Published by Oxford University Press on behalf of the International Epidemiological Association
International Journal of Epidemiology 2011;40:417–428
doi:10.1093/ije/dyq238

Diabetes mellitus and tuberculosis in countries with high tuberculosis burdens: individual risks and social determinants

Jeremy D Goldhaber-Fiebert,[1]* Christie Y Jeon,[2] Ted Cohen[3,4] and Megan B Murray[3,4,5]

[1]Department of Medicine, Stanford Health Policy, CHP/PCOR, Stanford University School of Medicine, Stanford, CA, USA, [2]Center for Infectious Disease Epidemiologic Research, Mailman School of Public Health, Columbia University, New York, NY, USA, [3]Department of Epidemiology, Harvard School of Public Health, Boston, MA, USA, [4]Division of Global Health Equity, Brigham and Women's Hospital, Boston, MA, USA and [5]Infectious Disease Unit, Massachusetts General Hospital, Boston, MA, USA

*Corresponding author. Stanford Health Policy, CHP/PCOR, Stanford Medical School, 117 Encina Commons, Stanford, CA 94305-6019, USA. E-mail: jeremygf@stanford.edu

Accepted 8 November 2010

Background A growing body of evidence supports the role of type 2 diabetes as an individual-level risk factor for tuberculosis (TB), though evidence from developing countries with the highest TB burdens is lacking. In developing countries, TB is most common among the poor, in whom diabetes may be less common. We assessed the relationship between individual-level risk, social determinants and population health in these settings.

Methods We performed individual-level analyses using the World Health Survey ($n = 124\,607$; 46 countries). We estimated the relationship between TB and diabetes, adjusting for gender, age, body mass index, education, housing quality, crowding and health insurance. We also performed a longitudinal country-level analysis using data on per-capita gross domestic product and TB prevalence and incidence and diabetes prevalence for 1990–95 and 2003–04 (163 countries) to estimate the relationship between increasing diabetes prevalence and TB, identifying countries at risk for disease interactions.

Results In lower income countries, individuals with diabetes are more likely than non-diabetics to have TB [univariable odds ratio (OR): 2.39; 95% confidence interval (CI): 1.84–3.10; multivariable OR: 1.81; 95% CI: 1.37–2.39]. Increases in TB prevalence and incidence over time were more likely to occur when diabetes prevalence also increased (OR: 4.7; 95% CI: 1.0–22.5; OR: 8.6; 95% CI: 1.9–40.4). Large populations, prevalent TB and projected increases in diabetes make countries like India, Peru and the Russia Federation areas of particular concern.

Conclusions Given the association between diabetes and TB and projected increases in diabetes worldwide, multi-disease health policies should be considered.

Keywords Type 2 diabetes mellitus, *Mycobacterium tuberculosis*, disease interaction, developing countries, social determinants, observational study

Introduction

When chronic non-communicable diseases proliferate faster than infectious diseases recede, previously uncommon disease interactions can take on population health significance. Recent systematic reviews[1,2] suggest that type 2 diabetes mellitus (T2DM) increases individual risk of *Mycobacterium tuberculosis* (TB) disease. Country-level analyses suggest that TB prevalence is mediated by both social determinants and public health strategies.[3,4] Yet, strikingly little work has been done to assess the relationship of TB and diabetes at the individual level in countries where TB prevalence is highest and diabetes prevalence is rising most rapidly. Given increases in diabetes and the persistence of TB in these areas, the relationship of individual risks, social determinants and population health impacts due to interactions between diabetes and TB should be assessed.

Classical descriptions of epidemiologic transition involve the replacement of infectious diseases of deprivation with non-communicable diseases of affluence,[5] though currently many countries face growing dual disease burdens.[6] Diabetes prevalence continues to rise rapidly in developing countries, driven by changes in diet and lifestyle.[7] Though historically having fewer diabetic individuals than their share of the world's population would imply, by 2025, India, China, Indonesia, Pakistan and Brazil alone are projected to carry nearly half the world's diabetes burden.[7] In many countries, TB epidemics continue, fueled by drug resistance,[8] HIV/AIDS[9,10] and social inequalities.[4]

Analyses that inform both TB and diabetes policies must estimate the individual-level relationship between the two conditions and translate it into projections of future population burden, accounting for mediating effects of social determinants and prevailing health policies. Though few such studies exist, it is suggested that the impact of a diabetes/TB interaction may play a substantial role in fueling the ongoing TB epidemic in India.[11] Given existing data limitations, such studies have necessarily depended on the assumption that the strength of association between diabetes and TB risk is the same as that estimated almost exclusively from non-population-representative studies from higher income countries.

In order to appreciate the global population health significance of rising diabetes prevalence in the presence of persistent TB epidemics in settings where current TB burdens are high, we evaluated the relationship of diabetes and TB at both individual and country levels using population-representative data from largely lower income countries.

Methods

An individual-level cross-sectional analysis examined the association between symptoms of TB and self-reported diagnosed diabetes conditioning on known TB risk factors across individuals from 46 countries. This analysis was repeated for countries grouped by geographic region to assess how the relationship as well as mediating influences of social determinants varied across regions. A country-level analysis examined the association between diabetes and TB prevalence across 163 countries. Its goals were to assess the impact of longitudinal increases in diabetes prevalence on changes in TB prevalence and incidence; and identify countries potentially 'at risk' for TB/diabetes interactions because of the high prevalence of both.

Individual-level analysis

Data were derived from individual responses to the World Health Organization's (WHO) 2002–03 World Health Survey (WHS).[12,13] This analysis included individuals in countries that had sampling weights available and used the WHS long-form questionnaire, providing self-reported diabetes diagnosis and symptoms of TB. The main analysis employed data on individual adults ($n = 124\,545$; representing approximately 400 million people) from all 46 countries for which these data are available (Table 1).

