up such innovative schemes are needed. Community financing to mobilize resources for healthcare has been found very effective in reaching a large number of low-income populations who would otherwise have no financial protection against the cost of illness (Ekman 2004). In the wake of the constitutional amendment, provincial governments must strategize to ensure fair financing for facilitating access to healthcare, especially for maternal and child healthcare services (Mazhar and Shaikh 2012).

5. Donor Contributions for Developmental Assistance

Pakistan's unstable macroeconomic indicators and uneven economic growth have resulted in a sizable proportion of the population living in poverty. Although the Government of Pakistan embarked on a poverty reduction strategy that aimed to create jobs, alleviate poverty and improve social indicators (Government of Pakistan 2007), the available finances in a poor country such as Pakistan have not been sufficient to meet MDG targets. To bridge the gap, it is imperative to augment domestic fundraising by seeking enhanced donor contributions for developing countries. It would be worthwhile to tap into the potential of some credible international non-governmental organizations and development partners to help increase the allocation of the health budget (Ejaz et al. 2011). Global solidarity is essential to help low-income countries assuage poverty and increase investment in development plans of the health sector. Under Official Developmental Assistance commitments, high-income countries are pledged to develop the financial capacity of middle- and low-income countries (World Health Organization 2005). This would allow the state to spend more on development plans compared to non-development ones, which would be a fundamental prerequisite for meeting the 35 US dollar per capita spending on health needed to attain the MDGs (World Health Organization 2001). Although Pakistan's health sector has never been entirely dependent on donor financing for health, except for some vertical programs, weaning ourselves off that proportion of funding should be the eventual goal.

Conclusion

Taking stock of healthcare financing in Pakistan provides some critical conclusions: insufficient allocations from tax revenue for the health sector; unjustifiably high amounts spent on tertiary care concentrated in urban areas; visible inequities in access to healthcare and, most serious of all, inefficient distribution of funds and low utilization that result in exclusion of the poor from the health system. Progression toward the MDGs will necessitate extensive political and economic reforms in the civil service and governance structures, and a fair allocation of resources to the health sector (Shaikh 2008; United Nations 2011). Devolution of administrative and financial powers to the provinces in Pakistan should be seen as an opportunity. The provinces must strategize to empower the districts to build their local managerial capacity and accountability mechanisms. The health sector of Pakistan is yearning for a transformational strategy to deliver just and fair financing with a pro-poor approach. Devolution empowers provinces to develop efficient and innovative financing mechanisms that are needed immediately to diminish the overwhelming influence of the private health sector and minimize out-of-payments. Support from the federal government, development partners and training institutions during this transition will enhance technical capacity of provinces and even the districts to experiment with innovative modes of financing.

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Reprint

Global Access to Safe Water: Accounting for Water Quality and the Resulting Impact on MDG Progress*

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Abstract

Monitoring of progress towards the Millennium Development Goal (MDG) drinking water target relies on classification of water sources as "improved" or "unimproved" as an indicator for water safety. We adjust the current Joint Monitoring Programme (JMP) estimate by accounting for microbial water quality and sanitary risk using the only-nationally representative water quality data currently available, that from the WHO and UNICEF "Rapid Assessment of Drinking Water Quality". A principal components analysis (PCA) of national environmental and development indicators was used to create models that predicted, for most countries, the proportions of piped and of other-improved water supplies that are faecally contaminated; and of these sources, the proportions that lack basic sanitary protection against contamination. We estimate that 1.8 billion people (28% of the global population) used unsafe water in 2010. The 2010 JMP estimate is that 783 million people (11%) use unimproved sources. Our estimates revise the 1990 baseline from 23% to 37%, and the target from 12% to 18%, resulting in a shortfall of 10% of the global population towards the MDG target in 2010. In contrast, using the indicator "use of an improved source" suggests that the MDG target for drinkingwater has already been achieved. We estimate that an additional 1.2 billion (18%) use water from sources or systems with significant sanitary risks. While our estimate is imprecise, the magnitude of the estimate and the health and development implications suggest that greater attention is needed to better understand and manage drinking water safety.

