Comprehensive Analysis of Electronic Health Records to Characterize The Association Between Intimate Partner Violence and Mental Health

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Abstract

Intimate partner violence (IPV) involves physical, emotional, and sexual harm to the survivor. To characterize the relationship between mental health and IPV, we utilized electronic health records (EHR) data from IBM Explorys. Focusing on 15 mental health conditions and IPV, we queried cohorts of patients with these conditions to discover additional medical terms, including symptoms, findings, and diagnoses that are prevalent in these cohorts. We then systematically assessed the (i) direct association (co-occurrence, i.e., relative prevalence of a medical term in a cohort compared to the background population) and (ii) indirect association (the similarity between co-occurrence profiles) between all pairs of these mental health conditions. Our results showed that direct and indirect measures of association provide complementary insights into the relationship between pairs of conditions. Using this framework, we discovered several patterns of association among 16 different mental health related conditions.

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1 Introduction

Intimate partner violence (IPV) is a serious public health problem accompanied by substantial morbidity and mortality, including physical, sexual, and emotional components. IPV can be defined as a current or past partner's acts or behaviors that intentionally aim to cause bodily, emotional, sexual, or financial harm [1, 2, 3]. One in four women reported experiencing severe IPV during their lifetime [3]. Although men can also be victims of IPV, women are significantly more likely to be victimized and sustain injuries [1, 4]. IPV victimization might include physical violence characterized by the involvement of physical force such as being slapped, pushed, kicked, or beaten up; sexual violence characterized by unwanted and forced actions of sexual nature, and emotional violence characterized by harm to emotional well-being through acts such as degradation, controlling and isolating [3, 4, 5].

IPV is often linked to various physical and mental health consequences [6, 7]. Reported adverse health effects of IPV extend from minor injuries and cuts, and chronic conditions to acute severe injuries, and even death [8, 9]. Furthermore, injuries to the head, neck, and face are also common, and strongly associated with traumatic brain injury (TBI) [3, 10]. TBI among the victims of IPV might also be linked to certain mental health challenges due to changes in the brain's structure and connectivity of neural networks [11]. Recent research also indicates that emotional (or psychological) abuse, i.e., continual emotional mistreatment of a person through degradation, intimidation, and control, is highly prevalent in intimate relationships [12] and co-occurs frequently with physical violence [5]. Coupling with physical abuse, emotional abuse diminishes a person's self-worth and/or emotional well-being and is associated with the development of depression, anxiety, and post-traumatic stress disorder (PTSD) by changing the perception of the world, self, and others [13, 14, 15].

Depending on factors such as the extent and duration of abuse, availability and access to social support, and socioeconomic status, victims of IPV can become fearful, confused, disempowered, emotionally dependent, and become susceptible to developing mental health issues [13, 16, 17]. The effects of IPV are complex, long-lasting, and require treatment also focusing on the co-morbid and co-occurring issues. Furthermore, the presence of mental health issues was identified as both a risk factor for and consequence of IPV [18, 19]. In this paper, to provide in-depth insights into the complex relationship between IPV and mental health, we systematically investigate the co-morbidity of IPV and

Table 1: **Mental health conditions investigated in this study.**

Cohort	Description	Cohort	Description
ADHD	Attention deficit hyperactivity disorder	ASPD	Antisocial personality disorder
Anxiety	Anxiety disorder	Bipolar	Bipolar disorder
Borderline	Borderline personality disorder	Depression	Major depressive disorder
NPD	Narcissistic personality disorder	Neurosis	Neurosis
OCD	Obsessive-compulsive disorder	PanicAttack	Panic attack
PersonalityDis	Personality disorder	PsychoticDis	Psychotic disorder
PTSD	Post-traumatic stress disorder	SubstanceAbuse	Substance abuse
TBI	Traumatic Brain Injury	IPV	Domestic Abuse

15 mental health conditions using abundant electronic health records (EHR) data from Explorys. For this purpose, we use two measures of association between a pair of conditions:

- *Direct Association (Co-occurrence)* quantifies the relative prevalence of one condition in the presence of the other condition, as compared to the background population.
- *Indirect Association (Similarity of Co-Occurence Profiles)* quantifies the shared variance between the co-occurrence profiles of the two conditions. The co-occurrence profile of a condition is a vector in the space of medical terms, where each entry in the vector represents the co-occurrence of the condition with each medical term.