The main outcome was the presence of symptoms of active TB disease. Microbiological confirmation was not possible as the WHS did not include mycobacterial culture or sputum smear microscopy. We classified active TB as an affirmative response to two questions: 'Over the last 12 months, have you had blood in your phlegm or have you coughed blood?' and 'Over the last 12 months, have you experienced cough lasting 3 weeks or longer?'. It has previously been shown that such questions have sensitivities between 65 and 70% and specificities between 55 and 75% for TB with other respiratory conditions also associated with an affirmative answer.[14–16]

The main predictor was the presence of T2DM. Because the WHS did not test fasting-plasma glucose, we classified individuals as having diabetes if they responded affirmatively to the question: 'Have you ever been diagnosed with diabetes (high blood sugar)?' It has previously been shown that the sensitivities and specificities of such questions are ~65–85% and 95–99%, respectively, compared with biochemical markers or clinical records, with overall Kappas of 0.70–0.85.[17–22] Though the cross-sectional nature of the analysis precluded statements about time ordering and causality, we interpreted a positive association between our outcome and predictor as evidence consistent with prior longitudinal studies showing that diabetes increased subsequent risk of developing active TB.[1,23–26]

The model included covariates that have previously been associated with TB: gender, age categorized in 10-year intervals; body mass index (BMI) categorized as $\leqslant 17$, 17–20, 20–25, 25–30, $\geqslant 30$; schooling in years categorized as <1, 1–7, 8–12, >12; current daily smoking and the number of years a person has

Table 1 Countries from the WHS included in the individual-level analysis

Country	*N* (survey responses)	Actual population represented[a]	Per-capita GDP (PPP I$2005)
Congo	1010	310 000	244
Ethiopia	46	307 000	546
Malawi	4585	3 111 000	608
Nepal	12	14 000	910
Burkina Faso	1529	1 052 000	939
Mali	349	445 000	944
Bangladesh	421	5 183 000	953
Chad	2106	1 211 000	987
Ghana	2897	4 931 000	1053
Zambia	2052	2 086 000	1066
Comoros	1523	103 000	1127
Kenya	3521	11 500 000	1274
Senegal	641	433 000	1401
Mauritania	1416	404 000	1566
Laos	4449	2 187 000	1573
Cote d'Ivoire	1768	3 353 000	1672
Vietnam	2974	35 400 000	1780
India	4380	82 700 000	1816
Pakistan	1481	14 300 000	1937
Georgia	2410	2 550 000	2649
Philippines	7518	32 800 000	2686
Sri Lanka	3833	6 075 000	3092
China	3812	3 780 000	3115
Morocco	1050	4 871 000	3212
Paraguay	4541	2 172 000	3640
Namibia	2894	555 000	4140
Swaziland	1005	129 000	4256
Ukraine	583	7 548 000	4324
Dominican Republic	2639	2 412 000	5192
Bosnia Herzegovina	776	2 028 000	5448
Tunisia	3349	3 427 000	5677
Ecuador	1549	2 880 000	5879
Kazakhstan	3957	8 654 000	6748
Uruguay	2763	2 129 000	7598
South Africa	1016	8 170 000	7733
Brazil	380	8 795 000	8017
Mauritius	2186	396 000	9070
Russia	3223	47 400 000	9549
Malaysia	4316	9 133 000	10 420
Mexico	23 283	37 800 000	10 815
Croatia	888	3 000 000	11 551
Estonia	884	1 208 000	12 921
Slovakia	1139	2 571 000	13 660
Czech Republic	650	7 736 000	17 635
Spain	5788	29 600 000	25 922
United Arab Emirates	955	793 000	40 712

[a]Based on sample weights from the WHS.

been a daily smoker; drinking at least 1 drink per day in the previous week; urban or rural residence; number of individuals living in the household, number of individuals per room; socio-economic status defined by whether the house had floors made from tile, cement, brick or wood and walls made from cement, brick, stone or wood, whether the house had toilet facilities flushed to a piped sewage system or septic tank, per-capita household total expenditure in the previous month expressed in year 2003 international dollars calculated using purchasing power parity (PPP)[27] and having health insurance.

We estimated univariable associations between TB and each covariate as unadjusted odds ratios (ORs). Given the large sample size, we included all covariates in the multivariable models to obtain adjusted ORs. We fit two multivariable models. The first included all covariates except diabetes to assess how ORs for known TB risk factors changed from the crude analyses when they were simultaneously included. The second included all covariates and diabetes to assess the final adjusted relationship of TB and diabetes.

The multivariable analysis was repeated for individuals from subgroups of the countries formed by geographic regions (Africa, Asia, Latin America and Europe). ORs were compared for consistency of relationships across regions.

To explore the effects of relative socio-economic status on the relationship between TB and diabetes, we augmented the multivariable model with indicator variables for an individual's relative expenditure (household expenditure tertile) compared either with other individuals in the same country or with individuals in all countries in the same per-capita gross domestic product (GDP) quintile. We also included interactions between diabetes and the relative expenditure measures. Additionally, we assessed interactions between gender, age, smoking and alcohol consumption and measures of relative expenditure.

To assess potential bias due to non-response, we compared the association between TB and each covariate separately for the sample restricted to individuals who responded for all covariates and for all individuals who provided a response for the particular covariate. We assessed the possibility of misclassification of diabetes and TB due to self-report. Since self-reported diagnosed diabetes may not capture true diabetes status, we confirmed that other covariates had expected relationships with self-reported diabetes (e.g. positive association with higher BMI). Collinearity between variables in the multivariable model was assessed using correlation coefficients, with those highly collinear variables deleted one at a time in an analysis to assess the extent to which collinearity impacted ORs and confidence intervals (CIs).

All individual-level analyses used logistic regressions with individual sampling weights (13), country-fixed

effects and robust standard errors clustered by country.

Country-level analysis

Data included adult population size and diabetes prevalence,[28,29] WHO estimates of TB prevalence and incidence,[30] and per-capita GDP expressed in year 2005 international dollars using PPP.[31] Included countries had total adult populations of 3.2 billion in 1995 and 3.6 billion in 2003.

We examined the relationship between TB prevalence and TB incidence, diabetes prevalence, and per-capita GDP longitudinally between 1990–95 and 2003–04. Longitudinal changes in TB incidence, TB prevalence and diabetes prevalence from 1990–95 to 2003–04 were characterized by logistic regression to quantify the association between increases in diabetes and in TB (prevalence or incidence) conditioning on a country's GDP quintile in 1995. We also identified countries with relatively high TB and diabetes prevalence using a cut-off that also provided sufficient numbers of dual burden countries with WHS data for further individual-level sub-analyses (both values above the 45th percentile across all countries in 2003).

Software

All analyses were undertaken using Stata/SE 10.1 for Windows (StataCorp, USA).

Results

Individual-level analysis

In 46 mainly low- and middle-income countries, individuals reporting a diabetes diagnosis were more likely to have symptoms of TB (coughing blood or blood in sputum, cough lasting 3 weeks or longer) (univariable OR: 2.39; 95% CI: 1.84–3.10; multivariable OR: 1.81; 95% CI: 1.37–2.39).

