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Intimate partner violence, circulating glucose, and non-communicable Disease: Adding insult to injury?

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ABSTRACT

Analyzing data from the 2015–2016 Indian Demographic and Health Survey (N = 41,768), we investigate how women's circulating glucose varies with the severity of intimate partner violence (IPV) they have experienced in the last year and how their likelihoods of corresponding noncommunicable diseases vary with IPV severity in their lifetime. Consistent with a physiological stress response, women who have recently experienced severe IPV exhibit higher glucose levels and are more likely to have extremely high levels—forewarning of disease development—than women who have not experienced IPV. Correspondingly, women who have ever experienced severe IPV in their lifetime have 33%–200% higher probabilities of diabetes, heart disease, thyroid disorders, and cancer and are 70% more likely to have any of these diseases and 175% more likely to have multiple than women who have experienced none.

One in three women worldwide experiences intimate partner violence (IPV) in their lifetime (World Health Organization 2013). Women who experience IPV tend to exhibit poorer physical health outcomes than those who do not, including more injuries, higher rates of sexually transmitted infections, and higher rates of inflammatory conditions like ulcers and arthritis (for a review, see Campbell (2002)). Moreover, women who experience IPV also tend to exhibit poorer mental health, including higher rates of post-traumatic stress disorder (PTSD), anxiety, depression, and suicidal ideation (see Golding (1999) for a review). Given that chronic stress can elicit sustained physiological responses that "weather" the human body (Geronimus et al., 2006), IPV-related stress, like other chronic stressors (Chrousos 2009; Reiche et al., 2004), may further contribute to the development of non-communicable diseases (NCDs).

Despite much speculation, few studies have been able to investigate this latter possibility. Among those that do, the majority have examined small, non-representative samples from the United States or Europe (Yim & Kofman, 2019). Nonetheless, several studies suggest that women who experience severe and/or chronic IPV present with higher waking cortisol levels and blunted diurnal cortisol trajectories relative to women who have not (Johnson et al., 2008; Pinna et al., 2014)—findings consistent with physiological stress responses. Given that cortisol helps regulate metabolic functioning, including the suppression of insulin receptors and the production and circulation of glucose, these studies point to the possibility that, in the short-run, experiencing IPV should be associated with higher levels of circulating glucose. If glucose upregulation, or the elevation of baseline glucose levels in the bloodstream, is sustained over time, either because of repeated IPV incidents or because of prolonged periods of IPV-related stress, then it may contribute to women's risk of developing certain NCDs over the long-run.

In this study, we offer a novel investigation of the relationships between the severity of recent IPV and women's circulating glucose and between the severity of lifetime IPV and glucose-related NCDs—diabetes, heart disease, thyroid disorders, and cancer—drawing on nationally representative data from the 2015–2016 Indian Demographic and Health Survey (DHS). Through these analyses, we make three contributions to existing literature. First, we examine the relationship between IPV severity and circulating glucose—a key biomarker linking stress-related hormones like cortisol to NCDs like diabetes—among women who have not yet been diagnosed with one of these diseases. In so doing, we highlight an IPV-glucose link among women for whom glucose levels should foretell of NCD development. Second, by examining variation across IPV severity, we explore a potential "dose effect." If the stress of IPV increases with its severity (Fikree & Bhatti, 1999; Varma et al., 2007), then associations between IPV, glucose, and NCDs should be more pronounced among women with a history of severe violence victimization. Third, by utilizing a large, nationally

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representative dataset, we evade sample selection bias while further highlighting population-level health disparities and morbidity rates as they relate to women's history of IPV. This includes analyses of how IPV severity relates to women's likelihood of having *any* glucose-related NCDs—a broad marker of morbidity in the aggregate—and how it further relates to their likelihood of having *multiple* glucose-related NCDs, which has an amplifying effect on women's health and risk of early mortality (Laing et al., 2003).

India offers a particularly compelling case study because its institutional environment, including patrilocal marriage customs, low divorce rates, low female labor force participation, and limited asset ownership among women, makes it difficult for the average woman to leave an abusive husband (Anderson, 2007; Bloch & Rao, 2000; Panda & Agarwal, 2005; Roychowdhury, 2019). Many Indian women who face IPV may therefore do so chronically. Moreover, many women who experience IPV in India also experience abuse from other members of their husband's family (Kalokhe et al., 2016). One in three women of reproductive age in India experiences IPV in her lifetime (National Family Health Survey 2016). Furthermore, injuries are the second most common cause of excess mortality among Indian women, with intentional injuries accounting for approximately one-third of injurious fatalities among those of reproductive age (though some of these intentional injuries may be self-inflicted) (Anderson & Ray, 2010).

IPV, Women's health, and hypothalamic pituitary adrenal upregulation

IPV can directly compromise women's health in several ways. One is through injuries and physical traumas, which can result in longer-term neurological and musculoskeletal repercussions (Campbell, 2002); impaired hearing, vision, and speech (Coker, Smith, et al., 2000; Leserman et al., 1998); and paralysis, chronic pain, and joint diseases (Breiding et al., 2008; Golding, 1994; Ochs et al., 1996). When IPV includes sexual violence, it can also contribute to sexual, reproductive, and urological health problems, ranging from pelvic pain to an increased risk of HIV, unwanted pregnancy, cervical cancer, and urological infections (Coker, Sanderson, et al., 2000; Coker, Smith, et al., 2000; Jewkes et al., 2010; Pallitto et al., 2005).

