Implementation of key demand-reduction measures of the WHO Framework Convention on Tobacco Control and change in smoking prevalence in 126 countries: an association study

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Summary

Background The WHO Framework Convention on Tobacco Control (WHO FCTC) has mobilised efforts among 180 parties to combat the global tobacco epidemic. This study examined the association between highest-level implementation of key tobacco control demand-reduction measures of the WHO FCTC and smoking prevalence over the treaty's first decade.

Methods We used WHO data from 126 countries to examine the association between the number of highest-level implementations of key demand-reduction measures (WHO FCTC articles 6, 8, 11, 13, and 14) between 2007 and 2014 and smoking prevalence estimates between 2005 and 2015. McNemar tests were done to test differences in the proportion of countries that had implemented each of the measures at the highest level between 2007 and 2014. Four linear regression models were computed to examine the association between the predictor variable (the change between 2007 and 2014 in the number of key measures implemented at the highest level), and the outcome variable (the percentage point change in tobacco smoking prevalence between 2005 and 2015).

Findings Between 2007 and 2014, there was a significant global increase in highest-level implementation of all key demand-reduction measures. The mean smoking prevalence for all 126 countries was 24·73% (SD 10·32) in 2005 and 22·18% (SD 8·87) in 2015, an average decrease in prevalence of 2·55 percentage points (SD 5·08; relative reduction 10·31%). Unadjusted linear regression showed that increases in highest-level implementations of key measures between 2007 and 2014 were significantly associated with a decrease in smoking prevalence between 2005 and 2015). Each additional measure implemented at the highest level was associated with an average decrease in smoking prevalence of 1·57 percentage points (95% CI –2·51 to –0·63, p=0·001) and an average relative decrease of 7·09% (–12·55 to –1·63, p=0·011). Controlling for geographical subregion, income level, and WHO FCTC party status, the per-measure decrease in prevalence was 0·94 percentage points (–1·76 to –0·13, p=0·023) and an average relative decrease of 3·18% (–6·75 to 0·38, p=0·079). This association was consistent across all three control variables.

Interpretation Implementation of key WHO FCTC demand-reduction measures is significantly associated with lower smoking prevalence, with anticipated future reductions in tobacco-related morbidity and mortality. These findings validate the call for strong implementation of the WHO FCTC in the WHO's Global Action Plan for the Prevention and Control of Non-communicable Diseases 2013–2020, and in advancing the UN's Sustainable Development Goal 3, setting a global target of reducing tobacco use and premature mortality from non-communicable diseases by a third by 2030.

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Introduction

Tobacco use is the single greatest preventable cause of death in the world. Globally, tobacco kills nearly 6 million people a year and is a risk factor for six of the eight leading causes of death.[1] Moreover, global tobacco use exerts an extraordinary toll on economic wellbeing, causing more than US$1 trillion in health-care costs and lost productivity annually.[2]

In response to the growing tobacco epidemic, WHO's Framework Convention on Tobacco Control (FCTC) was adopted in 2003 and came into force in 2005. The WHO FCTC is an evidence-based treaty that obligates 180 parties (179 countries plus the European Union as of March, 2017) to implement a broad array of supply and demand reduction tobacco control measures.[3]

To help countries meet their commitments to the treaty and implement important policies that prevent and reduce tobacco use, in 2008, WHO developed the MPOWER technical assistance package corresponding to WHO FCTC articles: article 6 (raise taxes on tobacco), article 8 (protect people from tobacco smoke), articles 11 and 12 (warn about the dangers of tobacco), article 13 (enforce bans on tobacco advertising, promotion, and sponsorship [TAPS]), article 14 (offer

For the **WHO's Framework Convention on Tobacco Control (FCTC)** see http://www.who.int/tobacco/framework/WHO_FCTC_english.pdf

Research in context

Evidence before this study

We searched MEDLINE, PubMed, and Google Scholar for studies published in English or French from database inception to Nov 30, 2016. We also askded tobacco control experts about any articles that might have been submitted or in press. We also searched Google Scholar and Google for grey literature. Two studies were identified that examined the empirical relationship between the implementation of tobacco control demand measures of the WHO FCTC and smoking prevalence. First, Dubray and colleagues (2015) found that overall, countries with higher MPOWER composite scores in 2008 experienced greater decreases in current tobacco smoking between the years 2006 and 2009. Fewer than 60 countries had sufficient data to meet the inclusion criteria. Second, Anderson and colleagues (2016) found a negative association between higher policy scores (articles 6, 8, 11, 13, and 14 in 2010) and change in smoking prevalence between 2010 and 2015.