Using these two notions of association, we systematically investigate the relationship between 16 mental health related conditions (Table 1) to answer the following questions: 1) What information does each notion of association provide on the relationship between pairs of conditions? 2) What specific patterns of direct and indirect association can we discover between pairs of mental health conditions by comprehensively analyzing abundant EHR data? 3) What insights do the indirect and direct association of IPV with other health conditions provide on the mental health risks and consequences of IPV? Note that our list includes conditions that may not be directly classified as mental health conditions but are related to mental health, including traumatic brain injury, which is an organic cerebral injury that could be associated with mental health conditions. Our list also includes several personality disorders. We include these conditions in our analyses as the relationship between IPV and mental health can potentially be mediated, moderated, or confounded by these conditions.

2 Methods

Data Collection. IBM Explorys Therapeutic Dataset provides the Explorys Cohort Discovery tool, which allows querying for demographic criteria and/or keywords (for findings or diagnoses) to construct a cohort of records that satisfy the criteria. The database then returns a file that contains the frequencies of all *medical terms* (diagnoses and findings) that have non-zero frequency in the cohort. The frequency of a term in a cohort is defined as the number of records that contain the term, where frequencies are rounded to the nearest 10 for enhanced privacy. Using this tool, we investigate the potential health correlates of Intimate Partner Violence (IPV) and 15 mental health-related conditions (Table 1) in the population of women 18 to 65 years of age. We query the Explorys Cohort Discovery tool to generate the following cohorts (queried in July 2020):

- *BG Cohort*: All records of women 18-65 years of age with a diagnosis of a disease.
- *IPV Cohort*: All records of women 18-65 years of age containing 'Domestic Abuse' in the findings field.
- *Mental Health Condition Cohorts:* For each of the 15 conditions listed in Table 1, we run a query to retrieve the cohort for all records of women 18-65 years of age listing the corresponding condition as a finding.

Querying and Cohort Formation. Each query result (i.e., cohort) X contains the following information: (1) Cohort size $N(X)$ indicating the total number of records in X, (2) a list of terms T_X that appear in at least one record in the cohort (there are around $18\,000$ terms in the database), and (3) frequency table that contains for each medical term $t \in T_X$ the number of records that contain t. To denote frequencies, we use the following notation:

- N : Total number of records in the background population.
- $N(t)$: Number of records in the background population that contain term t.
- $N(X)$: Total number of records in cohort X. This is equal to the number of records in the background population that contain X as a term (Figure 3).
- $N(t, X)$: Number of records in cohort X that contain term t.

For each condition X and term t, we construct a 2×2 contingency table, containing following entries: $N(t, X)$, $N(\neg t, X)$, $N(t, \neg X)$, $N(\neg t, \neg X)$. Here, $\neg$ indicates logical negation, e.g. $N(t, \neg X)$ denotes the number of records that contain term t but not the condition X. Thus, $N(t, \neg X) = N(t) - N(t, X)$.

Assessing Direct Association via Co-occurrence. For each condition X and term t, we quantify the degree of co-occurrence between X and t using odds ratio:

$$\text{OR}(t, X) = (\text{N}(t, X)\text{N}(\neg t, \neg X)) \,/\, (\text{N}(\neg t, X)\text{N}(t, \neg X)) \tag{1}$$

and log-odds ratio $\text{LOR}(t, X) = \log_2(\text{OR}(t, X))$.

Identification of Co-occurring Terms. Our previous work using electronic health records (EHR) data from Explorys [20] suggested considerable bias, where most terms with non-zero frequency exhibit positive association with a condition of interest. Indeed, as seen Figure 3, for all of the 16 conditions we consider in this study, the mean OR across all terms that appear in the cohort is above 2.5 (for most conditions, the mean OR is close to 5). To take into account this bias, we assess the significance of the prevalence of term t in cohort X using different null levels for odds ratio. Namely, for a given false discovery rate (FDR) α and null threshold τ for odds ratio, we say t is significantly prevalent in X at threshold τ if:

$$\text{OR}(t, X) \gg_\alpha \tau : \qquad \frac{\text{LOR}(t, X) - \tau}{SE(t, X)} > z^*_\alpha. \tag{2}$$

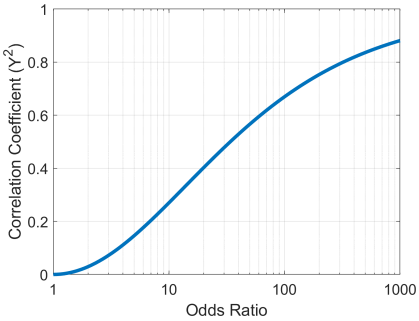

Fig 1: **The relationship between odds ratio and normalized co-occurrence (Y^2).**