Table 2 describes the characteristics of included individuals from the 46 WHS countries. Of the study population, 1.4% reported coughing blood or blood in their sputum in the past 12 months as well as cough lasting $\geqslant$3 weeks and were classified as having TB, while 3.6% reported being diagnosed with diabetes. The study population included slightly more women than men, and the majority of individuals were <40 years of age. Most individuals were normal weight (BMI 20–25) though 5.5% had a BMI <17%, and 8.7% had a BMI >30. Of individuals, 59.3% reported $\geqslant$8 years of schooling. Nearly 20% were smokers, and 8.4% reported drinking at least 1 drink per day. Over two-thirds lived in homes with good floors and walls, but only half lived in homes with good toilet facilities. Approximately half lived in urban areas. There was substantial variation in household size (5th to 95th percentile: 1–11 people), crowding (5th to 95th percentile: 0.3–5.0 people per room) and monthly per-capita household expenditure (5th to 95th percentile: I$3.0–I$474 per person). Approximately 40% of individuals reported having health insurance.

In univariable analyses (Table 3), TB (coughing blood or blood in sputum and cough lasting $\geqslant$3 weeks) is positively associated with reporting a diabetes diagnosis (OR: 2.39; 95% CI: 1.84–3.10), increasing age ($\geqslant$60 years; OR: 3.54; 95% CI: 2.53–4.94), lower BMI (BMI $\leqslant$ 17; OR: 4.01; 95% CI: 2.56–6.27), longer duration of daily smoking (each additional year, OR: 1.02; 95% CI: 1.01–1.04) and greater household crowding (additional person per room, OR: 1.01; 95% CI: 1.01–1.03). TB was negatively associated with more education (>12 years schooling, OR: 0.17; 95% CI: 0.09–0.31), a home with good floors and walls or with a good toilet (OR: 0.59; 95% CI: 0.43–0.83 and OR: 0.82; 95% CI: 0.68–0.98, respectively), an urban location (OR: 0.67; 95% CI: 0.53–0.85), the number of people in the household (additional person, OR: 0.95; 95% CI: 0.93–0.97); and having health insurance (OR: 0.72; 95% CI: 0.52–0.99).

When we assessed these relationships in the multivariable analysis including all covariates except diabetes (Table 3), the positive association between TB and male gender strengthened (OR: from 1.18 to 1.34). The multivariable adjustment attenuated the apparent effect of age ($\geqslant$60 years, OR: from 3.54 to 2.93), more education (>12 years schooling, OR: from 0.17 to 0.27), good floor and walls (OR: from 0.59 to 0.75), good toilet (OR: from 0.82 to 1.24), urban location (OR: from 0.67 to 0.80) and health insurance (OR: from 0.72 to 0.85). Other significant ORs changed by <0.05 between univariable and multivariable analyses.

In the multivariable model that included diabetes, TB was positively associated with diabetes (OR: 1.81; 95% CI: 1.37–2.39)—reduced from the univariable analysis (OR: 2.21) (Table 3). The relationship between TB and age was further attenuated ($\geqslant$60 years, OR: 2.74; 95% CI: 1.93–3.89). The remaining relationships remained virtually unchanged, with ORs differing by $\leqslant$0.03.

Repeating the multivariable model for individuals living in African, Asian, European and Latin American countries separately (Table 4), diabetes and TB maintained a remarkably consistent and generally significant relationship (OR: 1.96; 95% CI: 1.23–3.12; OR: 1.74; 95% CI: 0.82–3.72; OR: 2.38 95% CI: 1.08–5.24; OR: 1.99; 95% CI: 1.44–2.75, respectively for each region). TB risk was also positively associated with increasing age most strongly in Africa and Asia; and household crowding most strongly in Europe. TB risk was negatively associated with schooling and urban location.

Including a measure of relative expenditure (per-capita household expenditure tertile), compared either with other individuals of the same country or with to individuals within the same GDP quintile, did not alter the direction or magnitude of our main

Table 2 Characteristics of WHS respondents

Variable	Included in main analyses ($N = 124\,545$)[a] Value	All responding to a given question N	Value
Symptoms of TB (%)	1.4	193 867	1.7
Self-reported T2DM (%)	3.6	206 174	3.5
Male (%)	47.7	227 480	47.8
Age <30 years (%)	30.0	227 116	31.5
Age 30–39 years (%)	21.2	227 116	21.1
Age 40–49 years (%)	18.6	227 116	17.9
Age 50–59 years (%)	13.0	227 116	13.0
Age ⩾60 years (%)	17.2	227 116	16.5
BMI <17 (%)	5.5	161 353	6.1
BMI 17–20 (%)	20.7	161 353	44.4
BMI 20–25 (%)	43.9	161 353	20.9
BMI 25–30 (%)	21.2	161 353	20.4
BMI ⩾30 (%)	8.7	161 353	8.2
School <1 year (%)	13.5	226 615	23.6
School 1–7 years (%)	27.2	226 615	28.5
School 8–12 years (%)	44.0	226 615	36.0
School >12 years (%)	15.3	226 615	11.9
Current daily smoker (%)	19.8	223 402	22.7
Time daily smoker, years, [mean (SD)]	3.5 (9.3)	223 402	3.9 (10.0)
At least one drink per day (%)	8.4	216 281	7.3
House with good floor and walls (%)	72.8	216 487	62.1
House with good toilet (%)	48.9	223 217	44.7
Urban (%)	49.4	234 491	45.0
Household members (people), [mean (SD)]	5.1 (2.8)	235 157	5.4 (2.9)
People per room (people), [mean (SD)]	1.8 (1.6)	231 209	2.0 (1.7)
Per-capita household expenditure (I$2005 per month), [mean (SD)]	142.9 (357.1)	225 341	125.0 (344.8)
Respondent insured (%)	39.8	199 664	29.8

All means and standard deviations are weighted using sampling weights.
[a]Those included in the main analyses (univariable and multivariable) were required to have responded to questions for all covariates in the model.

findings (Appendix Table 1, available at *IJE* online). Similarly, when relative expenditure and its interaction with diabetes were included, the direction and magnitude of our main findings did not change. Importantly, no specific pattern of excess TB risk conditional on diabetes at particular relative expenditure levels emerged. Similarly, when we considered interactions between relative expenditure and gender, age, smoking and alcohol consumption, the direction and magnitude of the relationship between TB and diabetes did not change, nor did we observe strong gradients between relative expenditure and any of these other variables.