Added value of this study

Our study offers a comprehensive global assessment of the effect of the change in progress of highest-level implementation of key tobacco control demand-reduction measures of the WHO FCTC on reductions in smoking prevalence over the treaty's first decade. First, our analyses were done with a cohort of 126 countries for which WHO had computed trend estimates of smoking prevalence for 2005 and 2015. Second, the outcome variable was the difference in smoking prevalence over a broader 10-year period (2005–15), corresponding to the first decade of the WHO FCTC. Third, the predictor variable for each of the 126 countries was the change in the number of key demand-reduction measures that had been implemented at the highest level between 2007 (WHO's first analysis) and 2014 (WHO's most recent analysis), rather than the single timepoint measures used in Dubray and colleagues' and Anderson and colleagues' studies. Our study's use of changes in the number of highest-level implementations allows for a more rigorous assessment of whether increases in implementation of tobacco control demand-reduction measures were associated with decreases in prevalence. Additionally, the present study assessed the effect of five key WHO FCTC measures on changes in smoking prevalence over a 10-year period, whereas the other studies examined the association of an aggregate policy score with change in smoking prevalence over a 3-year (Dubray and colleagues) or a 5-year (Anderson and colleagues) period.

Implications of all the available evidence

Although the progress of WHO FCTC ratification has been remarkable (179 countries and the European Union, covering nearly 90% of the world's population), implementation of the treaty has been slow and has not always been at the highest level. The present results show that countries that have implemented key demand-reduction measures of the WHO FCTC at the highest level have experienced significant decreases in smoking prevalence, with the magnitude of the decrease being proportional to the number of highest-level implementations. Finally, these results support the call for full implementation of the WHO FCTC in WHO's Global Action Plan for the Prevention and Control of Non-communicable Diseases 2013–2020 and Sustainable Development Goal 3.

help to quit tobacco use), and article 20 (monitoring tobacco use).[1]

Evidence shows that the WHO FCTC has accelerated implementation of measures in three crucial policy domains: TAPS bans,[4] smoke-free laws,[5] and health warnings on tobacco packaging.[6] Studies have shown that strong implementation of WHO FCTC key demand-reduction measures have led to dose-response effects for comprehensive smoke-free laws[7] and pictorial health warnings.[8,9] Although research shows that tobacco tax and price increases are the fastest acting and most effective of all the key measures, progress has been much slower in this policy domain.

So far, however, only two studies have addressed the important issue of whether WHO FCTC policies are associated with reductions in tobacco use at the population level. Dubray and colleagues[10] found that overall, countries with higher MPOWER composite scores in 2008 experienced greater decreases in current tobacco smoking between the years 2006 and 2009. Anderson and colleagues[11] used WHO report data from 2010[12] to generate policy percentage scores (from 0% to 100%) for articles 6, 8, 11, 13, and 14. They found a negative association between the overall combined policy score at a single timepoint (2010) and differences in smoking prevalence between 2010 and 2015.

Our study reports a broader and more comprehensive assessment of the effect of five key WHO FCTC demand-reduction measures on tobacco smoking prevalence than both previous studies. Our analyses included a cohort of 126 countries: every country where tobacco smoking prevalence trend estimates for 2005 and 2015 were available.[13] The outcome variable was the change in smoking prevalence over a 10-year period (2005 to 2015), corresponding to the first decade of the WHO FCTC. The predictor variable for each of the 126 countries was the change in the number of key measures that had been implemented at the highest level between 2007 (the first year that WHO examined implementation of these measures) and 2014 (the most recent examination) rather than the single timepoint measure used in the two previous studies.[10,11] Both previous studies performed their analyses with the four-point implementation scale, which gave equal weight to any advance, regardless of

whether it fulfilled parties' obligations to meet the WHO FCTC guidelines. By contrast, the present study focuses on the effect of fully implementing a policy at the highest level, the level acknowledged by scientific literature as the most effective for reducing tobacco use.

This assessment study was a rigorous test of the global progress of the implementation of key demand-reduction measures over the first decade of the WHO FCTC. We tested the hypothesis that countries implementing policies at the highest level experienced significant decreases in current tobacco smoking prevalence. Examination of the association between differences in the putative cause (highest-level implementation of demand-reduction measures) and differences in the outcome (smoking prevalence) conforms to best practices in policy assessment.[14] Finally, among WHO FCTC parties, the assessment addressed the question of whether parties that had implemented a greater number of demand-reduction measures at a level approximately equivalent to the guidelines of the corresponding WHO FCTC articles had greater reductions in tobacco smoking prevalence over the first decade of the treaty than did countries with fewer measures.

Methods

Study design and key measures included

This study represents an analysis of WHO data from 126 countries. Data on five key WHO FCTC demand-reduction measures (referred to as key measures) in 2007 and 2014 were taken from the WHO Report on the Global Tobacco Epidemic 2015,[15] articles 6 (tobacco taxes), 8 (protection from exposure to tobacco smoke), 11 (health warnings), 13 (TAPS), and 14 (tobacco cessation). Article 12 was not included because first, the criteria for highest level of achievement changed between 2007 and 2014, and second, media campaigns and other article 12 interventions are of a transient nature (could occur sporadically). MPOWER also calls for countries to monitor tobacco use and prevention policies (article 20), but although monitoring is a crucial tobacco control activity, it is not a demand-reduction measure and thus was not included in the analyses.

WHO assesses the level of achievement of key measures on a scale of 2–5, where 2 is the lowest level, and 5 is the highest level (1=no data available). Figure 1 presents the criteria for the highest level of achievement for each measure. For all 126 countries, each of the five key measures was allocated 1 point in 2007 and 1 point in 2014 if it reached the highest level of achievement or 0 points if it did not. A country could also score –1 point if a highest-level policy was in place in 2007 but not in 2014. For each country, the number of measures at the highest level was summed for 2007 and for 2014. The predictor variable was the 2014 total minus the 2007 total for each country.