IPV may also affect women's health via nutritional intake. This is because women in abusive relationships oftentimes experience restricted access to household resources, including food (Fong et al., 2016). As a consequence, in India and elsewhere, women in abusive relationships are more likely to be underweight than others (Ackerson & Subramanian, 2008; Ferdos & Rahman, 2018), which may affect their risk of developing metabolic and cardiovascular diseases (Gupta et al., 2016; Lu et al., 2014; Shantha et al., 2009).

Research on chronic stressors furuther indicates that IPV may be related to women's risk of disease by activating a cascade of stress-related physiologic responses that, over time, wear on the body (Clark et al., 2007; McEwen, 1998). That is, chronic stress exposure leads to the chronically increased activation of the hypothalamic pituitary adrenal (HPA) axis, which modulates the body's metabolic pathways through a process known as allostasis (McEwen, 1998). When a woman's HPA axis is overactivated, her body compensates for expected stress-related demands through allostatic adjustments including elevated cortisol and insulin suppression (McEwen, 1998; McEwen & McEwen, 2017). These processes can result in the upregulation of glucose circulation in the blood.

Over time, this chronic activation or upregulation of stress-related systems including the HPA axis increases peripheral indicators of risk (e.g. elevated glucose creation and circulation), thereby increasing a person's risk of cardiometabolic and immune related morbidities including diabetes, hypertension, and cardiovascular disease, among others (Goosby et al., 2018; Goosby et al., 2017; Green & Darity, 2010; Hatzenbuehler, 2009; House et al., 1994). Chronic upregulation of the HPA axis increases cortisol secretion, which signals continued circulating blood glucose while suppressing insulin hormone receptors which control uptake of blood sugar into cells for future use and elevated adrenal secretion, which increases vascular activation for circulation (Sapolsky 2006). This continual feedback loop elevates the risk of diabetes mellitus (Type 2 diabetes, insulin resistent) and risk of cardiovascular disease as a result of related blood coagulation and vascular damage (Harris et al., 2017; Rozanski et al., 1999). Nascent evidence also suggests that certain forms of cancer and thyroid disorders are associated with stress-related metabolic dysregulation generally and as indicated by glucose metabolism in clinical studies, though the mechanisms remain under investigation (Chrousos 2009; Ranabir & Reetu, 2011; Reiche et al., 2004; Stocks et al., 2009).

For some women, IPV is likely a powerful enough source of stress to elicit glucose upregulation. In India and Pakistan, women who have experienced IPV report higher levels of anxiety, depression, PTSD, and suicidality, and lower levels of life satisfaction than those who have not (Chowdhary & Patel, 2008; Fikree & Bhatti, 1999; Varma et al., 2007), particularly when they have experienced severe IPV (Fikree & Bhatti, 1999; Varma et al., 2007). Consistent with physiological stress responses, several studies from the United States document higher waking cortisol levels and flatter diurnal cortisol trajectories among IPV survivors than among other women (Johnson et al., 2008; Pinna et al., 2014). Moreover, one study from Norway finds that women who have ever experienced IPV have lower high-density lipoprotein cholesterol and higher triglycerides than those who have not (Stene et al., 2013), suggesting potential metabolic consequences of IPV.

Relatedly, one study in India finds that women who have ever experienced physical or sexual IPV in their lifetime are more likely to have high circulating glucose levels (141–160 mg/dL) than women who have not (though they are not more likely to have extremely high levels (>160 mg/dL)) (Pengpid & Peltzer, 2018). Building upon this study, we analyze the same data (the 2015–2016 Indian DHS) but explore a potential dose effect of recent IPV *severity* on circulating glucose, focusing specifically on women who have never been diagnosed with a related NCD, for whom glucose acts as a *precursor* to disease development. Further, we explore potential dose effects in terms of related disease morbidity rates, including differences in the prevalence of having *any* and *multiple* glucose-related NCDs.

IPV and the Indian epidemiological context

Considering that IPV is a common, stressful experience and that chronic stress can lead to HPA overactivity, resulting in the upregulation of glucose and other metabolic processes, IPV may positively contribute to the prevalence of NCDs. Over the last few decades, India has experienced a sharp increase in the morbidity and mortality of NCDs (Gupta et al., 2016; Mohan et al., 2006), even against the backdrop of persistently high rates of chronic malnutrition and underweight—a phenomenon commonly referred to as the "double burden of malnutrition" (International Institute for Population Sciences 2017; Kolčić, 2012).

Since the 1980s, the prevalence of diabetes has increased by as much as 72% in some parts of India (Mohan et al., 2006), while rates of heart disease have nearly doubled over the same period (Gupta et al., 2016). This rise in heart disease reflects a notable increase in prevalence at younger ages—a third (31%) of all heart disease mortalities now occur under the age of 60 (Gupta et al., 2016). To date, most investigations of these diseases within India have focused on their demographic and behavioral correlates, and indicate that both diabetes and heart disease are equally prevalent among women and men (Gupta et al., 2008; Jayawardena et al., 2012). They also indicate that diabetes is more prevalent in urban areas and among highly educated, wealthier subpopulations who can access the widest range of foods (Corsi & Subramanian, 2012; Jayawardena et al., 2012). Although heart disease is also more common in urban areas, it is more prevalent among less educated populations, primarily owing to higher rates of tobacco use among this group (Gupta et al., 2008; Gupta et al., 1994).