In multivariable analyses restricted to nine countries with high burdens of both TB and diabetes (Table 5), the relationship between TB and diabetes strengthened slightly (OR: from 1.81 to 2.00) (Appendix Table 2, available at *IJE* online).

Findings were generally robust to sensitivity analyses assessing selection bias, self-report of diabetes and the symptomatic definition of a TB case (Appendix Tables 3, 4, and 5, available at *IJE* online). Though some variables, namely those related to socioeconomic status, housing quality and crowding were collinear, findings from the multivariable analysis were largely unaffected by this collinearity.

Country-level analysis

Over 10 years, TB was more likely to increase in countries where diabetes prevalence increased (for TB

Table 3 Univariable and multivariable relationship between symptoms of TB, self-reported T2DM and other covariates

Variable	Value	*N*	TB (%)	Univariable analyses Unadjusted OR (95% CI)	Multivariable analysis without T2DM Adjusted OR (95% CI)	Multivariable analysis with T2DM Adjusted OR (95% CI)
Self-reported T2DM	No	120 104	1.33	1		1
	Yes	4441	3.16	2.39 (1.84–3.10)		1.81 (1.37–2.39)
Sex	Female	68 001	1.38	1	1	1
	Male	56 544	1.65	1.18 (0.90–1.54)	1.34 (0.92–1.95)	1.33 (0.92–1.93)
Age (years)	20–29	30 081	1.04	1	1	1
	30–39	30 411	1.20	1.37 (0.97–1.95)	1.44 (1.01–2.04)	1.44 (1.01–2.05)
	40–49	22–981	1.14	1.49 (1.24–1.78)	1.49 (1.20–1.86)	1.46 (1.17–1.83)
	50–59	14 951	1.78	2.28 (1.38–3.75)	2.12 (1.32–3.39)	2.03 (1.25–3.29)
	⩾60	19 931	2.37	3.54 (2.53–4.94)	2.93 (2.10–4.09)	2.74 (1.93–3.89)
BMI (m/kg^2)	<17	4038	4.56	4.01 (2.56–6.27)	3.89 (2.45–6.18)	3.91 (2.47–6.19)
	17–20	18 417	1.53	1.48 (1.25–1.75)	1.53 (1.27–1.83)	1.54 (1.28–1.84)
	20–25	57 911	1.07	1	1	1
	25–30	31 510	1.26	1.24 (0.92–1.68)	1.14 (0.87–1.50)	1.12 (0.85–1.47)
	⩾30	12 669	1.12	1.12 (0.81–1.54)	0.99 (0.74–1.33)	0.96 (0.72–1.27)
School (years)	None	16 874	3.06	1	1	1
	1–7	41 342	1.86	0.79 (0.54–1.15)	0.91 (0.60–1.38)	0.90 (0.59–1.37)
	8–12	53 655	0.99	0.42 (0.27–0.64)	0.64 (0.39–1.04)	0.64 (0.40–1.04)
	>12	12 674	0.28	0.17 (0.09–0.31)	0.27 (0.13–0.53)	0.27 (0.13–0.53)
Current daily smoker	No	105 000	1.32	1	1	1
	Yes	19 545	1.71	1.26 (0.97–1.62)	0.87 (0.59–1.27)	0.87 (0.59–1.27)
Time daily smoker[a]	<8	109 514	1.35	1.02 (1.01–1.03)	1.01 (0.99–1.03)	1.01 (0.99–1.03)
(years)	8–15	4075	1.18			
	15–25	5579	1.11			
	>25	5377	2.63			
At least one drink per day	No	115 135	1.44	1	1	1
	Yes	9410	0.97	0.91 (0.53–1.56)	0.84 (0.49–1.46)	0.84 (0.48–1.48)
House with good floor and walls	No	32 055	2.40	1	1	1
	Yes	92 490	1.02	0.59 (0.43–0.83)	0.75 (0.57–1.00)	0.74 (0.56–0.99)
House with good toilet	No	61 049	1.66	1	1	1
	Yes	63 496	1.13	0.82 (0.68–0.98)	1.24 (0.94–1.63)	1.23 (0.94–1.62)
Urban	No	58 339	1.77	1	1	1
	Yes	66 206	1.02	0.67 (0.53–0.85)	0.80 (0.67–0.97)	0.80 (0.66–0.96)
Household members[a]				0.95 (0.93–0.97)	0.95 (0.93–0.98)	0.95 (0.93–0.98)
	Q1	27 190	0.93			
	Q2	20 773	1.32			
	Q3	43 370	1.16			
	Q4	33 212	1.86			
People per room[a]				1.03 (0.99–1.07)	1.04 (0.99–1.09)	1.04 (0.98–1.09)
	Q1	30 963	0.90			
	Q2	30 176	1.07			
	Q3	24 907	1.28			
	Q4	38 499	2.02			

(continued)

Table 3 Continued

Variable	Value	*N*	TB (%)	Univariable analyses Unadjusted OR (95% CI)	Multivariable analysis without T2DM Adjusted OR (95% CI)	Multivariable analysis with T2DM Adjusted OR (95% CI)
Per-capita household expenditure[a]				1 (1.00–1.00)	1 (1.00–1.00)	1 (1.00–1.00)
	Q1	31 124	1.89			
	Q2	30 976	1.52			
	Q3	31 283	1.02			
	Q4	31 162	0.95			
Respondent insured	No	80 306	1.77	1	1	1
	Yes	44 239	0.83	0.72 (0.52–0.99)	0.85 (0.65–1.12)	0.84 (0.63–1.10)

[a]These variables enter the regression models as continuous variables. We present quartiles in the Table to clearly illustrate the change in TB prevalence across the range of variable values.

prevalence: OR: 4.7; 95% CI: 1.0–22.5; for TB incidence: OR: 8.7; 95% CI: 1.9–40.0) and in countries with lower per-capita, base year GDP (highest vs lowest GDP quintile for TB prevalence: OR: 0.09; 95% CI: 0.02–0.42; for TB incidence: OR: 0.03; 95% CI: 0.01–0.14)]. This is the case despite the fact that higher diabetes prevalence accompanied lower TB prevalence in both the 1990s and 2000s. Countries with higher diabetes prevalence tended to have lower TB prevalence and incidence in both periods (1990–95: Spearman's rho: prevalence −0.53; $P < 0.0001$ and incidence −0.52; $P < 0.0001$; 2003–04: ρ: prevalence −0.62; $P < 0.0001$ and incidence −0.63; $P < 0.0001$). There is also a strong GDP gradient: TB prevalence and incidence had a negative association with per-capita GDP (1990–95: rho: prevalence −0.75; $P < 0.0001$ and incidence −0.72; $P < 0.0001$; 2003–04: rho: prevalence −0.77; $P < 0.0001$ and incidence −0.74; $P < 0.0001$), whereas diabetes prevalence was positively associated with per-capita GDP (1990–95: rho: 0.57; $P < 0.0001$; 2003–04: rho: 0.64; $P < 0.0001$).