Here, $SE(t, X) = \sqrt{1/N(t, X) + 1/N(t, \neg X) + 1/N(\neg t, X) + 1/N(\neg t, \neg X)}/\ln(2)$ denotes standard error, z_α denotes the critical value obtained from normal inverse cumulative distribution (e.g., $z_\alpha = 1.96$ for $\alpha = 0.05$), and z^*_α denotes the critical value adjusted for multiple hypothesis testing to bound FDR using the Benjamini-Hochberg (BH) procedure [21]. The hypotheses being tested for each cohort X correspond to T_X, the set of terms that have non-zero frequency in X. The results we present in the next section are based on the categorization of the co-occurrence of terms with a condition into three levels:

- *High association with X:* Terms t with $OR(t, X) \gg_\alpha 20$.
- *Moderate association with* X: Terms t with $OR(t, X) \gg_\alpha 10$.
- *Minor association with* X: Terms t with $OR(t, X) \gg_\alpha 5$.

Normalized Measure for Co-occurrence. To provide a more interpretable measure for the strength of co-occurrence and to facilitate comparisons with our measure of indirect association (described below), we transform odds ratios to be between $[0, 1]$ (where 0 indicates no association and 1 indicates perfect association). For this purpose, we compute the squared Yule's Y-coefficient [22]:

$$Y^2(t, X) = \left(\frac{\sqrt{OR(t, X)} - 1}{\sqrt{OR(t, X)} + 1} \right)^2 \tag{3}$$

The relationship between odds ratio and this measure is shown in Figure 1.

Assessing Indirect Association (Similarity of Co-Occurrence Profiles). In assessing co-occurrence, the relative frequency of conditions or the over- or under-representation of some conditions in the utilized datasets can add bias to computed co-occurrence scores (including odds ratio and thus Y^2). Recent studies show that associations between rare conditions become more visible when multi-variate models are incorporated [23] and consideration of overlap of symptoms results in more reliable assessment of co-morbidity [24]. Motivated by these considerations, we also assess the indirect association between conditions using an "association of co-occurrences" approach. Similar approaches have been successfully applied to improve the reliability of disease gene prioritization [25], drug response prediction [26], prediction of protein-protein interactions using context profiles [27], and prediction of drug interactions from individual drug response profiles [28].

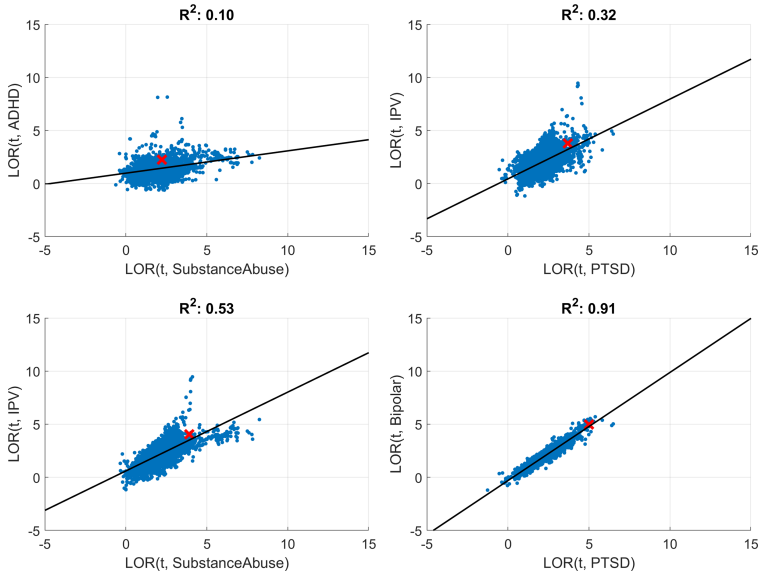

Fig 2: **Assessment of the indirect association (similarity of co-occurrence profiles) between pairs of conditions.** Each panel represents a different condition pair (ADHD-Substance Abuse, IPV-PTSD, IPV-Substance Abuse, or Bipolar-PTSD). Each blue dot represents a medical term and the x and y-axes indicate the log-odds ratio of each condition with the respective term. The black line shows the best fit linear line and the red point (shown with X) indicates the co-occurrence of the corresponding condition pair (as measured by LOR). The similarity of the co-occurrence profiles of the two conditions is quantified as the R^2 of this regression line, which is shown at the top of the panel for each pair.