Research on other NCDs, like thyroid disorders and cancer, have similarly centered on diet, substance use, and demographic background. These studies document higher rates of hyper- and hypothyroidism among Indian women than among Indian men (Bose et al., 2015; Shantha et al., 2009; Unnikrishnan et al., 2013). In contrast, cancer rates differ depending on the type of cancer in question. For instance, lung, larynx, and oral cancer—cancers that are associated with smoking, a behavior much more common among men—are more frequently observed among men than among women (Mallath et al., 2014). However, the incidences of other cancers like leukemia, liver, and colorectal are more comparable across genders, while anatomy-specific cancers, namely breast and ovarian cancer, are exclusively observed among women (Mallath et al., 2014).

Comparable and sometimes even higher rates of NCDs among women than men are somewhat surprising given that women in India tend to have much lower household status and are correspondingly served less food (Das Gupta 1995; Desai et al., 2010), especially expensive foods like dairy and sweets (Palriwala, 1993). This means that, on average, women receive less caloric intake than men, which is reflected in their higher rates of being underweight (Goswami et al., 2016; Siddiqui & Donato, 2017). Likewise, stark gender differences are also observed with respect to alcohol and tobacco. Whereas 29% of men consume alcohol and 45% use tobacco, the same is true in only 1% and 7% of women, respectively (International Institute for Population Sciences 2017). These patterns suggest that, compared with men, women should be at lower risk of NCDs like diaebetes, heart disease, thyroid disorders, and some forms of cancer. Yet, if IPV elicits a sustained physiological stress response that contributes to NCD development, as we propose, then its pervasiveness and severity may help explain this puzzling epidemiological paradox.

Data and methods

Sample

We analyze recent Indian DHS data, collected between 2015 and 2016. Only one random woman per household was selected to participate in the IPV module and IPV questions were only administered if the interviewer could ensure the selected woman's privacy. These procedures help to ensure participants' safety and the accuracy of IPV reporting. Ninety-six percent of selected respondents participated in the IPV module.

Because the majority of relationships in India occur within marriage, and because the DHS did not collect information on the timing of widowhood and divorce, we restrict our analyses to married women who completed the IPV module. Given that pregnancy, breastfeeding, and menopause may temporarily affect IPV and women's health, we also restrict our sample to women who did not report one of these statuses. Including these women and adjusting for these statuses leads to substantilvely similar conclusions but attenuates estimated effect sizes and reduces their precision (Appendix A). Information on any control variable in our analysis was missing in 3.5% of remaining observations; on any disease in 2.2%; and on glucose in 0.6%. Considering this rarity, we handle missing information with listwise deletion, for a final analytic sample of 42,126 women.

Measures

IPV. IPV questions are based on a modified version of the Conflict Tactics Scale (CTS) (Straus et al., 1996). Because women's mental health exhibits a dose response to IPV (Golding, 1999), we divide lifetime IPV history into three categories based on the severest form of violence they reported: none, moderate, or severe. According to the CTS classifications, moderate violence is defined as when a woman's spouse has "pushed, shaken, or thrown something at her," "slapped her," or "twisted her arm or pulled her hair." Severe violence is defined as when her spouse has "punched her with a fist or something that could hurt," "kicked, dragged, or beat her up," "tried to choke or burn her," "threatened or attacked her with a knife, gun, or any other weapon," "forced her into unwanted sex," "forced her into other unwanted sex acts," or "forced her to have sex when she didn't want to." If a respondent reported that a specific act had ever occurred, she was also asked whether it occurred within the last twelve months specifically. We use this temporal information to create a measure of recent IPV severity, defined in the same way as lifetime severity but with respect to the prior year only. Online Appendix B provides the lifetime and one-year incidence and prevalence of individual violence items. Thirty-one percent of respondents ever experienced IPV in their lifetime, with 16% reporting moderate only and 15% reporting severe IPV (Table 1). Twenty-four percent of respondents experienced any IPV in the last year, with 12% reporting moderate only and 12% severe forms of violence (Table 1).

Glucose. The DHS assessed glucose levels by drawing blood samples from respondents. Glucose levels ranged between 20 and 499 mg per deciliter, with an average of 104.46 (Table 1). High glucose levels among Indian women, on average, are consistent with biomedical research suggesting that South Asians tend to have higher adiposity and higher levels of glucose and high-density lipoprotein cholesterol than do white Europeans with comparable body mass indexes (BMIs) (Dudeja et al., 2001; Ntuk et al., 2014; Patel et al., 2016). To assess if women had glucose levels above thresholds indicative of being on a path toward diabetes (or of being an undiagnosed diabetic), we also tested two dichotomous indicators: $\geq$150 and$\geq$250 mg/dL.

Body composition. Body mass index is calculated by dividing respondents' height (in meters) by their weight squared (in kilograms). Given that being under- or overweight places women at higher risk for certain diseases, we also create a categorical indicator of underweight ($<$18.5), normal (18.5–23), and overweight ($>$23). This threshold of overweight is consistent with existing research on the relationship between BMI and diabetes risk in India (Ntuk et al., 2014). According to this classification, 16% of women were underweight, 40% normal, and 44% overweight.

We also examine arm circumference—an alternative measure of body mass that better reflects body fat (Wang et al., 1994). Because having an arm circumference $<$22 cm is indicative of severe malnourishment (James et al., 1994), we additionally assess a dichotomous indicator of having an arm circumference below this threshold. Fourteen percent of women had an arm circumference $<$22 cm (Table 1).