Covariates

The World Bank classifies countries by gross national income per capita into four categories: low income (US $1035 or less), low-middle income ($1036–$4085), upper-middle-income ($4086–$12 615), and high income ($12 616 or more).[16] A country was classified as a WHO FCTC party if it had ratified the WHO FCTC before the 2014 WHO MPOWER data were collected (1=WHO FCTC party; 2=WHO FCTC non-party).

The 22 UN geographical subregions are Eastern Africa, Middle Africa, Northern Africa, Southern Africa, Western Africa, Northern America, Caribbean, Central America,

Taxation (article 6)	Smoke-free policies (article 8)	Warning labels (article 11)	Bans on advertising, promotion, and sponsorship (article 13)	Cessation programmes (article 14)
Taxes comprise at least 75% of retail price of the most popular brands of cigarettes	All public places completely smoke-free: • Health-care facilities • Educational facilities • Universities • Government facilities • Indoor offices • Hospitality venues (restaurants, bars, pubs, etc) • Public transportation	Large warnings covering an average of at least 50% of the front and back of the package* with all appropriate characteristics: • Specific warnings are mandated and rotated • Describing the harmful effects of tobacco use on health • Located on individual packs and any outside packaging used in retail sale • Large, clear, visible, and legible • Written in (all) principal language(s) of the country • Including pictures or pictograms (photographic or graphic)	A ban on all forms of direct and indirect advertising: • National television and radio • Local magazines and newspaper • Billboards (and all other outdoor advertising) • Point-of-sale advertising • Free distribution by mail or other means • Promotional discounts • Non-tobacco goods and services identified with brand names • Brand name of non-tobacco goods and services used for tobacco products • Appearance of tobacco brands or products in television and films • Sponsored events	A national toll-free quit line, and both nicotine replacement treatment and some or all cessation services partially or fully cost-covered

Figure 1: **WHO criteria for the highest level of achievement of key tobacco control demand-reduction measures**
*Replaced 2007 criterion, which did not require warning to cover an average of 50% of the front and back (only at least 50% of the principal display area of the pack).

	Taxation (article 6)	Smoke-free policies (article 8)	Warning labels (article 11)	Bans on advertising, promotion, and sponsorship (article 13)	Cessation programmes (article 14)	All five key measures
All 126 countries						
2007	3 (2%)	7 (6%)	7 (6%)	4 (3%)	10 (8%)	0
2014	28 (22%)	35 (28%)	32 (25%)	16 (13%)	20 (16%)	1 (1%)
p value*	<0·0001	<0·0001	<0·0001	<0·0001	0·006	..
WHO FCTC parties (n=116)						
2007	3 (3%)	7 (6)%	7 (6%)	4 (3%)	10 (9%)	0
2014	28 (24%)	34 (29%)	31 (27%)	16 (14%)	18 (16%)	1 (1%)
p value*	0·0001	0·0001	0·0001	0·0001	0·021	..
WHO FCTC non-parties (n=10)†						
2007	0	0	0	0	0	0
2014	0	1 (10%)	1 (10%)	0	2 (20%)	0

Data are n (%). FCTC=Framework Convention on Tobacco Control. *McNemar test, which tests the differences in the proportion of countries with highest level demand-reduction measures implemented between 2007 and 2014. †McNemar tests could not be computed for FCTC non-parties.

Table 1: **Number of countries with key tobacco control demand-reduction measures at the highest level of achievement in 2007 and in 2014**

South America, Southern Asia, Eastern Asia, South-Eastern Asia, Western Asia, Central Asia, Eastern Europe, Northern Europe, Southern Europe, Western Europe, Australia and New Zealand, Melanesia, Micronesia, and Polynesia.[17] Dummy variables were used to code all subregions (0 *vs* 1).

Outcome variable

The outcome variable was the change in estimated tobacco smoking prevalence for each country between 2005 and 2015 (2015 prevalence minus the 2005 prevalence). We used the estimates of tobacco smoking prevalence in individuals aged 15 years or older derived by WHO for 2005 and 2015 to compute the outcome variable. Estimates for 116 countries were extracted from the WHO Global Report on Trends in Prevalence of Tobacco Smoking 2015;[15] prevalence estimates for an additional ten countries computed after the publication of the report were provided by WHO. Data for use of smokeless tobacco are scant in most countries; thus, it was not possible to include prevalence trend estimates for smokeless use.

See Online for appendix

WHO derived prevalence estimates from a Bayesian meta-regression of data from surveys done between 1990 and 2014 in each country. Data were sourced from country-provided surveys submitted to the WHO FCTC Implementation Database and the WHO Comprehensive Information Systems for Tobacco Control database.[15]

Statistical analysis

McNemar tests were done to test differences in the proportion of countries that had implemented each of the measures at the highest level between 2007 and 2014. Four linear regression models were conducted to examine the association between the predictor variable (the change between 2007 and 2014 in the number of key measures implemented at the highest level and the relative change), and the outcome variable (the percentage point change and the relative change in tobacco smoking prevalence between 2005 and 2015). Diagnostic tests showed that the linear regression model was appropriate for the analysis with respect to the assumptions of linearity, normality of percentage point change in smoking prevalence, and homoscedasticity.