In 2003–04, 29 countries had both higher burdens of diabetes (>4.6% prevalence) and TB (>0.06% prevalence) (Table 5). These high-TB/high-diabetes burden countries represent 28% of the adult population (approximately 1 billion people) of the 163 countries.

Discussion

Individuals in lower income countries, where the majority of the world's TB burden is located, were more likely to report symptoms of active TB disease if they also reported a prior diagnosis of T2DM. At the population level, between the 1990s and early 2000s, TB prevalence and incidence were more likely to increase in countries in which diabetes prevalence increased, conditioning on base year, per-capita GDP. Countries of particular concern given their size, substantial TB burdens and large projected increases in diabetes prevalence[7,30] include Brazil, China, India, Peru and the Russian Federation.

While epidemiologic transitions classically involve shifts from infectious to non-communicable diseases, the lingering presence of both diseases heightens the risk of interaction. With nearly 1 billion individuals currently living in developing countries with substantial burdens of both TB and diabetes and rising trends of diabetes prevalence worldwide, our findings highlight the need for appropriate public health action.

This work contributes to a growing body of evidence on the importance of the TB/diabetes relationship. Notably, it considers population-representative data with large sample sizes from lower income countries, examining the relationship at both the country and individual level. The results confirm TB's relationship with known risk factors, adding further confidence in the analysis. Using data from countries with higher TB burdens, its findings provide population-representative confirmation for prior systematic reviews of studies conducted largely in selected sub-populations from higher income countries.[1,2]

We interpret the association between a self-reported diabetes diagnosis and TB symptoms as evidence of an association between the biological presence of diabetes and active TB disease. Self-report can potentially bias this interpretation.[32] In groups unlikely to know their diabetes status, true diabetes prevalence will likely be underestimated.[33] In light of this under-reporting, our estimate may be biased toward the null, given that true diabetics who were misclassified as non-diabetics or were excluded from the analysis due to non-response are also likely to be at risk for TB. Self-reported TB symptoms also have less than perfect sensitivity and specificity compared with gold-standard diagnostics. Of particular concern is that TB symptoms may be non-specific since pneumonia and bronchitis can cause hemoptysis of substantial duration, as previously reported.[34,35] Thus, the estimated relationship may also partly represent the

Table 4 World region comparison of the relationship between symptoms of TB, self-reported T2DM and other covariates*

	All countries ($N = 124\,545$) OR (95% CI)		Africa ($N = 35\,896$) OR (95% CI)		Asia ($N = 37\,153$) OR (95% CI)		Europe ($N = 16\,341$) OR (95% CI)		Latin America ($N = 35\,155$) OR (95% CI)	
Self-reported T2DM	1.81	1.37–2.39	1.96	1.23–3.12	1.74	0.82–3.72	2.38	1.08–5.24	1.99	1.44–2.75
Male	1.33	0.92–1.93	1.17	0.68–2.04	1.69	1.11–2.56	0.84	0.28–2.49	0.95	0.62–1.44
Age (years)										
30–39	1.44	1.01–2.05	1.42	0.90–2.24	1.39	0.88–2.20	4.60	1.92–11.0	1.01	0.87–1.18
40–49	1.46	1.17–1.83	1.36	0.70–2.63	1.63	1.30–2.05	2.00	0.62–6.50	1.12	0.90–1.38
50–59	2.03	1.25–3.29	2.24	1.10–4.56	2.71	1.09–6.79	1.22	0.22–6.74	1.02	0.50–2.07
>60	2.74	1.93–3.89	1.58	1.10–2.28	4.47	3.34–5.98	2.29	0.69–7.55	1.10	0.55–2.17
BMI (years)										
<17	3.91	2.47–6.19	0.99	0.48–2.05	4.50	3.12–6.51	1.69	0.51–5.61	0.39	0.14–1.08
17–20	1.54	1.28–1.84	1.32	0.86–2.02	1.49	1.34–1.64	1.99	0.92–4.32	1.93	0.60–6.16
25–30	1.12	0.85–1.47	0.58	0.31–1.09	1.12	0.62–2.02	2.97	0.99–8.88	1.26	0.99–1.62
⩾30	0.96	0.72–1.27	1.05	0.69–1.59	0.39	0.14–1.07	2.34	1.21–4.49	0.97	0.71–1.31
School (years)										
1–7	0.90	0.59–1.37	0.79	0.60–1.05	1.04	0.53–2.04	0.39	0.23–0.66	0.64	0.41–1.01
8–12	0.64	0.40–1.04	0.48	0.31–0.72	0.65	0.28–1.54	0.38	0.15–0.97	0.53	0.35–0.78
>12	0.27	0.13–0.53	0.23	0.07–0.82	0.26	0.08–0.84	0.24	0.08–0.78	0.04	0.01–0.46
Current daily smoker	0.87	0.59–1.27	0.89	0.45–1.78	0.91	0.64–1.29	0.18	0.02–1.39	1.05	0.82–1.34
Time daily smoker	1.01	0.99–1.03	1.00	0.99–1.01	1.00	0.98–1.03	1.05	0.98–1.13	0.98	0.94–1.03
At least one drink per day	0.84	0.48–1.48	1.55	0.73–3.29	0.76	0.33–1.72	0.77	0.26–2.22	0.51	0.12–2.19
House with good floor and walls	0.74	0.56–0.99	0.71	0.51–1.00	0.79	0.55–1.15	0.56	0.06–5.63	0.82	0.77–0.87
House with good toilet	1.23	0.94–1.62	0.91	0.40–2.09	1.39	0.95–2.04	0.78	0.51–1.21	1.46	1.27–1.68
Urban	0.80	0.66–0.96	0.74	0.36–1.50	0.80	0.61–1.04	1.31	0.76–2.25	0.70	0.57–0.86
Household members (#)	0.95	0.93–0.98	0.99	0.96–1.03	0.92	0.88–0.96	0.97	0.77–1.21	0.94	0.91–0.97
Household members per room	1.04	0.98–1.09	1.03	0.92–1.15	1.03	0.95–1.11	1.58	1.08–2.30	1.07	0.98–1.16
Per-capita household expenditure	1.00	1.00–1.00	1.00	1.00–1.00	1.00	0.99–1.00	1.00	1.00–1.00	1.00	1.00–1.00
Respondent insured	0.84	0.63–1.10	0.62	0.37–1.03	0.96	0.47–1.96	1.09	0.34–3.50	0.93	0.87–0.99