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1. Introduction

The United Nations Millennium Development Goals (MDGs) include Target 7c, to halve the "proportion of the population without sustainable access to safe drinking-water" between 1990 and 2015 [1]. The Joint Monitoring Programme for Water Supply and Sanitation (JMP) of the World Health Organization (WHO) and the United Nations Children's Fund (UNICEF) reports progress towards meeting this goal [2]. The corresponding MDG indicator is the "proportion of households using water from an improved source," and is reported on a country-by-country basis [1]. Sources are classified as improved or unimproved as shown in Table 1, according to whether they are "protected from outside contamination" [2]. The MDG indicator thereby conflates access to certain water sources with use of safe water. However, data and monitoring mechanisms regarding the safety of water sources at a national scale when the MDG targets were cast were, and remain, scant. As such, at the time the MDGs were developed, there was no credible alternative approach to an indicator that allows for the calculation of a percentage figure easily aggregated to the country and global scales and amenable for use as a target given the types of data available.

Table 1. JMP Classification of drinking-water source types as improved or unimproved [2].

Source class	Type of source
Unimproved drinking-water source	Unprotected dug well, unprotected spring, cart with small tank or drum, surface water (e.g., river, dam, lake, pond, stream, canal or irrigation channel) and bottled water
Improved drinking-water source (piped to dwelling, plot or yard)	Piped water connection located inside the user's dwelling, plot or yard
Improved drinking-water source (other sources)	Public taps or standpipes, tube wells or boreholes, protected dug wells, protected springs and rainwater collection

Using this approach, WHO and UNICEF estimate that 5.8 billion people used improved sources in 2010, with 783 million using unimproved water sources [3]. Treating use of an improved source as an indicator for use of safe water is likely to overestimate the population using safe water, since some improved sources may provide water that is microbiologically or chemically contaminated whether at source or by the time it reaches the home and is consumed [4,5]. On the other hand, most unimproved sources do not provide safe drinking water, so underaccounting of safe water coverage due to unimproved sources providing safe water is likely to be small [6,7].

In 2010, WHO and UNICEF released data on water quality and sanitary risk (i.e., risk of contamination) associated with improved sources from five countries as part of the Rapid Assessment of Drinking-Water Quality (RADWQ) study which had been undertaken between October 2004 and April 2005 [8–12]. The RADWQ study is the only source of nationally-representative drinking water quality data amenable to analysis for microbial contamination disaggregated by water source type.

A recent analysis of these data found that accounting for water source compliance with WHO water quality guidelines significantly reduced the estimates of safe water access relative to the JMP figures, as well as national-level progress towards the MDG target, in four of the five countries [13]. However, this study did not account for sanitary risk, and did not extrapolate beyond the five countries for which data were available. We use both the water quality and sanitary risk data from the RADWQ studies to extrapolate to other countries, and estimate global figures. We believe our study is the first to use the available nationally-representative water safety data to estimate the proportion of the global population with access to safe drinking water and the concomitant impact on estimates of global progress towards MDG Target 7c with a method that accounts for differences between countries in factors affecting water source safety.

2. Methods

2.1. Drinking Water Source Type Classification

Here we considered "piped" sources as the subset of MDG-classified improved sources that are piped connections to a user's dwelling, plot, or yard, and "other-improved" sources as all other improved drinking water sources as described in Table 1.

2.2. Drinking Water Quality Data

The RADWQ data was collected following the methodology described in Howard et al. [14]. The RADWQ data includes a nationally-representative sample of approximately 1,600 improved water sources in each of Ethiopia, Jordan, Nicaragua, Nigeria, and Tajikistan [8–12]. A population-weighted sample was taken of each source type that provided water to at least 5% of the national population in four of the five countries [8–12]. In Nicaragua, no single improved source type other than utility piped supplies covered more than 5% of the population, so several other-improved source types, each covering less than 5% of the population, were sampled [11]. Each sampled source was tested for thermotolerant coliform bacteria (TTC), fluoride, arsenic, and nitrate, and subjected to a standardized sanitary inspection [14]. Sanitary inspections in the RADWQ surveys identified risk factors for faecal contamination for a water source from a standardized list for each water source type of 10 common risks [8–12]. Examples of sanitary risks on these lists included pipe breaks, supply discontinuities, poor drainage, and proximity to latrines and animal waste. The RADWQ studies reported sanitary risk as a categorical variable with four levels: 0–2, 3–5, 6–8, and 9–10 sanitary risks [8–12]. The RADWQ studies also provided cross-tabulations of sanitary risk levels and TTC contamination levels, except in the case of Nicaragua, which only reported the percentage of contaminated water sources in each sanitary risk level [8–12].