Model 1 was an unadjusted analysis in all 126 countries and for WHO FCTC non-parties only (n=10), and then for WHO FCTC parties only (n=116). Model 2 added the following covariates: WHO FCTC party status, 2016 World Bank Income Classification, and UN subregion. Interactions between each of the covariates and the predictor variable were also examined to test whether the association between WHO FCTC policy implementation and change in prevalence varied across each covariate. Model 3 was an unadjusted analysis for the relative change in tobacco smoking prevalence between 2005 and 2015 in all 126 countries and then for WHO FCTC parties only and for WHO FCTC non-parties. Model 4 tested the association between the change in the highest-level key measure implementation and the change in smoking prevalence expressed as a relative change in all 126 countries (with the covariates included in model 2). Analyses were done with SPSS (version 22).

Role of the funding source

The funder of the study had no role in the study design, data collection, data analysis, data interpretation, or writing of the report. The lead and corresponding authors (SG and GF, respectively) had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Results

Smoking prevalence estimates were available for 126 (65%) of 194 WHO member states. According to the 2016 World Bank classification, 45 (36%) were high-income countries, 32 (25%) were upper-middle-income countries, 32 (25%) were lower-middle-income countries, and 17 (13%) were low-income countries (appendix). Smoking prevalence estimates for 2005 and 2015, as well as percentage point change between 2005 and 2015 for each country are shown in the appendix. Nauru and Niue were not categorised by the World Bank; therefore, following WHO's standard procedure for countries without a World Bank classification, gross domestic product data from the Central Intelligence Agency World Factbook were used, resulting in both countries being classified as upper-middle-income countries. In FCTC parties (n=116), the mean treaty ratification date was 2005, where 116 (70%) of the included countries had become parties to the treaty. Andorra, Argentina, Cuba, Dominican Republic, Haiti, Indonesia, Morocco, Switzerland, the USA, and Zimbabwe were considered FCTC non-parties.

Table 1 presents the number of countries with key tobacco control demand-reduction measures in 2007 and 2014. By 2014, only one country (1%) had implemented all five key measures at the highest level, four countries (3%) had four measures, ten countries (8%) had three measures, 20 countries (16%) had two measures, 40 countries (32%) had one measure, and 51 countries (40%) had implemented no measures at the highest level. The appendix shows the change in scores for each key measure by country. A mean of 1·04 measures (SD 1·14) were implemented at the highest level by 2014.

Overall, there was a significant increase in the proportion of highest-level implementations in each key measure between 2007 and 2014 (table 1). In the 116 WHO FCTC parties, there was a significant increase between 2007 and 2014 in highest-level implementations in all five policy domains (p<0·0001 for articles 6, 8, 11, and 13; p=0·021 for article 14); by contrast, there was no significant increase in any of the key measures in the ten non-parties.

The mean smoking prevalence for all 126 countries was 24·73% (SD 10·32) in 2005 and 22·18% (8·87) in 2015, a mean decrease in prevalence of 2·55 percentage points (5·08; relative reduction of 10·31%; appendix). In WHO FCTC parties, the mean smoking prevalence in 2005 was 24·74% (10·41) and 22·11% (8·84) in 2015, a mean decrease of 2·62 percentage points (5·13; relative reduction of 10·63%). In WHO FCTC non-parties, the mean smoking prevalence in 2005 was 24·72% (9·79) and 22·97% (9·65) in 2015, a mean decrease of 1·75 percentage points (4·63; relative reduction of 7·07%).

From 2005 to 2015, smoking prevalence decreased in 90 (71%) of 126 countries, increased in 24 countries (19%), and did not change (a change of <1 percentage point) in 12 countries (10%; appendix).

In an unadjusted linear regression (model 1; table 2), increases in highest-level implementations of key measures between 2007 and 2014 were significantly associated with a decrease in smoking prevalence between 2005 and 2015 (p=0·001). Specifically, an increase of one additional highest-level implementation was associated with a mean decrease in smoking prevalence of 1·57 percentage points (95% CI –2·51 to –0·63). Figure 2 presents the scatterplot of the 126 countries showing this association.

In WHO FCTC parties only, an increase of one additional highest-level implementation was associated with a mean decrease in smoking prevalence of 1·44 percentage points (p<0·005; 95% CI –2·44 to –0·44). In non-parties, an increase of one additional highest-level implementation was associated with a mean decrease in smoking prevalence of 2·94 percentage points (95% CI –6·03 to 0·15), although this was not significant because of the small sample size (n=10).

In an adjusted model with all 126 countries, controlling for WHO FCTC status, World Bank income, and UN subregion, the association remained significant (p=0·023 model 2; table 2). Specifically, each additional measure implemented at the highest level was associated with an average decrease in smoking prevalence of 0·94 percentage points (95% CI –1·76 to –0·13) between 2005 and 2015. In WHO FCTC parties, each additional measure implemented at the highest level was associated with aw mean decrease in smoking prevalence of 0·98 percentage points (95% CI –1·81 to –0·14, p=0·022; analyses not shown in table 2).