Noncommunicable disease. Interviewers asked all respondents whether they currently had diabetes, "any heart disease," "a goiter or any other thyroid disorder," or "cancer" (specific cancer type was not recorded). Two percent of women reported having diabetes and heart disease; 3% a thyroid disorder; and 0.2% cancer (Table 1). To the extent that self-reports of disease are contingent on women receiving a diagnosis, disease status may be underreported. Nevertheless, the prevalence of each disease in our sample is consistent with estimates from other studies using alternative data sources (Gupta et al., 2008; Ramachandran, 2005; Unnikrishnan & Menon, 2011). To better gauge the relationship between lifetime IPV severity and morbidity more broadly, we further combine information on these four diseases to create dichotomous indicators of whether women have *any* and *multiple* of the four diseases (separately).

Controls. We adjust for factors known to be associated with IPV and/or women's health (Table 1). With the exception of the altitude of the survey cluster (which affects blood oxygen levels), these controls are reported by women. These include the number of years a woman had been married to her husband; her and her husband's age and her age-squared; whether her husband drinks alcohol; and altitude (in meters). To account for cultural and socioeconomic differences, we separately adjust for women's and their husband's education level (none, primary, secondary, and higher); women's religion (Hindu, Muslim, Christian, Sikh, or other); caste (scheduled tribe/caste, OBC, forward tribe/caste, and other); and household wealth quintiles (based on a continuous scale

Table 1
Descriptive statistics (N = 42,126).

	Mean	SD
IPV severity (self-reported)		
Lifetime		
None	.69	
Moderate	.16	
Severe	.15	
Last twelve months		
None	.76	
Moderate	.12	
Severe	.12	
Glucose (taken at survey)[a]		
Level (20–499 mg/dL)	102.69	26.94
Glucose≥150 (mg/dL)	.04	
Glucose≥250 (mg/dL)	.004	
Body mass (taken at survey)		
Body mass index (6.64–68.21)	23.05	4.75
BMI classification		
Underweight (BMI<18.5)	.16	
Normal (BMI 18.5 – <23)	.40	
Overweight (BMI≥23)	.44	
Arm circumference (5–80 cm)	25.94	3.48
Arm≤22 cm.	.14	
Disease (self-reported)		
Diabetes	.02	
Heart disease	.02	
Thyroid disorder	.03	
Cancer	.002	
Any of the four	.06	
Multiple of the four	.01	
Controls		
Years married (0–47)	16.51	8.68
Age (15–49)	35.13	7.96
Partner's age (15–95)	40.44	9.16
Partner consumes alcohol	.29	
Education		
None	.33	
Primary	.15	
Secondary	.42	
Higher	.10	
Partner's education		
None	.19	
Primary	.15	
Secondary	.52	
Higher	.14	
Religion		
Hindu	.82	
Muslim	.13	
Christian	.02	
Sikh	.02	
Other	.01	
Caste		
Scheduled tribe/caste	.28	
OBC	.46	
Forward tribe/caste	.24	
Other	.03	
Parity		
None	.10	
One	.12	
Two	.34	
Three	.22	
Four	.11	
Five or more	.10	
Height (1.01–2.09 m)	1.52	.06
Household wealth quintile		
Poorest	.14	
Poor	.19	
Middle	.21	
Wealthy	.22	
Wealthiest	.24	
Urban location	.36	
Distance to health facility		
Big problem	.39	
Not a big problem	.28	
No problem	.34	
Altitude (-4-5951 m)	252.36	310.66

[a] Glucose is assessed among women who had not eaten, drank, or smoked anything within half an hour of the survey and who did not report any of the four diseases (N = 24,494).

of household assets and material goods). To account for differences across early childhood endowments, we also control for women's height. To account for the fact that parity is positively associated with diseases like diabetes (Fowler-Brown et al., 2010) and with IPV (Weitzman, 2014), we include fixed effects for parity (ranging from 0 to 5+). In consideration of geographic differences in lifestyle and access to healthcare, we further include a categorical indicator of a woman's distance to the nearest health facility (self-reported as no problem, not a big problem, or a big problem); a dummy indicating whether she lives in an urban area; and state fixed effects. (Because state fixed effects omit observations from states with no variation in the outcome, we re-estimate models of binary outcomes without adjusting for state. The results lead to substantively similar conclusions overall.)

Analytic strategy

We begin by assessing the relationship between IPV and circulating glucose. Because glucose should be sensitive to immediate stressors, here we focus on IPV severity *in the last year*. To ensure that glucose serves as a harbinger of disease, we focus this first component on seemingly healthy women who did not report having any disease of interest. To further reduce measurement error, we also restrict this component to women who had not eaten, drunk anything besides water, or smoked within half an hour before the biomarker assessment (n = 24,494). Compared to seemingly healthy women who *had* eaten, drunk, or smoked anything in the preceding half-hour, this analytic subsample had, on average, lower and less disperse glucose readings (Appendix C). They were also less likely to be overweight and had smaller arms, suggesting that differences in very recent consumption may reflect broader differences in consumption overall. Consistent with this interpretation, this analytic subsample was slightly less socially advantaged than the subsample excluded for recently eating, etc., particularly when it came to caste, parity, and household wealth (Appendix C). First we estimate glucose and logged glucose using linear regression to reveal absolute and percent differences in glucose levels as they pertain to recent IPV severity.[1] Next we use logistic regression to estimate the relationship between IPV severity and having circulating glucose≥150 and≥250 mg/dL. These thresholds are clear indicators of when women's glucose levels are so high that they are at risk of diabetes or have already become (undiagnosed) diabetics. All models of glucose adjust for the full set of controls, and to be conservative, further adjust for respondents' BMI. As a supplement, we additionally examine models that further adjust for women's daily diet (any fruits, vegetables, meat, etc.) and alcohol and tobacco use. The results are highly similar to those presented below (available upon request).