Let $T = \bigcap_X T_X$ be the set of all medical terms that occur in all cohorts of interest. For a given condition X, we define the co-occurrence profile $\mathbf{c}_X \in \mathbb{R}^{|T|}$ of X as a vector of log-odds ratios, where each dimension represents a term t and $\mathbf{c}_X(t) = \text{LOR}(X, t)$. We then assess the indirect association between X and Y as the R^2 (shared variance) of $\mathbf{c}_X$ and $\mathbf{c}_Y$. Figure 2 illustrates this process for four pairs of conditions with different patterns of indirect association.

3 Results

Cohort sizes and the distribution of prevalence scores (odds ratios) of all medical terms for each of the 16 conditions of interest are shown in Figure 3. As seen in the figure, for all conditions, a medical term that has a non-zero frequency in a cohort has an odds ratio close to 5 on average. This observation suggests systematic bias in odds ratios, as the null distribution of log odds ratios would have zero mean. However, the extent of the bias for each cohort appears to be specific to the condition, e.g., the mean odds ratio for ADHD and TBI is considerably lower than that for

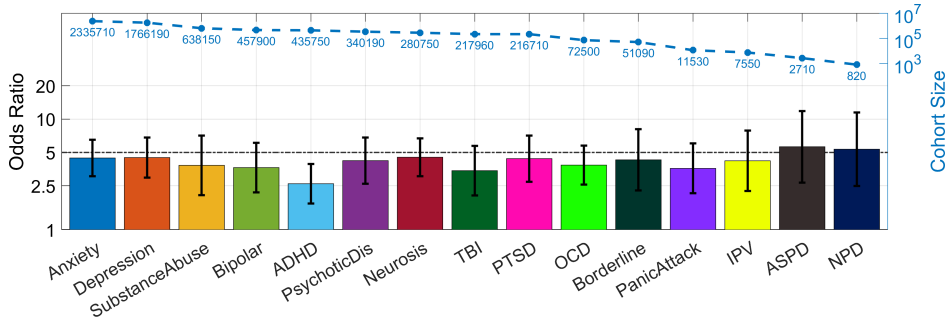

Fig 3: **Cohort sizes and the background distribution of odds ratios for the conditions of interest.** The conditions are sorted according to cohort size, shown by the blue dotted line. Each colored bar shows the mean association level (odds ratio) of all terms that have non-zero frequency in the corresponding cohort with the corresponding condition, the error bar shows standard deviation across these terms. Averages and standard deviations are computed using log-odds ratios. Odds ratio = 5 line is highlighted.

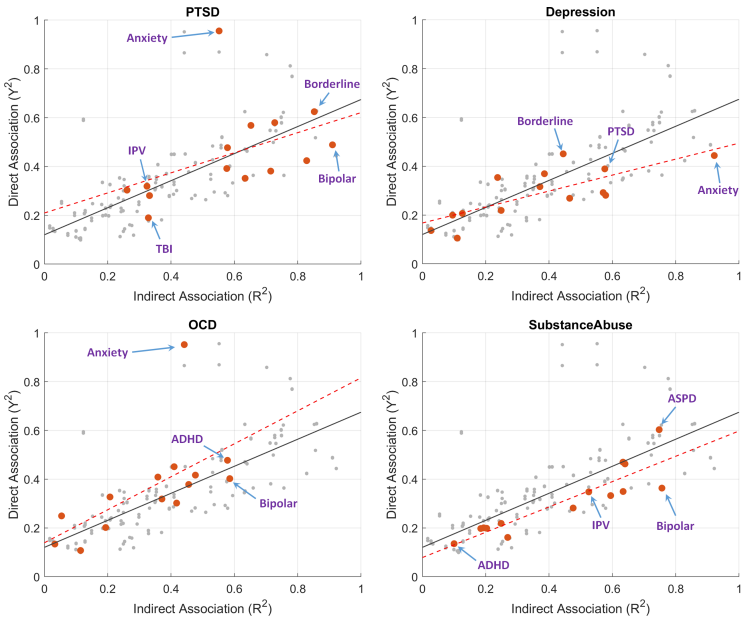

Fig 4: **The relationship between direct and indirect association.** In all panels, the grey dots show the scatter plot of direct association (Y^2, transformed odds ratio of co-occurrence) and indirect association (R^2, shared variance between co-occurrence profiles), for all pairs of the 16 conditions considered (120 pairs in total). The black line shows the regression line for these 120 points (identical in all panels). For each of PTSD, Depression, OCD, and Substance Abuse, the respectively labeled panel highlights the association of that condition with all other 15 conditions in red. The red dashed line shows the regression line for these 15 points. The points representing a select set of conditions are identified in each panel.

conditions with a similar cohort size. One explanation for this bias is that many terms with negative association with the conditions may not be observed (since they may have very low frequency). However, there are also other factors associated with the nature of EHR data that inflate odds ratios [29]. We also observe that prevalence scores tend to exhibit higher variance and higher averages for smaller cohorts.