For each of the five countries, we used the RADWQ data to compute the percentages of piped water sources and other-improved water sources that were "safe" by virtue of not testing positive for TCC [15]. We computed the percentages of safe sampled piped and other-improved sources that also had greater than two sanitary risks on the sanitary risk inspection that accompanied the water quality tests for each sampled water source. We used this threshold to identify systems with all but the lowest aggregated level of sanitary risk reported in the RADWQ studies. We considered any one sanitary risk to represent an elevated risk of water contamination or re-contamination that is not captured by water quality testing at a single point in space and time. Where multiple piped or other-improved water source types were tested within a country, the percentages were computed as an average weighted by the population using each source type. The population receiving drinking water from each source in 2004 to 2005 was estimated from RADWQ project reports. The RADWQ study made no attempt to assess the safety of water from unimproved sources, other than the case of tanker trucks in Nigeria [9]. In the absence of such data, we assumed that 100% of unimproved sources do not provide safe water.

2.3. Synthetic Covariates from Principal Components Analysis

In order to estimate global access to safe water, empirical statistical models capturing the relationship between faecal contamination or sanitary risk proportions and country-level economic, governance, health, social and environmental characteristics were built. Covariates were chosen based on the availability of data for countries with 2010 JMP estimates and on their relation to drinking water quality.

The following country-level indicators were explored: gross domestic product per capita (GDP) [16], the World Bank's Government Effectiveness (GE) score [17], the Human Development Index [18], the Water Quality Index (WQI) from Yale's Environmental Performance Index [19], annual aggregate precipitation [16], percent of population attaining tertiary education [20], and under-5 diarrheal morbidity rates [16]. Due to many of these varia-

bles being highly correlated, and the small size of our dataset, the models were limited to one or two covariates. Principal Components Analysis (PCA) was used to create uncorrelated synthetic variables that captured the most variance in those national characteristics. This analysis was performed with Stata 10.1.

2.4. Predicting Drinking Water Safety Proportions for Piped and Other-Improved Sources

Four fractional logit models were built based on the data points listed in Table 2, one for each of the proportions of: safe piped sources, safe other-improved sources, safe piped sources with elevated sanitary risk, and safe other-improved sources with elevated sanitary risk. We modeled the sanitary risk proportions of safe sources, since faecally-contaminated sources were assumed to be unsafe regardless of their level of sanitary risk. The fractional logit model as developed by Papke and Wooldridge [21], rather than minimizing the sum-of-squares error, is a quasi-maximum likelihood method. The fractional logit is superior to an ordinary least squares (OLS) regression because the predicted values of such models are not guaranteed to be restricted to values between 0 and 1. This method is also superior to the common alternative of performing an OLS regression on the logit transformation of the proportion (log-odds regression), in that the predicted values of the proportions from such a model are not recoverable without making significant assumptions.

Candidate covariates used in the models were the first three PCA components from the analysis described in section 2.3. For each of the four dependent variables, models using combinations of these three components were run and the models having the greatest log-likelihoods while maintaining a significant difference from the null model were chosen.

Table 2. Cross-tabulation of TTC contamination and sanitary risk for piped and other-improved water sources [8–12].

Piped *					
	% Sanitary risk category safe	TTC Count (cfu/100 mL)			
		<1	1–10	10–100	>100
Ethiopia					
0–2 (Very Low San. Risk)	88%	78	1	8	2
3–5 (Low San. Risk)	89%	220	9	14	5
6–8 (Med. San. Risk)	70%	40	5	11	1
9–10 (High San. Risk)	0%	0	1	0	0
Jordan					
0–2 (Very Low San. Risk)	100%	1233	1	0	0
3–5 (Low San. Risk)	100%	404	0	0	0
6–8 (Med. San. Risk)	NA	0	0	0	0
9–10 (High San. Risk)	NA	0	0	0	0
Nigeria					
0–2 (Very Low San. Risk)	89%	108	10	3	1
3–5 (Low San. Risk)	79%	263	48	23	1
6–8 (Med. San. Risk)	72%	115	14	26	5
9–10 (High San. Risk)	23%	3	3	5	2
Tajikistan					
0–2 (Very Low San. Risk)	91%	1038	100	0	0
3–5 (Low San. Risk)	72%	91	35	1	0
6–8 (Med. San. Risk)	48%	10	11	0	0
9–10 (High San. Risk)	NA	0	0	0	0