*Reference categories for variables like age, BMI, and schooling have ORs or 1.0 and are not shown in the table.

relationship between diabetes and other respiratory ailments. If diabetes were also positively associated with these other respiratory ailments, the relationship we estimated would be biased away from the null. Unfortunately, we know of no population-representative data sets including laboratory tests for TB and diabetes. Of some reassurance, our estimates are strikingly consistent with non-population-representative studies employing gold standard diagnostics.[1,2]

It is possible that individuals who develop complications of diabetes severe enough to seek more frequent medical care are more likely to be diagnosed with TB—leading to an observed association between TB and diabetes, though tuberculosis may have preceded diabetes. In our analysis, this possibility is unlikely because symptoms of TB were self-reported (i.e. blood in cough and cough lasting ⩾3 weeks) as occurring in the past year, while diabetes diagnosis could have occurred at any time in the person's life. Furthermore, for many people, the timescale of TB infection to symptoms is shorter than the timescale from the development of diabetes to the experience of symptoms that they themselves notice.

To the extent that the risks of both TB and T2DM are increased by HIV/AIDS, increases in HIV/AIDS could account for some of the association we have estimated here. It is well accepted that TB resurgence in many countries has been increased by HIV/AIDS. However, a review of the literature[36–42] on the

Table 5 Countries with high prevalence of both T2DM and TB

Country	T2DM prevalence (%)	TB prevalence (%)	Adult population	Included in WHS analysis
India	5.9	0.31	603 677 000	Yes
Brazil	5.2	0.08	109 901 000	Yes
Russian Federation	9.2	0.16	105 244 000	Yes
Pakistan	8.5	0.33	72 760 000	Yes
Republic of Korea	6.4	0.13	34 147 000	No
Romania	9.3	0.19	16 392 000	No
Peru	5.1	0.22	15 397 000	No
Malaysia	9.4	0.13	13 280 000	Yes
Iraq	7.7	0.20	11 962 000	No
Afghanistan	8.2	0.66	11 130 000	No
Yemen	7.7	0.14	8 137 000	No
Ecuador	4.8	0.20	7 548 000	Yes
Guatemala	5.5	0.11	5 620 000	No
China, Hong Kong SAR	8.8	0.08	5 424 000	No
Dominican Republic	10.0	0.12	4 991 000	Yes
Bolivia	4.8	0.29	4 480 000	No
El Salvador	6.2	0.07	3 620 000	No
Croatia	5.8	0.07	3 412 000	Yes
Honduras	5.7	0.10	3 302 000	No
Nicaragua	6.1	0.08	2 567 000	No
Mauritius	10.7	0.14	786 000	Yes
Qatar	16.0	0.08	393 000	No
Djibouti	4.9	1.14	300 000	No
Suriname	8.6	0.10	251 000	No
Brunei Darussalam	10.7	0.06	209 000	No
Belize	5.7	0.06	124 000	No
Micronesia	6.7	0.06	82 000	No
Kiribati	6.2	0.06	60 000	No
Palau	8.7	0.09	12 000	No

relationship between diabetes and HIV/AIDS finds no studies reporting evidence of a causative increase—notably, Hepatitis C co-infection and the use of highly active anti-retroviral therapy (HAART) particularly when protease inhibitors are included increase the risk of diabetes. In our sample of countries, those with the highest HIV/AIDS prevalence generally had low access to HAART in 2003, and, therefore, we believe that the possibility is small that HIV/AIDS explains the TB/diabetes relationships that we have observed.

In our country-level analysis, we interpret the longitudinal increase in TB prevalence associated with diabetes prevalence as evidence suggestive of a causal relationship between diabetes and TB manifesting at the population health level. Differential changes in country health-care systems leading to increased diagnosis of both diabetes and TB could also produce this result; a possibility we cannot exclude. However, we note that most developing countries between the 1990s and early 2000s did not drastically expand their diabetes screening, diagnostic or management services. Also, in our country-level analyses, we adjusted for country-fixed effects and per-capita GDP levels as proxies for the types of care provided by health systems. Additionally, in the individual-level analysis, even after adjusting for health insurance status and per-capita income, individuals with diagnosed diabetes were more likely to report symptoms of TB.

While the sample size in the study is large, a substantial number of individuals are excluded in the multivariable analysis because of non-response to survey items. Those not providing complete responses

tended to be poorer and have less education, though reassuringly, in univariable analyses, the association between TB and the covariates were similar for the restricted study sample and all individuals providing responses to a given item.

The mechanisms by which diabetes increases TB risk at the individual and population levels remain to be elucidated. Our individual-level analysis is cross-sectional and cannot distinguish the temporal ordering of diabetes onset, TB infection and TB symptom onset. Country-level analyses do not capture patterns of population mixing or other risk factors contributing to the observed associations. While the country- and individual-level relationships we estimate are broadly consistent, we do not observe even stronger associations of TB and diabetes in socioeconomic subpopulations where these two diseases are most likely to mix. However, if failure to be diagnosed with diabetes were associated with relative poverty, then differential under-diagnosis could explain our failure to detect an economic gradient.

Future research priorities include epidemiologic and modeling studies. Prospective cohort studies employing biochemical tests to definitively detect TB and diabetes at multiple time points can address the time ordering of diabetes onset and TB infection or reactivation. Such studies can also link individual and population risks including the interactions of risk factors and interplay of social determinants. Policy analyses using computer-based population models translate TB/diabetes associations and trends in prevalence into projections of future burdens. Such models can also assess the relative value of strategies including accelerating the availability of diabetes interventions and combining or targeting diabetes and TB initiatives.[11,43] Interventions reducing diabetes could potentially reduce individual-level risks of TB and indirectly avert increases in TB population prevalence.

An increase in the individual risk of TB associated with T2DM has important public health implications. At a national level, the seriousness of this risk depends crucially on the current and future levels and distributions of TB, diabetes and their risk factors throughout the population. Proactive evidence-based prevention policies are crucial for countries facing large TB/diabetes burdens.

Supplementary data

Supplementary data are available at *IJE* online.