Direct Association (Co-occurrence) vs. Indirect Association (Similarity of Co-ocurrence Profiles). The relationship between direct association (Y^2) and indirect association (R^2) is empirically illustrated in Figure 4. As seen in the figure, direct association and indirect association are correlated across all pairs of the 16 mental health related conditions. However, when we consider a specific condition and its association with the 15 remaining conditions, we observe various different patterns. For example, the slope of the best fit line for Obsessive Compulsive Disorder (OCD) is higher than the slope for all pairs (i.e., the majority of red dots for OCD are above the gray line), whereas Depression and Substance Abuse exhibit a smaller slope (i.e., the majority of red dots for these conditions are below the gray line). In other words, OCD tends to show stronger direct association than indirect association with other conditions, whereas Depression and Substance Abuse exhibit stronger indirect association. Post-Traumatic Stress Disorder (PTSD) exhibits more variance in terms of the relationship between its direct and indirect association with other conditions - where both the direct and indirect association of PTSD with almost all mental health conditions are stronger.

An important outlier in terms of direct association (co-occurrence) is Anxiety, which exhibits very strong co-occurrence with PTSD and OCD. Note that, since the Anxiety cohort is ten-fold larger than the PTSD and OCD cohorts, this strong association can be considered as one-directional, i.e., if PTSD (OCD) is present, anxiety is also very likely to be present (but not vice versa). However, the indirect association of anxiety with PTSD and OCD is weaker; suggesting that anxiety is co-morbid with a variety of other conditions which may not be co-morbid with PTSD or OCD. In contrast, Depression exhibits strong indirect association with Anxiety despite having modest direct association, which suggests that Depression and Anxiety have a broad range of shared co-morbidities although they may not necessarily be co-

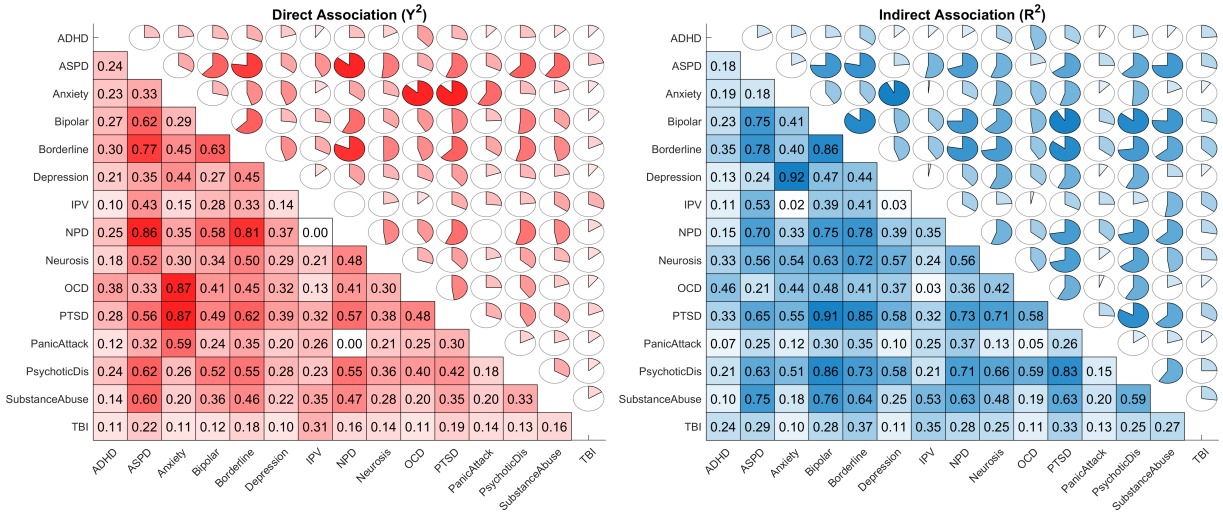

Fig 5: **Pairwise associations between the conditions of interest.** (Left) Direct association (co-occurrence) measured by $0 \leq Y^2 \leq 1$ (transformed odds ratio), where closer to 1 indicates that the conditions are likely to co-occur together. (Right) Indirect association measured by $0 \leq R^2 \leq 1$ (shared variance between co-occurrence profiles), where closer to 1 indicates that the conditions are likely to co-occur with similar terms. The numbers in each cell (in the bottom left side), the area of the filled circles (in the top right side), and the darkness of colors indicate the strength of the association for the corresponding pair of conditions.

morbid with each other. These examples and observations suggest that our measure of indirect association (shared co-occurence), alongside direct assessment of co-occurrence, provides a more comprehensive view of the relationship between pairs of mental health conditions.