Table 2. Continued

Other-Improved **					
	% Sanitary risk category safe	TTC Count (cfu/100 mL)			
		<1	1–10	10–100	>100
Ethiopia					
0–2 (Very Low San. Risk)	94%	192	2	3	8
3–5 (Low San. Risk)	72%	567	76	94	46
6–8 (Med. San. Risk)	41%	122	46	76	53
9–10 (High San. Risk)	0%	0	2	0	3
Nigeria					
0–2 (Very Low San. Risk)	78%	364	71	31	0
3–5 (Low San. Risk)	80%	256	31	33	1
6–8 (Med. San. Risk)	81%	105	9	15	1
9–10 (High San. Risk)	38%	12	9	10	1
Tajikistan					
0–2 (Very Low San. Risk)	77%	121	28	6	2
3–5 (Low San. Risk)	89%	146	15	3	0
6–8 (Med. San. Risk)	54%	7	4	1	1
9–10 (High San. Risk)	NA	0	0	0	0

* All crosstabulations from RADWQ project reports; The Nicaragua report did not include them.
** No other-improved sources tested in Jordan.

The resulting models were used to extrapolate the proportions calculated from the RADWQ countries to the remaining countries with JMP data for 2010. The predicted proportion of piped or other-improved sources uncontaminated with TTC for each country was multiplied by the corresponding JMP estimate of the population using piped or other-improved water, respectively, to estimate the population with access to microbiologically safe piped or other-improved water in each country. Similarly, the predicted proportion of uncontaminated piped or other-improved sources with elevated sanitary risk was multiplied by the estimated population with access to uncontaminated piped and other-improved water sources. 95%-confidence interval upper and lower bounds for each figure were calculated by using the standard errors of the model coefficients. This method of calculating confidence intervals assumes the RADWQ studies are perfectly accurate in their reported percentages. This assumption is necessary as the complete RADWQ data sets were not available and we were therefore unable to calculate standard errors for the RADWQ country percentages.

2.5. Adjusting MDG Target 7c Progress Estimates

We re-estimated MDG progress towards global safe water access by accounting for faecal contamination of piped or other-improved water sources, as well as sanitary risks of piped or other-improved sources for which faecal contamination was not detected. The 1990 baseline estimates obtained from JMP were multiplied by the estimated proportions of people with piped and other improved water sources for which such sources were estimated to be unsafe by virtue of having tested positive for TTC. This was repeated to account for piped and other-improved sources with sanitary risks. In the absence of any trend data, proportions estimated based on the 2004–2005 RADWQ data were used to estimate both 2010 and 1990 water source safety. Projections of the global proportion of people without access to safe water in 2015 according to JMP data, and accounting for water quality, were based on linear extrapolations of the 1990–2010 JMP and water quality-adjusted data, respectively. This is the same method used by

JMP to make its projections [22]. The 2015 MDG targets were calculated by halving the original and recalculated 1990 baselines.

3. Results

The results of the RADWQ studies in the form of cross-tabulations of detected TTC contamination levels and sanitary risk scores, aggregated into piped and other-improved sources, are shown in Table 2. Within each country, TTC contamination rates for each water source type generally increase with increasing sanitary risk, indicating the expected association between water contamination and the presence of sanitary risk factors.

The aggregated results of the RADWQ studies are presented in Table 3. The relationship between sanitary risk and TTC contamination differs between countries. For example, even though all Jordan's piped water supplies are uncontaminated, almost a quarter have more than two sanitary risks; while less than 9% of Tajikistan's uncontaminated piped supplies have more than two sanitary risks. Data were available such that the PCA could be performed for 150 countries, accounting for 92.5% of the global population (Table 4). The first three components explained 84% of the variance among these countries. The first component shows that GDP, GE, HDI, and Tertiary Education rates all covary and contribute similar information. The second component is dominated by annual aggregate precipitation, and the third component by the WQI. The spread of the five RADWQ countries with respect to the dominant variables of the first three components are shown in Table 5.

Table 3. Contamination of piped and other-improved sampled sources with TTC, and sanitary risk of safe sources [8–12].

Source type, by country	Thermotolerant coliform (TTC) contamination*		Sanitary risk of safe sources
	TTC-Uncontaminated (Safe) (%)	Sources sampled (n)	>2 Sanitary Risks (%)
Ethiopia			
Piped	87.6	838	60.7
Other-Improved	55.0	764	67.1
Jordan			
Piped	99.9	1639	24.7
Other-Improved	NA	0	NA
Nicaragua			
Piped	85.5	600	47.3
Other-Improved	33.5	888	56.5
Nigeria			
Piped	77.0	630	77.9
Other-Improved	76.0	949	50.6
Tajikistan			
Piped	88.6	1286	8.9
Other-Improved	82.0	334	55.8

* Data aggregated from RADWQ reports. TTC contamination judged against guideline value of <1 TTC per 100 mL as indicated in the WHO Guidelines for Drinking Water Quality [15];

** Only 44% of the protected springs in Tajikistan were found to be adequately protected for designation as an improved source.