Controlling for BMI allows us to estimate the effect of IPV on glucose *net* of its effects on women's current body composition, but it does not reveal the extent to which BMI—a snapshot measure of health with important implications for sustained life course morbidities (Goosby et al., 2016)—could be a potential mediator. To mediate this relationship, IPV must share a significant association with women's body mass that is in a comparable direction to the association it shares with glucose. Therefore, as a second step, we predict women's BMI and arm circumference. Here we assume that IPV has a sustained effect on women's bodies over time and thus focus our attention on *lifetime* IPV severity (an assumption confirmed through supplementary analyses in which we use a categorical indicator of IPV timing defined as never, only recently, only in past years, and ongoing (past and recent years) to

[1] To estimate percent differences, we exponentiate the coefficients on IPV severity in the model where glucose is logged.

predict these outcomes). We first estimate continuous BMI using linear regression, followed by BMI classification (underweight, normal, or overweight) using multinomial regression. Similarly, we estimate continuous arm circumference using linear regression and having an arm circumference <22 cm using logistic regression. All body composition models include the full set of controls listed in Table 1. Given compositional and sample size differences between the glucose and body mass subsamples (Appendix C), and given our interest in body composition as a potential mediator of the relationship between IPV and glucose, we re-estimate all models of body composition restricting the sample to women analyzed in the glucose models. The results lead to substantively similar conclusions overall.

Finally, we assess the relationship between IPV severity and diabetes, heart disease, thyroid disorders, and cancer and between IPV severity and whether a woman has any or multiple of these diseases (separately) using logistic regression. To illustrate differences in the estimated prevalence of NCDs by lifetime IPV severity, we convert the results to predicted probabilities. Because IPV should have a longer-term effect on the risk of disease, in this component we again rely on our indicator of *lifetime* IPV severity. Here we adjust for the full set of controls and BMI. We do not test whether circulating glucose mediates the relationship between IPV severity and disease status because glucose upregulation is a dynamic process that must be sustained over time in order to impact disease. Assessing mediation with cross-sectional data could therefore be misleading.

All analyses are weighted using DHS survey weights to ensure the representativeness of our findings. To account for correlations between respondents within the same survey cluster, we cluster standard errors by survey cluster. For the ease of interpretation, we exponentiate the result of logistic and multinomial regressions to express differences in terms of odds-ratios. Although we focus our attention on the results of multivariate models, bivariate estimates are provided in Appendix D.

Results

How does circulating glucose vary with IPV severity in the last year?

Table 2 presents the results of models estimating circulating glucose. The first column shows that women who recently experienced severe IPV have 1.85 mg more glucose per deciliter in their blood than do women who have not. This translates into a 2% difference in the circulating glucose levels of women reporting severe and no IPV, as shown in the second column.

Fig. 1, which plots a histogram of the fitted values from the first model, illuminates the distributional differences that give rise to these disparities: A greater fraction of women reporting no IPV appear at the very low end of the distribution than of women reporting severe IPV, while the reverse is true at the top end. That women with a recent history of severe IPV are more likely to be at the top-end of the distribution is further indicated by the third and fourth models in Table 2—they have 45% higher odds of having ≥150 mg/dL and 122% higher odds of ≥250 mg/dL than women who have experienced no IPV in the last year. Consistent with a dose effect, moderate IPV is associated with 39% higher odds of having≥150 mg/dL than no IPV, but not with the higher threshold.

Table 2
Circulating glucose, estimated from linear and logistic regressions.

			Hyperglycemia	
	Glucose (mg/dL)	Ln (glucose)	≥150 mg/dL	≥250 mg/dL
IPV severity in last year (ref: none)				
Severe	1.85*	0.02*	1.45*	2.22*
	(0.81)	(0.01)	(0.22)	(0.80)
Moderate	0.97	0.01	1.39†	1.54
	(0.82)	(0.01)	(0.24)	(0.64)
Constant	76.90***	4.33***	0.00***	0.00***
	(12.65)	(0.08)	(0.00)	(0.00)
Observations	24,494	24,494	24,494	22,662

Note: Analyses are limited to women who did not eat, drink, or smoke anything within half an hour of survey and who do not report currently having any disease. All models adjust for controls listed in Table 1, BMI, and state fixed effects. Because of these fixed effects, women from states with no variation in the outcome are automatically omitted from a given model, which results in smaller numbers of observations in the last model.
Robust standard errors, clustered by survey cluster, in parentheses.
***p < 0.001, **p < 0.01, *p < 0.05, †p < 0.1.

The results of our first analyses thus indicate that women who experienced severe IPV in the prior year have higher circulating glucose and are more likely to have especially high levels of glucose than women who experienced none. Although the estimated difference in average glucose levels between women who experienced severe and no IPV is small, the robustness of our results across all specifications indicates that this significant difference is unlikely an artifact of Type I error. Recent moderate IPV is less consistently associated with higher glucose levels than no IPV, suggesting a possible dose effect.