Comprehensive View of Associations Between All Pairs of Conditions. The direct and indirect association between all pairs of the 16 conditions are shown in Figure 5. As seen in the figure, the strongest direct associations (co-occurrence) we observe are between Anxiety and OCD ($Y^2 = 0.87$, corresponding to $OR > 400$)/PTSD ($Y^2 = 0.87$). Furthermore, Narcissistic Personality Disorder (NPD) exhibits strong co-occurrence with Anti-Social Personality Disorder (ASPD, $Y^2 = 0.86$) and Borderline Personality Disorder ($Y^2 = 0.81$, $OR > 300$). Other pairs that exhibit strong co-occurrence include ASPD and Borderline ($Y^2 = 0.77$, $OR > 200$), Bipolar Disorder and Borderline ($Y^2 = 0.63$, $OR > 90$), and Bipolar Disorder and ASPD ($Y^2 = 0.62$, $OR > 90$). This is an example of a triangle we would observe if we were to construct a co-morbidity network using these direct association scores.

The conditions that exhibit weaker co-occurrence with other mental health conditions are Depression, IPV, and TBI. Note that this is relative to other co-ocurrence scores we observe, the direct association of these three conditions and many of the conditions considered is still strong; e.g. Depression exhibits the strongest direct association with Borderline ($Y^2 = 0.45$, $OR > 20$), Anxiety ($Y^2 = 0.44$, $OR > 20$), and PTSD ($Y^2 = 0.36$, $OR > 10$). It is important to note that Depression is also one of the most frequent mental health disorders in our dataset, appearing in 1.76M records (trailing Anxiety with 2.33M records and ahead of Substance Abuse with 638K records). IPV, on the other hand, exhibits strongest co-occurrence with ASPD ($Y^2 = 0.43$, $OR > 20$), Substance Abuse ($Y^2 = 0.35$, $OR > 10$), Borderline ($Y^2 = 0.33$, $OR > 10$), PTSD ($Y^2 = 0.32$, $OR > 10$), and TBI($Y^2 = 0.31$, $OR > 10$). It is interesting to note that TBI exhibits the strongest co-occurrence with IPV ($Y^2 = 0.32$, $OR > 10$), which is much stronger than any of the mental health conditions that are considered.

When we consider indirect associations (shared variance between co-occurrence profiles), we identify many pairs that exhibit strong indirect associations despite exhibiting relatively weaker direct associations. The most striking example is Depression and Anxiety, which exhibit the highest correlation between their co-occurrence profiles ($R^2 = 0.92$), despite having modest direct association ($Y^2 = 0.44$, $OR > 20$) as compared to many other condition pairs. We observe that Bipolar Disorder exhibits strong indirect association with most mental health conditions that are considered, including Borderline ($R^2 = 0.86$), Psychotic Disorder ($R^2 = 0.86$), PTSD ($R^2 = 0.85$), Substance Abuse ($R^2 = 0.76$), and NPD ($R^2 = 0.75$). In some cases, indirect associations appear to complete the triangles that