Table 4. Factor loadings, Eigenvalues, and Variances accounted for from PCA.

Variable	Comp 1	Comp 2	Comp 3	Comp 4	Comp 5	Comp 6	Comp 7
Eigenvalue	4.19	1.06	0.623	0.476	0.326	0.180	0.138
pc GDP	0.422	0.121	0.353	0.204	–0.429	0.647	0.199
GE	0.422	0.151	0.336	0.348	–0.0785	–0.715	0.219
HDI	0.441	0.0920	0.258	–0.101	0.399	0.0799	–0.745
Precipitation	–0.102	0.913	0.0051	–0.380	0.0029	–0.0178	0.106
WQI	0.331	0.237	–0.793	0.433	–0.0363	0.0497	–0.123
U5 Diarrhea	–0.384	0.214	0.227	0.642	0.537	0.210	0.100
Tert. Educ.	0.427	–0.137	–0.127	–0.280	0.601	0.131	0.567
Proportion	0.599	0.152	0.0885	0.0679	0.0466	0.0258	0.0197
Cumulative	0.599	0.751	0.839	0.908	0.955	0.980	1.00

Table 5. Spread of countries on dominant PCA Covariates.

	GE	Precipitation (mm)	WQI
Ethiopia	–0.35	848	55.3
Jordan	0.08	111	11.9
Nicaragua	–0.96	2391	57.1
Nigeria	–1.2	1150	20.1
Tajikistan	–0.91	691	42.8

We used the fractional logit models shown in Table 6 to predict proportions of piped and other-improved sources that provide safe water in every country for which 2010 JMP estimates were available. A comparison of the RADWQ countries' measured and predicted proportions is shown in Table 7. We estimate that 1 billion (confidence interval 0.75 to 1.6 billion) of the 5.8 billion using piped or other-improved sources receive faecally-contaminated water. This lowers the number of people estimated to use safe water from 5.8 billion (the 2010 JMP figure) to 4.8 billion, and increases the number or people with unsafe water from 0.78 billion to 1.8 billion as of 2010.

Table 6. Fractional Logit Models of Water Source Safety Proportions.

	Model			
Variable	% Piped Sources Safe	% Other-Improved Sources Safe	% Safe Piped Sources w/Elevated Sanitary Risk	% Safe Oth. Imp. Sources w/Elevated Sanitary Risk
Comp	1 0.879** (0.286)		–1.131*** (0.285)	
Comp 2	–0.436 * (0.209)	–0.792 *** (0.159)		
Comp 3				–0.350 *** (0.099)
Constant	3.188 (0.566)	0.370 (0.236)	–1.819 (0.707)	0.345 (0.075)
N	5	4	5	4
Residual df	2	2	3	2
Log pseudo-likelihood	–1.2305	–1.65	–2.119	–1.773

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$; one-tailed tests for hypothesized effects, robust standard errors in parentheses.

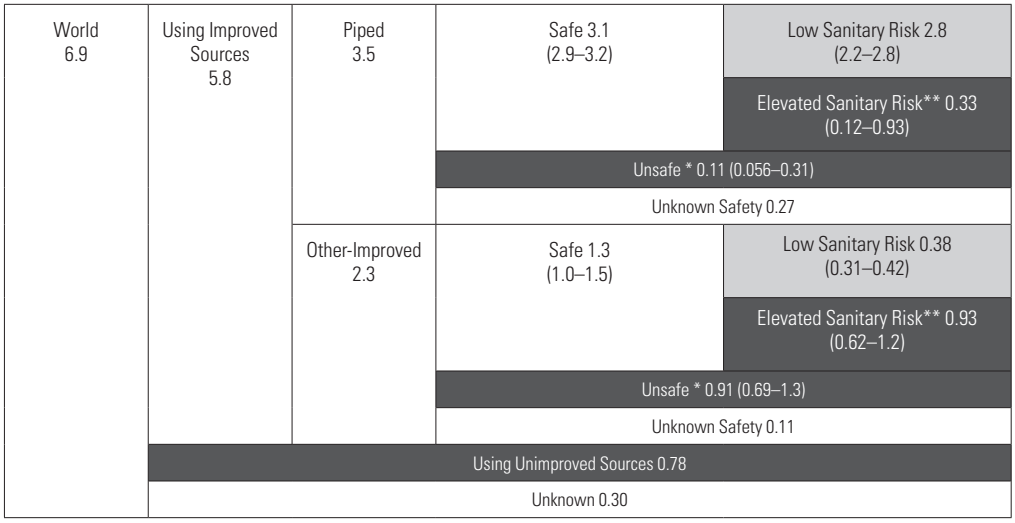
Of these 4.8 billion using safe water, approximately 1.2 billion people (confidence interval 0.75 to 2.1 billion) receive water from sources that are at risk of faecal contamination by virtue of having greater than two of the common sanitary risks for that source type as defined by RADWQ [14]. If a more stringent definition of safety (requiring both no faecal contamination and low sanitary risk) is used, then the estimate of the number of people with unsafe water is 3 billion, (confidence interval 1.5 billion to 3.9 billion). 302 million people reside in countries for which JMP estimates do not exist. An additional 370 million people reside in countries for which JMP estimates exist, but for which the data necessary for principal components analysis was unavailable. The safety of the water received by these 370 million is not estimated.