Acknowledgements

J.D.G.-F.: study conception and design, data collection, analysis and interpretation, drafting of manuscript and critical revision. C.Y.J.: study design, interpretation of results, critical manuscript revision. T.C.: study design, interpretation of results, critical manuscript revision. M.B.M.: study design, interpretation of results, critical manuscript revision.

Conflict of interest: The corresponding author confirms that he had full access to all the data in the study and had final responsibility for the decision to submit for publication. All authors affirm that they have no financial or personal relationships with other people or organizations that could inappropriately influence or bias their work. No funding source had any role in the study design; in the collection, analysis and interpretation of data; in the writing of the report; and in the decision to submit for publication.

KEY MESSAGES

- In lower income countries, symptoms of TB are more likely to occur in individuals reporting a past diabetes diagnosis.
- Countries with higher diabetes prevalence were more likely to see increases in TB between the mid-1990s and early 2000s.
- Of particular concern, populous countries including India, Peru and the Russia Federation, which have relatively large TB burdens, have seen rapid increases in their diabetes prevalence.

References

[1] Jeon CY, Murray MB. Diabetes mellitus increases the risk of active tuberculosis: a systematic review of 13 observational studies. *PLoS Med* 2008;**5:**e152.

[2] Stevenson CR, Critchley JA, Forouhi NG *et al*. Diabetes and the risk of tuberculosis: a neglected threat to public health? *Chronic Illn* 2007;**3:**228–45.

[3] Dye C, Lonnroth K, Jaramillo E, Williams BG, Raviglione M. Trends in tuberculosis incidence and their determinants in 134 countries. *Bull World Health Organ* 2009;**87:**683–91.

[4] Lonnroth K, Jaramillo E, Williams BG, Dye C, Raviglione M. Drivers of tuberculosis epidemics: the role of risk factors and social determinants. *Soc Sci Med* 2009;**68:** 2240–46.

[5] Omran AR. The epidemiologic transition. A theory of the epidemiology of population change. *Milbank Mem Fund Q* 1971;**49:**509–38.

[6] World Health Organization. *The World health report: 1999: Making a difference*. Geneva: World Health Organization, 1999.

[7] Wild S, Roglic G, Green A, Sicree R, King H. Global prevalence of diabetes: estimates for the year 2000 and projections for 2030. *Diabetes Care* 2004;**27:**1047–53.

[8] Raviglione M. XDR-TB: entering the post-antibiotic era? *Int J Tuberc Lung Dis* 2006;**10:**1185–87.

[9] Corbett EL, Watt CJ, Walker N *et al*. The growing burden of tuberculosis: global trends and interactions with the HIV epidemic. *Arch Intern Med* 2003;**163:**1009–21.

[10] Wells CD, Cegielski JP, Nelson LJ *et al*. HIV infection and multidrug-resistant tuberculosis: the perfect storm. *J Infect Dis* 2007;**196(Suppl. 1):**S86–107.

[11] Stevenson CR, Forouhi NG, Roglic G *et al*. Diabetes and tuberculosis: the impact of the diabetes epidemic on tuberculosis incidence. *BMC Public Health* 2007;**7:**234.

[12] Moussavi S, Chatterji S, Verdes E, Tandon A, Patel V, Ustun B. Depression, chronic diseases, and decrements in health: results from the World Health Surveys. *Lancet* 2007;**370:**851–58.

[13] *World Health Organization: World Health Survey.* http://www.who.int/healthinfo/survey/en/index.html (12 August 2009, date last accessed).

[14] Cohen R, Muzaffar S, Capellan J, Azar H, Chinikamwala M. The validity of classic symptoms and chest radiographic configuration in predicting pulmonary tuberculosis. *Chest* 1996;**109:**420–23.

[15] Rosen MJ. Chronic cough due to tuberculosis and other infections: ACCP evidence-based clinical practice guidelines. *Chest* 2006;**129(Suppl. 1):**197S–201S.

[16] Ayles H, Schaap A, Nota A *et al*. Prevalence of tuberculosis, HIV and respiratory symptoms in two Zambian communities: implications for tuberculosis control in the era of HIV. *PLoS One* 2009;**4:**e5602.

[17] Robinson JR, Young TK, Roos LL, Gelskey DE. Estimating the burden of disease. Comparing administrative data and self-reports. *Med Care* 1997;**35:**932–47.

[18] Wu SC, Li CY, Ke DS. The agreement between self-reporting and clinical diagnosis for selected medical conditions among the elderly in Taiwan. *Public Health* 2000;**114:**137–42.

[19] Goldman N, Lin IF, Weinstein M, Lin YH. Evaluating the quality of self-reports of hypertension and diabetes. *J Clin Epidemiol* 2003;**56:**148–54.

[20] Okura Y, Urban LH, Mahoney DW, Jacobsen SJ, Rodeheffer RJ. Agreement between self-report questionnaires and medical record data was substantial for diabetes, hypertension, myocardial infarction and stroke but not for heart failure. *J Clin Epidemiol* 2004;**57:**1096–103.

[21] El Fakiri F, Bruijnzeels MA, Hoes AW. No evidence for marked ethnic differences in accuracy of self-reported diabetes, hypertension, and hypercholesterolemia. *J Clin Epidemiol* 2007;**60:**1271–79.

[22] Molenaar EA, Van Ameijden EJ, Grobbee DE, Numans ME. Comparison of routine care self-reported and biometrical data on hypertension and diabetes: results of the Utrecht Health Project. *Eur J Public Health* 2007;**17:**199–205.

[23] Kishore B, Nagrath SP, Mathur KS, Hazra DK, Agarwal BD. Manifest, chemical and latent chemical diabetes in pulmonary tuberculosis. *J Assoc Physicians India* 1973;**21:**875–81.

[24] Oluboyo PO, Erasmus RT. The significance of glucose intolerance in pulmonary tuberculosis. *Tubercle* 1990;**71:**135–38.

[25] Goyal BN, Dubey AL, Joshi LD, Saxena HN. Study of diabetic status in pulmonary tuberculosis. *J Diab Assoc India* 1978;**18:**191–97.

[26] Singh MM, Biswas SK. AS. Impaired glucose tolerance in active pulmonary tuberculosis. *Indian J Tuberculosis* 1984;**31:**118–21.

[27] *World Bank*. *World Development Indicators*. http://www.worldbank.org/data (12 August 2009, date last accessed).

[28] King H, Aubert RE, Herman WH. Global burden of diabetes, 1995-2025: prevalence, numerical estimates, and projections. *Diabetes Care* 1998;**21:**1414–31.