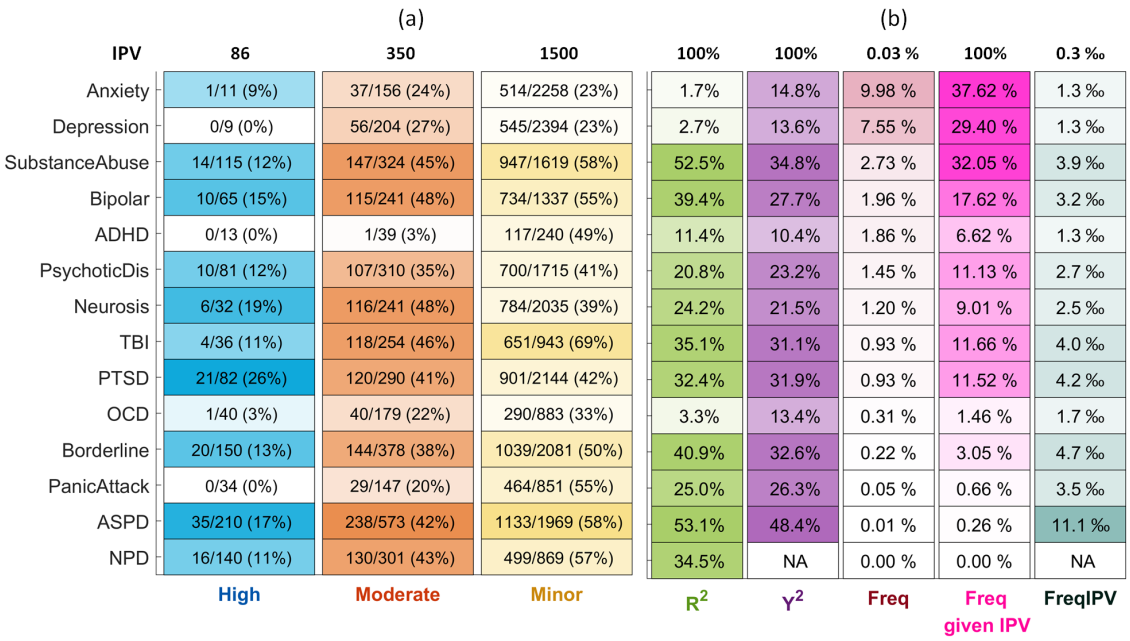

Fig 6: **The association between intimate partner violence and mental health conditions.** Each row represents a condition, sorted from top to bottom in decreasing order of cohort size. (a) Number of terms that significantly co-occur with IPV and the condition of at three levels of co-occurrence: High ($OR \gg 20$), Moderate ($OR \gg 10$), Minor ($OR \gg 5$). The top row displays, in bold, the number of terms that co-occur with IPV with odds-ratio higher than the respective threshold. Each cell displays $x/y(z\%)$, where y is the number of terms that co-occur with the condition, x shows the number of terms that co-occur with both IPV and the condition, and z shows the fraction of x in y as a percentage; where co-occurrence is defined at the respective thresholds. (b) The association of IPV and the condition as quantified by our framework. R^2: indirect association (shared variance between co-occurrence profiles), Y^2: direct association (obtained by transforming odds ratios), Freq: the fraction of records in the background cohort that contain the condition, Freq given IPV: the fraction of records in the IPV cohort that contain the condition, FreqIPV: the fraction of records in the condition cohort that contain IPV. All statistics range between 0 and 1, and are shown as percentages.

are missing an edge in the co-occurrence network; e.g., Substance Abuse and PTSD both exhibit strong co-occurrence with ASPD (respectively $Y^2 = 0.60$ and $Y^2 = 0.56$), but weaker co-occurrence with each other ($Y^2 = 0.35$), yet the shared variance of their co-occurrence profiles is $R^2 = 0.63$. IPV exhibits strongest indirect association with Substance Abuse ($R^2 = 0.53$), ASPD ($R^2 = 0.53$), Bipolar Disorder ($R^2 = 0.39$), and TBI ($R^2 = 0.35$).

In-Depth Analysis of Association with Intimate Partner Violence. We next investigate the relationship between co-occurrence, shared co-occurrence, and cohort size in the context of association the association of each mental health condition with IPV. The results of this analysis are shown in Figure 6. In this analysis, we consider different levels of co-occurrence to investigate the overlap between the terms that are prevalent in IPV and each mental health condition. This approach delineates the differences between mental health conditions in terms of their association with IPV. For example, the indirect association of IPV with PTSD ($R^2 = 0.32$) is weaker than its indirect association with Substance Abuse, Bipolar, ASPD, Borderline, TBI, and NPD. However, when we consider the overlap of medical terms that exhibit significantly high co-occurrence ($OR \gg_{\alpha=0.05} 20$) with PTSD and IPV, PTSD clearly stands out among other mental health conditions. Namely, there are 86 and 82 medical terms that exhibit significantly high co-occurrence with respectively IPV and PTSD, 21 of which are common to both IPV and PTSD. In contrast, while IPV and PanickAttack share 25% of the variance in their co-occurrence profiles, they do not share any medical term that has significantly high co-occurrence with both conditions.