Table 7. Comparison of Measured and Predicted Proportions.

	% Piped Sources Safe		% Other-Improved Sources Safe		% Safe Piped Sources w/Elevated Sanitary Risk		% Safe Oth. Imp. Sources w/Elevated Sanitary Risk	
Country	RADWQ	Predicted	RADWQ	Predicted	RADWQ	Predicted	RADWQ	Predicted
Ethiopia	88%	85%	55%	55%	61%	59%	67%	57%
Jordan	100%	98%	NA	87%	25%	18%	NA	48%
Nicaragua	86%	85%	34%	33%	47%	33%	57%	6%
Nigeria	77%	77%	76%	68%	78%	73%	51%	51%
Tajikistan	88%	93%	82%	76%	9%	18%	56%	55%

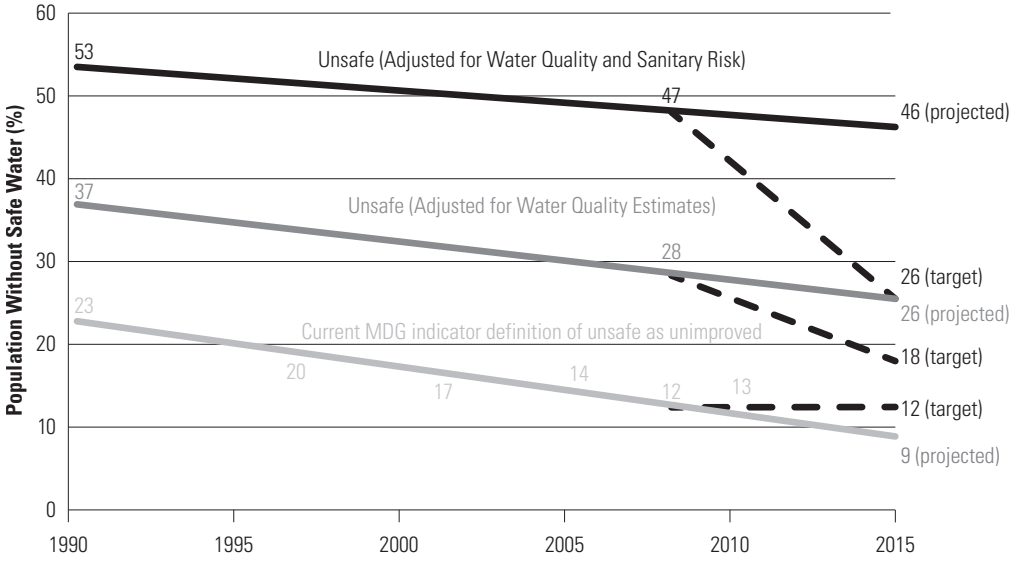
The full categorization of the world population of piped and other-improved water source users into categories based on faecal contamination and sanitary risk using our estimation methods is shown in Figure 1, where upper and lower bounds are shown in parentheses where available. The world's population is divided into those using improved sources, unimproved sources, and sources of unknown type. The improved source population is divided into those using piped and other-improved sources. Each of these two populations is divided into those using sources that are safe, unsafe, or unestimated safety. The populations using safe piped and safe other-improved sources are divided into those using sources with low and elevated levels of sanitary risks.

Figure 1. World population by water contamination status and sanitary risk for 2010 (billions).