The strong association between the number of key measures implemented and reductions in smoking prevalence did not differ across UN subregion, World Bank income category, or whether or not the country was a WHO FCTC party (all interactions p>0·30 after Bonferroni adjustment; analyses not shown in table 2).

	b	SE	*t* test	p value	95% CI
Unadjusted analysis					
Change in the number of highest-level implementations of key demand-reduction measures between 2007 and 2014 (all 126 countries)	–1·57	0·47	–3·31	0·001	–2·51 to –0·63
WHO FCTC parties (n=116)	–1·44	0·51	–2·84	<0·005	–2·44 to –0·44
WHO FCTC non-parties (n=10)	–2·94	1·34	–2·19	0·060	–6·03 to 0·15
Adjusted analysis					
Change in the number of highest-level implementations of key demand-reduction measures between 2007 and 2014	–0·94	0·41	–2·30	0·023	–1·76 to –0·13
2016 World Bank income level	–0·69	0·50	–1·39	0·167	–1·69 to 0·30
FCTC party status	0·74	1·36	0·55	0·587	–1·96 to 3·44
UN subregions					
Eastern Africa	2·30	1·78	1·29	0·200	–1·24 to 5·84
Middle Africa	17·57	2·87	6·13	<0·0001	11·89 to 23·26
Southern Africa	6·26	2·11	2·97	0·004	2·08 to 10·43
Western Africa	8·16	1·85	4·42	<0·0001	4·49 to 11·82
Northern America	–2·69	2·72	–0·99	0·325	–8·08 to 2·71
Caribbean	2·56	2·02	1·27	0·207	–1·44 to 6·56
Central America	–0·53	2·13	–0·25	0·804	–4·74 to 3·69
South America	–2·02	1·64	–1·23	0·221	–5·28 to 1·24
Southern Asia	1·20	1·97	0·61	0·544	–2·71 to 5·10
Eastern Asia	–0·59	2·03	–0·29	0·773	–4·62 to 3·44
South eastern Asia	1·87	1·62	1·16	0·249	–1·33 to 5·08
Western Asia	6·80	1·53	4·43	0·000	3·75 to 9·84
Central Asia	1·99	2·37	0·84	0·402	–2·71 to 6·69
Northern Africa	8·86	2·82	3·14	0·002	3·27 to 14·45
Eastern Europe	–0·57	1·53	–0·38	0·708	–3·60 to 2·45
Northern Europe	–3·68	1·53	–2·41	0·018	–6·72 to –0·65
Western Europe	–1·15	1·78	–0·65	0·518	–4·67 to 2·37
Melanesia	0·70	3·70	0·19	0·851	–6·64 to 8·04
Micronesia	–3·23	2·74	–1·18	0·241	–8·65 to 2·20
Polynesia	–1·31	2·33	–0·56	0·58	–5·93 to 3·32
Australia	–3·43	3·64	–0·94	0·347	–10·65 to 3·78

All interactions, model summary: F=0·74, p=0·76; p>0·30 after Bonferroni adjustment. b=unstandardised regression coefficient. FCTC=Framework Convention on Tobacco Control.

***Table 2*: Model 1 and model 2, unadjusted and adjusted linear regression analysis examining the association between the change in the number of key demand-reduction measures implemented at the highest level between 2007 and 2014 and the percentage point change in tobacco smoking prevalence between 2005 and 2015, controlling for 2016 World Bank income level, FCTC party status, and UN subregions**