Could nutritional differences explain differences in glucose levels across recent IPV severity?

Table 3 explores women's body composition. Here we see that women who ever experienced severe IPV in their lifetime have 0.33 lower BMIs than women who never experienced it; resulting in their also having 15% higher odds of being underweight and normal weight (each) relative to overweight. Women who experienced severe IPV also have, on average, 0.22 cm smaller arms than those who never experienced IPV; and correspondingly have 19% higher odds of an arm circumference≤22 cm as well.

Women who experienced moderate IPV similarly have an average BMI 0.21 lower than women who experienced none, reflecting that women with a lifetime history of moderate IPV have 9% higher odds of being underweight and 15% higher odds of being normal weight relative to overweight than women with no IPV history. Likewise, the arms of women who ever experienced moderate IPV measure .17 cm smaller than those of women with no IPV history in their lifetime, translating into 17% higher odds of having an arm circumference≤22 cm.

Do women who have ever experienced IPV have higher rates of disease?

To answer our last question of whether women who experience IPV are more likely to report having NCDs, Fig. 2 plots the predicted probabilities of diabetes, heart disease, thyroid disorders, and cancer and the predicted probabilities of having any and multiple of these diseases by women's highest lifetime IPV severity. These probabilities are calculated from the results of adjusted logistic regressions (presented in table format in the bottom panel of Appendix D). The first set of bars in Fig. 2, on the left-hand side, indicate that 3.2 percent of women who have experienced severe IPV report being diabetic, compared with 2.6 and 2.0 percent of women who have experienced moderate and no IPV (respectively). This 1.2 percentage point (60%) difference between women with a lifetime history of severe and no violence is significant ($P < 0.05$). Consistent with a dose effect, the 0.6 percentage point (30%) difference between women with a history of moderate and no violence is marginally significant ($P < 0.1$).

In the second set of bars, the reported rate of heart disease is 120% higher among women who have experienced severe IPV—3.1 percent—relative to women who have experienced none—1.4 percent ($P < 0.001$); and 55% higher than women who have experienced moderate IPV—2.0 percent ($P < 0.1$). Moreover, women who have experienced moderate IPV have a 43% higher probability of heart disease than do women who have experienced none ($P < 0.05$).

Similarly, 3.9 percent of women who experienced severe IPV report a

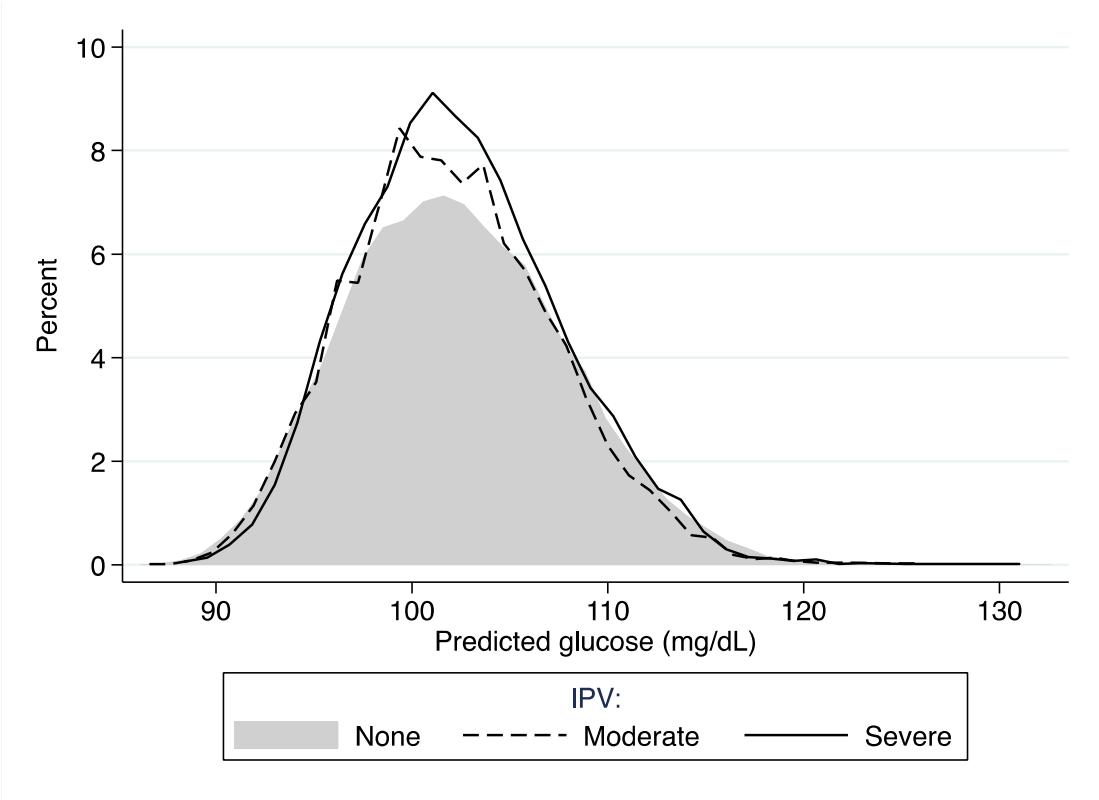

Fig. 1. Distribution of Predicted Glucose Levels (mg/dL) for Women Reporting No, Moderate, and Severe IPV in the Last Year. Estimates are derived from the first model in Table 3.