[29] *International Diabetes Federation*. *Diabetes Atlas*. http://www.eatlas.idf.org/ (26 October 2008, date last accessed).

[30] *World Health Organization*. *The stop TB strategy, case reports, treatment outcomes and estimates of TB burden*. http://www.who.int/tb/publications/global_report/2007/annex_2_download/en/index.html (12 August 2009, date last accessed).

[31] Heston A, Summers R, Aten B. *University of Pennsylvania Center for International Comparisons of Production, Income and Prices: Penn World Table Version 6.2* 2006. http://pwt.econ.upenn.edu (12 August 2009, date last accessed).

[32] Spiegelman D, Zhao B, Kim J. Correlated errors in biased surrogates: study designs and methods for measurement error correction. *Stat Med* 2005;**24:**1657–82.

[33] Danaei G, Friedman AB, Oza S, Murray CJ, Ezzati M. Diabetes prevalence and diagnosis in US states: analysis of health surveys. *Popul Health Metr* 2009;**7:**16.

[34] Joshi N, Caputo GM, Weitekamp MR, Karchmer AW. Infections in patients with diabetes mellitus. *N Engl J Med* 1999;**341:**1906–12.

[35] Muller LM, Gorter KJ, Hak E *et al*. Increased risk of common infections in patients with type 1 and type 2 diabetes mellitus. *Clin Infect Dis* 2005;**41:**281–8.

[36] Brar I, Shuter J, Thomas A, Daniels E, Absalon J. A comparison of factors associated with prevalent diabetes mellitus among HIV-Infected antiretroviral-naive individuals versus individuals in the National Health and Nutritional Examination Survey cohort. *J Acquir Immune Defic Syndr* 2007;**45:**66–71.

[37] Butt AA, McGinnis K, Rodriguez-Barradas MC *et al*. HIV infection and the risk of diabetes mellitus. *AIDS* 2009;**23:**1227–34.

[38] Carr A, Samaras K, Thorisdottir A, Kaufmann GR, Chisholm DJ, Cooper DA. Diagnosis, prediction, and natural course of HIV-1 protease-inhibitor-associated lipodystrophy, hyperlipidaemia, and diabetes mellitus: a cohort study. *Lancet* 1999;**353:**2093–99.

[39] Chronister CL, Gurwood AS. Type 2 diabetes in association with HIV-1 protease inhibitors in HIV-infected patients. *J Am Optom Assoc* 1998;**69:**695–98.

[40] Tien PC, Schneider MF, Cole SR *et al*. Antiretroviral therapy exposure and incidence of diabetes mellitus in the Women's Interagency HIV Study. *AIDS* 2007;**21:**1739–45.

[41] Urso R, Croce GF, Tubili C *et al*. [Dysmetabolic syndrome related to HIV-1 protease inhibitors. Review of the literature and personal data]. *Recenti Prog Med* 2000;**91:**78–85.

[42] Visnegarwala F, Chen L, Raghavan S, Tedaldi E. Prevalence of diabetes mellitus and dyslipidemia among antiretroviral naive patients co-infected with hepatitis C virus (HCV) and HIV-1 compared to patients without co-infection. *J Infect* 2005;**50:**331–37.

[43] Harries AD, Billo N, Kapur A. Links between diabetes mellitus and tuberculosis: should we integrate screening and care? *Trans R Soc Trop Med Hyg* 2009;**103:** 1–2.

Published by Oxford University Press on behalf of the International Epidemiological Association
 Advance Access publication 20 January 2011

International Journal of Epidemiology 2011;**40**:428–431
doi:10.1093/ije/dyq268

Commentary: Co-occurrence of tuberculosis and diabetes: new paradigm of epidemiological transition

Matthew J Magee,[1]* Henry M Blumberg[1,2,4] and KM Venkat Narayan[1,3,4]

[1]Department of Epidemiology, Rollins School of Public Health, Emory University, Atlanta, GA 30322, [2]Division of Infectious Diseases, Department of Medicine, Emory University School of Medicine, Atlanta, GA 30303, [3]Department of Medicine, Emory University School of Medicine, Atlanta, GA 30303 and [4]Hubert Department of Global Health, School of Medicine, Emory University, Atlanta, GA 30322, USA

*Corresponding author. Department of Epidemiology, Rollins School of Public Health, Emory University, 1518 Clifton Rd, NE, Atlanta, GA 30322, USA. E-mail: mjmagee@emory.edu

Accepted 15 December 2010

In his classic 1971 paper, Abdel Omran put forward the theory of *The Epidemiologic Transition,* positing that societies experience three principal stages of disease status: beginning with an Age of Pestilence and Famine, followed by an Age of Receding Pandemics and finally an Age of Degenerative Disease.[1] Although exceptions to Omran's theory exist,[2–4] the concept remains relevant to contextualize major shifts in epidemic dynamics. The recently observed co-occurrence of tuberculosis (TB) and diabetes mellitus (DM) pandemics, however, represents a new phenomenon in the classic epidemiological transition, a consequence of rapidly growing non-communicable diseases (i.e. DM)—a result of transitioning lifestyles towards greater intake of calories and lower physical activity—coupled with an inability to reduce the global burden of TB. The shifting epidemiology, sociology and clinical care of the concurrent DM–TB disease state, like the combination of other infectious and chronic diseases, will influence public health agendas and challenge the classical silos of communicable vs non-communicable diseases. This situation, however, may also offer major opportunities for research and for rethinking health systems' orientation and structure.

Omran accurately predicted that societal improvements in economic, social, cultural and political capacities would affect epidemic transitions, but he did not foresee that elements of globalization and economic development could so quickly bring about an Age of Degenerative Diseases before the Age of Receding Pandemics was curtailed. The increasing co-occurrence of TB and DM is a clear case in point, especially in countries with rapidly emerging economies such as India and China, resulting in a confluence of two pandemics—one communicable and another non-communicable. In this issue of the *IJE*, Goldhaber-Fiebert *et al*.[5] report an association between DM and TB from a population-based survey of low- and middle-income countries (LMIC) that is consistent with findings from previous research.[6–8] DM has been recognized as a risk factor for TB for decades, but although the link between DM and TB is not new, only with the recent explosive DM pandemic has the importance of understanding the relationships between DM and TB emerged as a global health priority.[7,9] TB causes enormous morbidity and mortality globally; annually, >9 million people develop active TB and nearly 2 million die due to TB—now the second leading cause of death from an