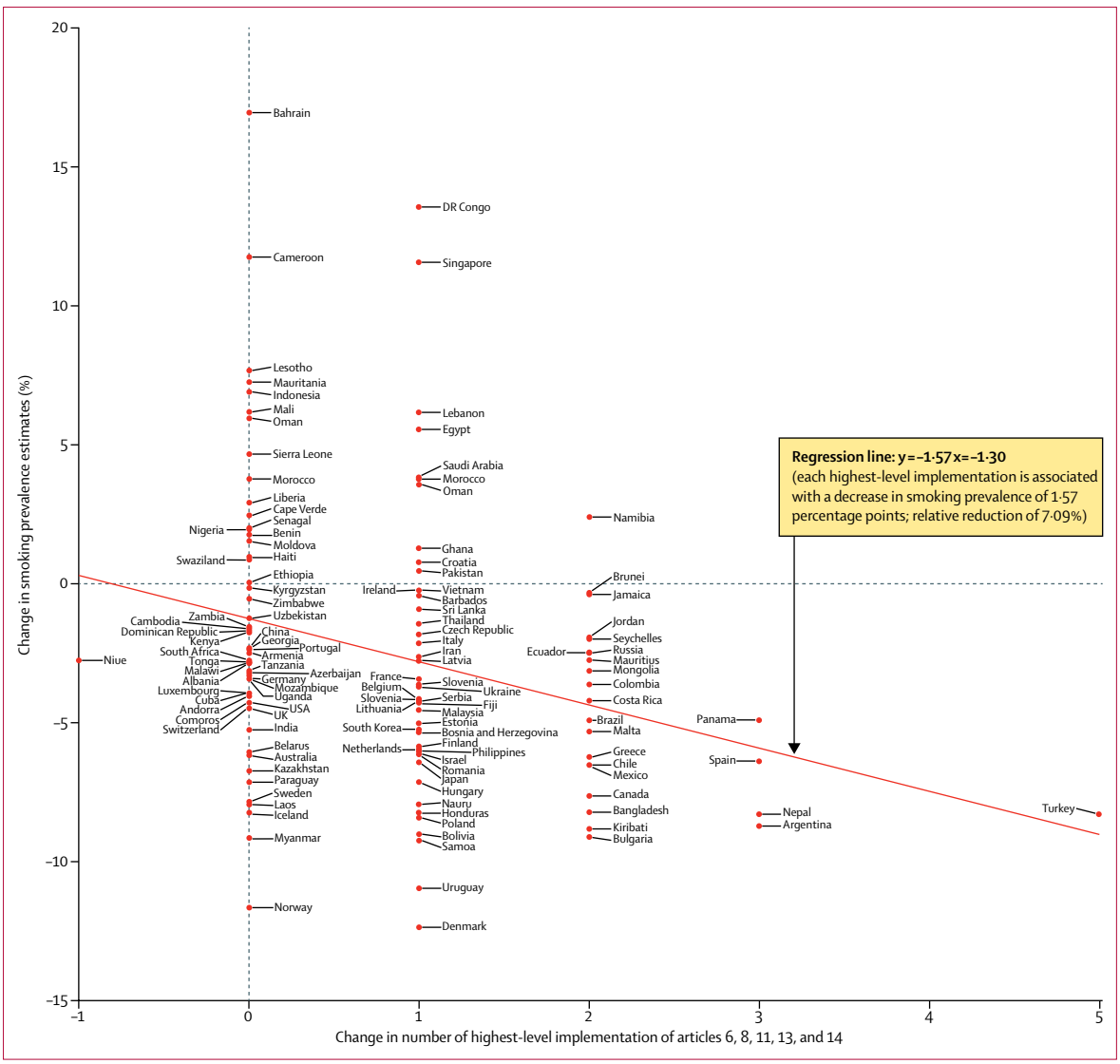

Figure 2: **Relation between change in the number of five key WHO FCTC demand-reduction measures implemented at the highest level between 2007 and 2014 (x-axis) and change in smoking prevalence between 2005 and 2015 (y-axis)**

The unadjusted and adjusted analyses for the relative change in smoking prevalence are presented in table 3. Each additional highest-level implementation was associated with a relative decrease in smoking prevalence of 7·09% in the unadjusted analysis (95% CI –12·55 to –1·63, p=0·011,) and 3·18% in the adjusted analysis (–6·75 to 0·38, p=0·079). Again, this association did not differ by UN subregion, World Bank income category, or party status (all interactions p>0·30 after Bonferroni adjustment; analyses not shown in table 3).

Discussion

Between 2007 and 2014, there was a significant increase in the proportion of countries that implemented each of the five key measures of the WHO FCTC at the highest level. This was consistent with the WHO FCTC Impact Assessment Expert Group's conclusion that the WHO FCTC has increased implementation of strong tobacco control measures.[18] Additionally, increases in the number of highest-level implementations between 2007 and 2014 were associated with significantly greater reductions in smoking prevalence over the WHO FCTC's first decade. In all 126 countries, each additional measure implemented at the highest level between 2007 and 2014 was associated with an average decrease in smoking prevalence of 1·57 percentage points between 2005 and 2015, a relative decrease of 7·09%. Thus, for example, countries that had implemented three additional highest-level measures experienced, on average, a decrease in smoking prevalence of 4·71 percentage points (1·57%×3), and a relative decrease of 21·27% (7·09%×3). The significant unadjusted association was maintained in the main adjusted model.

Both the unadjusted and adjusted associations were consistent across parties and non-parties, income classification, and UN subregion. The association between highest-level implementations and reductions in smoking prevalence was also observed in the non-parties: in the unadjusted analyses, each additional highest level implementation was associated with a decrease in smoking prevalence of 2·94 percentage points and a relative decrease of 9·97%, but neither was significant because of the small sample size (n=10).

The path from policy to reductions in tobacco use depends on two distinct stages: first, the likelihood that a country will implement a tobacco control measure, and second, the effect that the measure has on reducing tobacco use. The findings of this study show that the second stage is no different for WHO FCTC parties and non-parties. If any country implements a measure at the highest level, tobacco use is likely to decrease. However, the difference lies in the first stage: parties are more likely to implement strong measures. This might be due to the lower level of governmental support for tobacco control in non-parties (which also led them to remain non-parties), but it also might be due to non-parties' absence of access to the benefits that accrue from being a WHO FCTC party, such as greater regional and global cooperation and technical support for tobacco control as well as the expectations and obligations for advancing tobacco control among the parties. Therefore, although WHO FCTC parties and non-parties have an equal opportunity to reduce smoking if strong tobacco control measures are implemented, actually being a party is associated with greater likelihood of taking those opportunities through strong implementation of the key demand reduction measures.