Table 3
Body mass, estimated from linear, multinomial, and logistic regressions.

		BMI classification (ref: overweight)			
	BMI	Under-weight	Normal	Arm circum.	Arm ≤22 cm.
IPV severity in lifetime (ref: none)					
Severe	−0.33**	1.15*	1.15*	−0.22**	1.19**
	(0.11)	(0.06)	(0.08)	(0.08)	(0.08)
Moderate	−0.21*	1.09†	1.15*	−0.17*	1.17**
	(0.09)	(0.05)	(0.08)	(0.07)	(0.07)
Constant	22.16***	12.65***	28.55**	7.39***	17,575.99***
	(1.88)	(8.12)	(29.37)	(1.18)	(20,014.88)
Observations	42,126	42,126	42,126	42,074	42,074

Note: All models include the full set of controls listed in Table 1 and state fixed effects. Robust standard errors, clustered by survey cluster, in parentheses. ***p < 0.001, **p < 0.01, *p < 0.05, †p < 0.1.

thyroid disorder, which is 1.3 percentage points (50%) greater than women who experienced none ($P < 0.01$) and 1 percentage point (34%) greater than women who experienced moderate IPV ($P < 0.1$). With respect to cancer, 0.6 percent of women with a history of severe IPV report having some form of cancer, which is three times the prevalence—0.2 percent—among women with a lifetime history of no IPV ($P < 0.1$).

Overall, 9.5 percent of women who ever experienced severe IPV are estimated to have at least one of these diseases. This is 3.9 and 2.2 percentage points (70% and 30%) greater than among women who experienced no and moderate violence, respectively ($P < 0.001$, $P < 0.01$). Moreover, while 7.3% of women who experienced moderate IPV are estimated to have any disease, this is 1.7 percentage points (30%) greater than among women who experienced none ($P < 0.01$). Likewise, in terms of having multiple of these diseases, women who experienced severe IPV have the highest prevalence—1.1%, which is 0.7 and 0.4 percentage points (175% and 57%) more than women with respective histories of no and moderate IPV ($P < 0.01$, $P < 0.1$).

Thus, at the population level, the highest prevalence of four NCDs, both individually and when taken together, are estimated among women who have ever experienced severe violence from their husbands. Consistent with studies indicating a dose response, women who have experienced moderate IPV report significantly lower rates of heart disease and thyroid disorders and are less likely to have any or multiple diseases than women who have experienced severe IPV. At the same time, women with a history of moderate IPV report greater rates of diabetes and heart disease and are more likely to have at least one of the four diseases than women who have never experienced IPV.

Supplementary analyses

Could Unobserved Household or Environmental Factors Explain the Relationship between IPV and Women's Health?

While there are numerous reasons to believe that IPV affects women's health trajectories and risk of NCDs via the prolonged physiological responses they have to it, it is also possible that the relationship between IPV and disease is spuriously driven by unobserved factors. If so, then these factors should simultaneously affect both spouses' health. Investigating this possibility is especially important given that at least one study from Finland finds that men who have been arrested for IPV have higher circulating glucose and cortisol levels than do men with no criminal history of violence (Lindman et al., 1992). We therefore test whether IPV perpetration is associated with men's circulating glucose and NCD status in ways that mimic the association between IPV victimization and these outcomes among women. To do so, we re-estimate all models among husbands, replacing information about respondents with information about their husbands (e.g. caste, religion,

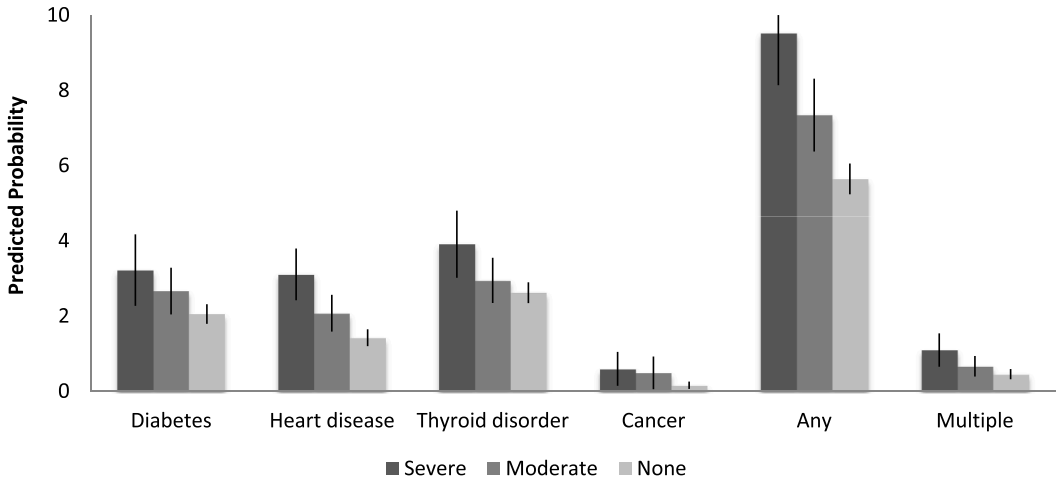

Fig. 2. Predicted Probability of Self-Reported Disease, by Lifetime History of Intimate Partner Violence. Predicted probabilities are derived by transforming the results of logistic regressions into marginal effects, holding all covariates as observed. All models include the full set of controls listed in Table 1, BMI, and state fixed effects. From left to right, N = 41,372; 41,387; 41,836; 32,231; 42,040; and 40,741; fluctuating numbers of observations primarily reflect the dropping of observations from states with no variation in the outcome.

and BMI). To examine undernourishment, we rely on the conventional threshold of 23 cm (arm circumference) among men (James et al., 1994).