* One billion people with improved sources that may be unsafe;
** 1.2 billion people with otherwise safe water with high sanitary risk

Figure 2. Comparison of MDG Target 7c baseline and target when including and excluding faecal contamination and sanitary risk in water safety.



Percentages of the world population for the purposes of adjusting the MDG Target 7c progress are calculated by assuming the populations with unknown water source types and water source safety are distributed similarly to the rest of the world. Accounting for faecal contamination based on our models increases the 1990 baseline estimate of the population without access to a safe water source from 23% to 37% (see Figure 2). In order to meet MDG Target 7c, the proportion without access to safe water would need to be reduced to 18% by 2015, while trends indicate this figure will be 26%. For 2010, the shortfall is 10 percentage points (680 million people), and we project an 8-percentage point shortfall in 2015, while JMP estimates, based on the indicator of use of an improved source, indicate that the MDG target has already been met.

Using a more stringent definition of water safety that requires water sources be both uncontaminated and of low sanitary risk would result in a 1990 baseline of 53% of the population, a target of 26%, and a 2015 projection of 46%. This would result in a 21-percentage point shortfall in 2010 and a 20-percentage point shortfall in 2015.

4. Discussion

Our estimates of the population with access to safe water were based on several assumptions that could contribute to over- or under-estimation.

We used the >1 cfu/100 mL TTC level as a threshold for considering water microbiologically safe, as did the RADWQ studies. E. coli and Enterrococci have been shown to be better indicators of waterborne disease risks than total TTC [23]. This could result in an overestimate of the population actually at risk of waterborne disease, as some sources testing positive for TTC may not be positive for E. coli.

We assumed that the relationships between water quality and national characteristics described by the models in Table 3 hold for countries other than the five countries assessed by RADWQ. The causal factors determining water quality for a given source type may differ from country to country and the causal relationships determining water quality for a given source type may differ from country to country. In addition, countries differ substantially regarding the mixture of predominant source types. For instance, protected springs were the only non-piped improved water source assessed by RADWQ in Tajikistan, while boreholes and protected wells were assessed in Ethiopia, Nicaragua, and Nigeria [8–12]. All non-piped "improved" sources were aggregated and treated as "other-improved". Given these country-to-country differences, the direction of

error will differ from country to country although the overall effect on the global estimates may be relatively small as the errors are aggregated.

The sanitary risk estimates are based on the proportion of safe sources assessed as having greater than two of the sanitary risks listed as possible on the RADWQ survey forms. Moreover, the RADWQ project reports stated that the lists of sanitary risks used in the survey could have been better tailored to country conditions [8–12]. Each of the possible risks on these forms probably contributes to a different level of actual risk for water contamination, but are weighted equally in the RADWQ methodology [8–12,14]. The relationship between the number of sanitary risks and the prevalence and degree of water contamination differs between countries (Table 2). Since any single sanitary risk is significant, use of this threshold (three or more risk factors) is likely to underestimate the population using unsafe water.

We assumed that no contamination occurs between the water point and the point and time of use.

However, such contamination is known to occur [5]. Water that is safe in a distribution system at one point may become contaminated at another point before it is received by the user, due to deficiencies in the distribution system [24]. Additionally, water that must be transported manually from the source to the home, and any water stored in the home, as is common with other-improved sources, can become contaminated due to unsanitary storage conditions [25]. We did not account for this due to lack of representative data. The effect may be greater for the estimates for "other-improved" sources than for piped sources. However, the effect is likely to be significant in the case of piped sources with discontinuous service that encourage users to store water in the home. These assumptions would tend to lead to an underestimate of the population using unsafe water.

We assumed that the proportion of piped and other-improved sources that provide safe water found in the RADWQ reports represent the safety of those sources over an entire year. This is likely incorrect, due to the transient nature of many contamination events [26]. One round of water quality testing is unlikely to capture the true extent of microbial contamination that might occur over a long period of time at a given source. As such, the RADWQ data likely substantively underestimate the proportion of water sources that are contaminated over an extended time period. The effect would be to underestimate the population using unsafe water.

We did not consider contamination from nitrates, arsenic, fluoride, or any of the chemical contaminants not tested for by the RADWQ project. This is because waterborne pathogens from faecal sources cause more disease than any other waterborne contaminant, and thermotolerant coliform bacteria measurement serves as an indicator for the presence of faecal contamination [15]. There is likely not complete overlap in terms of the types of contamination a given water source might face, so more water sources are probably unsafe than reliance on microbiological indicators alone would indicate. The effect of these assumptions is to underestimate the population using unsafe water.