Geographical subregions varied in the number of key demand-reduction measures implemented at the highest level and thus in reductions in smoking prevalence. For example, Northern Europe, South America, and Australia engaged in strong WHO FCTC implementation over the first decade of the WHO FCTC and experienced corresponding large reductions in smoking prevalence (–7·11, –6·75, and –6·20 percentage points, respectively). By contrast, Western, Middle and Northern African regions implemented very few WHO FCTC measures; these regions experienced increases in smoking prevalence (by 3·36, 12·60, and 4·60 percentage points, respectively). Countries in the same region often have similar goals, political will, challenges, and resources; thus, regional differences were expected.

These findings show the potential of tobacco control measures to reduce tobacco use. But the pace of highest-level implementations has been slow. For example, by 2014, only a fifth of countries (28 of 126) in the study sample had implemented tax measures at the highest level. This is disconcerting because raising tobacco taxes to increase prices is the most effective means of reducing tobacco use, especially in low-income and middle-income countries where smokers are more price-sensitive.[2,19–21]

	b	SE	*t* test	p value	95% CI
Unadjusted analysis					
Change in the number of highest-level implementations of key demand-reduction measures between 2007 and 2014 (all 126 countries)	–7·09	2·76	–2·57	0·011	–12·55 to –1·63
WHO FCTC parties (n=116)	–6·98	3·00	–2·33	0·022	–12·91 to –1·04
WHO FCTC non-parties (n=10)	–9·97	5·09	–1·96	0·086	–21·69 to 1·76
Adjusted analysis					
Change in the number of highest-level implementations of key demand-reduction measures of the WHO FCTC between 2007 and 2014	–3·18	1·80	–1·77	0·079	–6·75 to 0·38
2016 World Bank income level	–3·09	2·19	–1·41	0·161	–7·43 to 1·25
FCTC party status	4·36	5·96	0·73	0·466	–7·47 to 16·20
UN subregions					
Eastern Africa	2·54	7·82	0·32	0·746	–12·97 to 18·04
Middle Africa	158·43	12·55	12·62	<0·0001	133·53 to 183·33
Southern Africa	25·94	9·23	2·81	0·006	7·63 to 44·25
Western Africa	46·16	8·09	5·71	0·000	30·12 to 62·21
Northern America	–18·93	11·91	–1·59	0·115	–42·57 to 4·70
Caribbean	6·71	8·84	0·76	0·450	–10·83 to 24·24
Central America	–14·71	9·31	–1·58	0·117	–33·18 to 3·76
South America	–10·71	7·20	–1·49	0·140	–24·99 to 3·56
Southern Asia	–0·50	8·62	–0·06	0·954	–17·60 to 16·61
Eastern Asia	–3·48	8·90	–0·39	0·697	–21·14 to 14·18
South eastern Asia	5·65	7·09	0·80	0·427	–8·41 to 19·71
Western Asia	32·07	6·72	4·77	<0·0001	18·75 to 45·40
Central Asia	5·14	10·37	0·50	0·621	–15·43 to 25·72
Northern Africa	37·43	12·35	3·03	0·003	12·94 to 61·92
Eastern Europe	–0·02	6·68	0·00	0·998	–13·28 to 13·24
Northern Europe	–14·58	6·70	–2·18	0·032	–27·88 to –1·29
Western Europe	–6·41	7·78	–0·82	0·412	–21·84 to 9·03
Melanesia	2·77	16·22	0·17	0·865	–29·40 to 34·94
Micronesia	3·01	11·98	0·25	0·802	–20·76 to 26·78
Polynesia	–2·59	10·22	–0·25	0·800	–22·86 to 17·67
Australia	–22·11	15·93	–1·39	0·168	–53·72 to 9·50

All interactions, model summary: F=0·76, p=0·73; p>0·30 after Bonferroni adjustment. b=unstandardised regression coefficient. FCTC=Framework Convention on Tobacco Control.

Table 3: **Model 3 and model 4, unadjusted and adjusted linear regression analysis examining the association between the change in the number of key measures at the highest level between 2007 and 2014 and the relative change in smoking prevalence between 2005 and 2015, controlling for 2016 World Bank income level, FCTC party status, and UN subregions**

Although the largest increase among all highest-level implementations of key measures was article 8 (smoke-free policies), global progress here has still been slow. Article 8 guidelines call for "implementation of comprehensive smoke-free policies within five years of entry into force of the Convention for each party"[22] and yet, as of 2014, only 28% of countries had implemented such highest-level smoke-free laws. Comprehensive smoke-free laws are a crucial intervention in reducing the burden of smoking-attributable diseases and deaths by protecting people from exposure to second-hand smoke. Notably,

smoke-free environments not only protect non-smokers, but also encourage smokers to quit.[7]

There was a significant increase between 2007 and 2014 in the implementation of health warnings on cigarette packaging at the highest level (from seven to 32 countries). At present, 105 countries or jurisdictions require pictorial warnings, and 94 have warnings that cover at least an average of 50% (front and back) of the cigarette package.[9] Many studies have shown that large pictorial graphic warnings are the most effective.[8,9] Despite the excellent progress made in many countries, the treaty does call for parties to implement article 11 within 3 years after treaty ratification, and, so again, progress in this key policy domain has been slower than desired.