The results in Online Appendix E indicate that unobserved household or environmental factors may explain some but not all of the observed associations between IPV and women's health. Men whose wives report severe or moderate IPV have lower BMIs and smaller arm circumferences, on average, than men whose wives report no IPV, suggesting that unobserved material deprivation may at least partially explain the relationship between IPV and women's body mass. However, IPV perpetration is not significantly associated with husbands' glucose levels and shares less consistent and smaller associations with husbands' disease outcomes than is observed among women.

Discussion

This study offers a close examination of the relationship between recent IPV severity and circulating glucose and between lifetime IPV severity and several glucose-related NCDs among women in India. Our findings offer compelling evidence that recently experiencing severe IPV is associated with significantly higher circulating glucose levels among otherwise seemingly healthy women and is further associated with nefariously high glucose levels that typically portend diabetes. In keeping with this foretelling, ever experiencing severe IPV is associated with between 30% and 200% higher probabilities of having diabetes, heart disease, thyroid disorders, and cancer and with 70% and 175% higher probabilities, respectively, of having at least one and multiple of these diseases than never experiencing it. Moderate IPV is positively associated with some but not all of these outcomes, and often to a lesser degree than severe IPV, indicating a potential dose effect.

In India, rates of heart disease and diabetes are nearly comparable among women and men (Gupta et al., 2008) despite stark gender inequalities in social status, physical mobility, and household resource allocation (Das Gupta 1995; Desai et al., 2010). In light of the prevalence and severity of IPV in India, our findings may partially explain this puzzle. That is, if the stress of IPV gets "under the skin", as indicated by several studies in the United States, Europe, and South Africa (Jewkes et al., 2015; Johnson et al., 2008; Lindman et al., 1992; Pinna et al., 2014), and if this stress response includes glucose upregulation—as our findings suggest—then IPV should affect women's risk of developing select NCDs net of their food consumption.

Relatedly, our analysis of women's body mass confirmed that ever experiencing IPV—whether moderate or severe—is associated with having a lower BMI and a smaller arm circumference than never experiencing it. This finding, which is consistent with prior studies indicating that women in violent relationships experience greater food insecurity than those who do not (Fong et al., 2016), implies that nutritional intake is unlikely to explain differences in glucose and morbidity rates we observe. Ancillary analyses investigating *husbands'* health outcomes further indicated that IPV perpetration is also associated with lower BMIs and arm circumferences and positively associated with select morbidities among men, though to a lesser degree than among women. These gender parallels highlight that some associations may be partially driven by unobserved factors. Nonetheless, IPV perpetration is not associated with men's glucose levels, giving us little reason to believe that unobserved household or environmental factors explain much or all of the IPV-related differences in circulating glucose among women.

Despite its contributions, this study comes with several limitations. First, we analyze cross-sectional data. Studies of other chronic stressors (Geronimus et al., 2006; Simons et al., 2016) suggest that over time, repeated incidents of IPV should take a *cumulative* toll on women's physiological functioning and risk of disease. We are unable to document this possibility without repeated observations collected among the same women and/or in the absence of complete IPV histories and information on the timing of disease onset. Relatedly, our reliance on cross-sectional survey data (collected among *living* individuals) is suspect to survivor bias. If severe IPV results in direct fatalities or harms women's health to the point of early mortality, then women who experienced the most severe IPV will be absent from this study. This could bias the associations we document. Second, our most proximate measure of IPV pertains to violence occurring anytime within the last year. If physiological responses to IPV incidents diminish with time, then this wide time horizon may attenuate our results. Third, because the DHS did not assess mental health, we are unable to test the mediating role of stress. Finally, it remains possible that women who are severely abused are more likely to report diseases because of more frequent encounters with the healthcare system (leading to a higher likelihood of diagnosis). Such a possibility does not negate the observed association between IPV severity and glucose, however—an important indicator of physiological functioning that prognosticates NCD development.

Both the conclusions drawn from this study and the questions it opens up are of great relevance to epidemiologists, medical sociologists,

demographers, and health practitioners alike. Glucose levels are a critical component of individuals' metabolic and cardiovascular systems. Any relationship between IPV and this biomarker is thus indicative of a relationship between IPV and women's health trajectories, as is further suggested by greater self-reports of related NCDs among women who have ever experienced severe IPV. In the aggregate, these diseases and their underlying conditions affect life expectancy, population health, and public health expenditure.

Ethical statement

This study analyzed de-identified, publicly available data that, per the UT Institutional Review Board's guidelines, did not require ethical oversight. The authors have no Conflicts of Interest to declare.

CRediT authorship contribution statement

Abigail Weitzman: Conceptualization, Formal analysis, Writing - review & editing, conceptualized the initial idea for this study; procured the data; conducted all analyses; and took the lead on writing and editing the manuscript. **Bridget J. Goosby:** Conceptualization, Writing - review & editing, refined the study's ideas and conceptualization; and contributed to the writing and editing of the manuscript.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssmph.2020.100701.

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