We assumed that the proportion of piped and other-improved sources that are faecally contaminated, and the proportion of these with elevated sanitary risk, remained constant across time, at least backwards to 1990 for the purposes of recalculating the MDG baseline, and forwards to 2015 for projected proportions. This assumption was necessary due to a lack of equivalent data for the relevant time periods. The effect of this assumption will vary from country to country, and the overall effect on the global estimates may be relatively small as the errors are aggregated.

Since the RADWQ data was not disaggregated by rural and urban settings, we assumed that the proportions of sampled water sources complying with WHO guidelines and having significant levels of sanitary risk were the same in urban and rural settings. The effect of this assumption will vary from country to country.

We assumed that 100% of unimproved sources do not provide safe water. This is based on a lack of water quality data and a consequent reliance on the same methodology as JMP, treating

all such sources as unsafe due to the lack of sustainability of access and lack of protection against contamination characteristic of such sources. This assumption could result in an overestimate of the number of people receiving faecally contaminated water. However, this assumption does not overestimate those receiving water from sources with elevated sanitary risks, since unimproved sources by definition lack sanitary protection. In addition, the MDG indicator accounts for both access and water quality [1]. Since unimproved sources may not meet the access criterion of the indicator, the potential error of the assumption is further reduced.

We did not account for household water treatment (HWT). Use of adequate HWT strategies in households can reduce the health risks of water from contaminated sources (both improved and unimproved sources) and also the risk arising from water contamination during transport and household storage [25,27]. Among a sample of 67 low and middle-income countries, using data from the nationally representative Demographic and Health Surveys (DHS), 1.1 billion people use HWT [27]. However, the DHS surveys used did not confirm responses indicating HWT use with physical indicators in the home of such use. Additionally, it is unknown how these people might be distributed over the actual quality of their source water, how many of these people only use water that they have treated, or to what degree these people sustain the HWT strategy for long periods of time. There also exists the risk of recontamination of water post-treatment [28]. The number of people relying on HWT receiving safe water is likely much smaller than 1.1 billion. As such, the effect of the assumption is likely to be a relatively small overestimate of the population using unsafe water.

The effects of the above assumptions will vary between countries. As such, the country-level estimates for water source compliance and sanitary risk are not presented, as these are likely to be imprecise. However, the overall effect on the global estimates may be relatively small as the errors are aggregated.

The confidence intervals were calculated using the standard errors of the model parameter estimates, and did not account for the standard error of the dependent variable. The standard errors of the reported RADWQ figures were unavailable. This results in an underestimate of the upper bounds and an overestimate of the lower bounds.

5. Conclusions

We show that the MDG indicator (proportion of the population using an improved water source) used in assessing progress towards MDG Target 7c results in a substantive underestimate of the proportion of the population using unsafe water. The 2010 JMP data shows that 780 million people (11% of the population) use unimproved sources. We estimate that 1 billion (between a lower bound of 750 million and an upper bound of 1.6 billion) people using piped or other-improved water sources receive unsafe water, meaning 1.8 billion people did not have access to safe water in 2010.

Using a definition for safe water that includes the absence of faecal contamination in a one-off sample from a piped or other-improved source shows that the current indicator, based on the definition of an improved source alone, underestimated the progress required to meet the drinking-water component of MDG Target 7c by 10% of the global population, whereas the 2010 JMP progress estimate suggests that the MDG drinking-water target has already been achieved.

We estimate that an additional 1.2 billion (between 750 million and 2.1 billion) people using safe piped or other-improved sources are using sources that are at elevated risk of contamination unlikely to be detected by one-off, or perhaps even routine monitoring.

While these estimates are imprecise, their magnitude and health and development implications suggest that greater attention is needed to better understand and manage the problem of contamination of improved water sources. This study highlights the substantive differences between population estimates using water from an improved source and estimates of populations using water free of faecal contamination and water with low risk of faecal contamination. As increasing populations use piped and other-improved water sources it is likely that increasing attention will

be paid to water safety. The demand for evidence to inform effective policy making will increase in parallel. Here we use data from large scale dedicated surveys to gain preliminary insights. While the RADWQ methodology has provided valuable information regarding national water safety in terms of contamination and sanitary risk factors, further work is required to identify the most appropriate means to secure greater and more targeted evidence to inform decision-making.

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Conflict of Interest

The authors declare no conflict of interest.

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