Only 16 (13%) of 126 countries had implemented a complete TAPS bans by 2014, far fewer than desired given that the treaty calls for parties to implement comprehensive TAPS bans within 5 years of the entry into force of the WHO FCTC.[23,24] Research shows that tobacco marketing and promotional activities increase consumption of tobacco products and that bans on such activities reduce initiation and consumption, especially among young people.[25,26]

Finally, progress on tobacco cessation has been slow, particularly in lower-income countries. Although many countries might not offer cessation treatment because of perceived cost or low demand, there are several effective low-cost forms of cessation support that can be implemented quickly in all countries.[27] Global progress and success in tobacco cessation is imperative to reach the WHO and UN goal of 25% reduction in premature mortality from non-communicable diseases by 2025[28] and reduction by a third by 2030,[29] respectively, with a specific target of reducing tobacco use by 30%.[28,29]

Although the progress of WHO FCTC ratification has been remarkable (covering nearly 90% of the world's population) and the global implementation of all five key demand-reduction measures has increased since the WHO FCTC came into force, there are still many countries where implementation has fallen short of the standards set by WHO FCTC. Many countries are faced with multiple challenges in moving tobacco control forward, most notably, because of the role of the tobacco industry in delaying and weakening tobacco control policies, particularly in low-income and middle-income countries.[30] Strong implementation of the WHO FCTC article 5.3, which focuses on countering tobacco industry interference, is of crucial importance in fighting the tobacco epidemic and protecting public health.

There are some study limitations that warrant caution when interpreting the results. First, only 65% of the world's countries met the study inclusion criteria. This study did, however, include all 126 countries with available data, which included countries from all income classification levels, WHO regions, and UN subregions.

Second, there are limitations to the available data that might have resulted in an underestimation of the observed estimates or prevented more in-depth analyses. With regard to the first issue, the time interval of the predictor variable of the change of highest-level implementations (2007–14) does not align precisely with the outcome variable of change in smoking prevalence (2005–15). However, because the time interval of the predictor is fully nested within the outcome, it is likely that if anything, the observed estimates of effect are underestimates for those countries that implemented highest-level policies early in the life of the WHO FCTC. Another source of underestimation might have resulted from the fact that this study assessed policies implemented at the highest level, without taking into account the level of enforcement and compliance for the implemented policies. This discrepancy is unfortunately endemic in this area, which highlights the need for evidence systems that examine the actual effectiveness of policy implementation within and across different countries.[14,31]

In addition to the above, the available data prevented a more in-depth analysis of the effect of individual measures on smoking prevalence. As many countries implement tobacco control policies together or within a relatively close proximity in time (resulting in high multicollinearity in individual predictor variables), it is too difficult to untangle the effect of each policy on changes in smoking prevalence. These challenges point to the need for more rigorous and timely evaluation studies to assess the effect of tobacco control measures within and across countries.

Third, there are challenges in the consistency and quality of prevalence data. Some WHO prevalence estimates were from under-resourced countries where gathering quality prevalence data is difficult. In many countries across the spectrum, surveys were done at irregular intervals and both before and after policies were not always implemented. These data quality issues should not produce a bias in estimating the relationship between policy implementation and reductions in prevalence, but rather a greater uncertainty about its magnitude.

Fourth, this study focused on the association between five key tobacco control demand-reduction measures and smoking prevalence. Other demand and supply-reduction measures of the WHO FCTC were not considered because of the paucity of evaluation data and policy monitoring efforts on these measures. Thus, estimates of the effect of implementation of other tobacco control policies outside of MPOWER was not possible, therefore highlighting the strong need for evidence systems to track the progress and effect of the full range of WHO FCTC policies and guidelines. Moreover, there might be several other plausible factors that have influenced the decreases in smoking prevalence (eg, industry activities and interference and networks that affect the diffusion of knowledge and influence decision making with regards to WHO FCTC provisions);[32] however, it was not possible to assess many of these variables because of the unavailability of such data across the full range of countries studied. Additionally, this study necessarily focused on smoking because only scant

data exist on other forms of tobacco, including smokeless tobacco.

This finding highlights the importance of tobacco control in two global initiatives that have set goals of markedly reducing non-communicable diseases through reducing tobacco use: WHO's Global Action Plan,[28] and the UN's Sustainable Development Goals, which calls on countries to "strengthen the implementation of the World Health Organization Framework Convention on Tobacco Control in all countries, as appropriate".[29]

Contributors

SG and GTF conceived and designed the study, and prepared the drafts of the Article. SG did all the data analyses. All authors contributed to the interpretation of the data, to editing and revising all drafts, and have approved the final submitted manuscript.

Declaration of interests

We declare no competing interests. AC and KS are WHO employees; ETD'E was a WHO employee at the time when this Article was prepared; he is now retired from WHO.

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