Figure 6 also provides insights into the co-occurrence of each medical condition with IPV. We observe that, among the conditions we consider here, ADHD and OCD exhibit the most modest relative prevalence in the IPV cohort as compared to the background population. Yet, the relative prevalence of IPV in the OCD cohort as compared to the

background population is high (1.7%), as compared to that in the Anxiety, Depression, and ADHD cohorts (1.3% for all three conditions). This is in line with the modest indirect association IPV exhibits with these conditions. Substance Abuse has the second most relative prevalence (after Anxiety) in the IPV cohort ($Freq\ given\ IPV = 32.05\%$) despite being the third most prevalent condition (after Anxiety and Depression) in the background population ($Freq = 2.73\%$, approximately two-fifth of the frequency of Depression). ASPD stands out as a relatively rare condition that is strongly associated with IPV, where the relative prevalence of IPV in the ASPD cohort is 11.1%, the relative prevalence of ASPD in the IPV cohort is 0.26%, and the two conditions share 53.1% of the variance in their co-occurrence profiles, where 35 medical terms exhibit significantly high co-occurrence with both conditions.

4 Discussion

Violence against women is in endemic proportions and it leads to negative physical and psychological effects on the well-being of survivors. Multiple mental health issues can simultaneously affect the survivors of IPV. In this paper, our aim was to systematically investigate these co-occurring mental health issues in order to improve treatment outcomes for the survivors of IPV.

Meta-analytic studies investigating mental health outcomes as a result of intimate partner violence victimization consistently found that depression, PTSD, and anxiety are among the most frequently reported mental health concerns [7, 30, 19]. Consistent with the literature, we found that depression and anxiety significantly co-occur with IPV, where depression is observed in at least 29.4% of the IPV survivors in EHRs and anxiety is observed in at least 37.6%. Furthermore, while both depression and anxiety are highly common mental health issues (they are the two most prevalent mental health conditions among the 15 we consider), 1.3% of patients with one of these conditions were survivors of IPV ($> 40x$ the prevalence of IPV in the background population). Our results also showed that depression and anxiety exhibit strong indirect association with each other, i.e., they tend to co-occur with similar symptoms, findings, and diagnoses. In contrast, they exhibit weaker indirect association with IPV, i.e., the symptoms, findings, and diagnoses that co-occur with IPV tend to be different than those commonly observed for patients with anxiety or depression.

Depression and anxiety can be defined as mental health issues that affect how a person feels, thinks, and acts. Depressed individuals tend to have excessive hopelessness, and helplessness while individuals with anxiety have feelings of excessive worry or fear [31, 32]. Both anxiety and depression interferes with how IPV victims react to events and interferes with one's daily functioning [31, 32]. Both depression and anxiety can be moderator for more severe mental health issues [31, 33, 34]. Past studies also indicated that IPV victims are four times more likely to suffer from depression with high rates of suicidality [13]. Similarly, an observational multi-country study conducted by WHO found that emotional distress, suicidal thoughts, and suicidal attempts were consistently observed in various sites across the country [6]. Research findings also note worse mental health outcomes are associated with more severe and frequent IPV experiences [17].

Our results suggested that PTSD is highly associated with IPV in terms of both co-occurrence and similarity of co-occurrence profiles, where 4% of PTSD patients in the database are survivors of IPV and one in every four symptoms that occur in PTSD patients also occur in IPV survivors (and vice versa). In contrast, while IPV and Panick attack share 25% of the variance in their co-occurrence profiles, they do not share many medical terms that exhibit significantly high co-occurrence with both conditions. While we found that co-occurrence of PTSD and Panick Attack is weaker than the co-occurrence of either condition with IPV, we found that both of these conditions also significantly co-occur with Anxiety. However, another anxiety-associated disorder, namely OCD was one of the mental health conditions that exhibited the weakest association with IPV, in terms of both co-occurrence and similarity of co-occurrence profiles. This observation suggests that PTSD can be a mediating factor for IPV survivors who are experiencing symptoms of anxiety disorders and the etiology of these disorders in IPV survivors may have specific traits.

The prevalence rate of anxiety disorders is estimated to be 7.3 percent globally [35]. Anxiety disorders are highly heterogeneous in their etiology and psycho-biology [36] and are often co-morbid with other anxiety disorders [36]. For example, as an underlying mechanism for PTSD, panic, and other fear- and anxiety-related disorders, fear conditioning and extinction of fear provide a valuable paradigm [37, 38]. In contrast, for OCD, cognitive flexibility and inhibitory control provide an explanatory paradigm [39]. Based on our results, fear conditioning and extinction of fear may be underlying the association between IPV and anxiety disorders, however further investigation is needed to characterize

the etiology of anxiety disorders in IPV survivors.

Our results indicate that after Substance Abuse was also highly associated with IPV in terms of both co-occurrence (32% of IPV survivors had Substance Abuse in their record, and 3.9% of records with Substance Abuse also contained IPV) and similarity of co-occurrence profiles (the co-occurence profiles of IPV and Substance abuse share 52.5% of their variance). The literature highlights the bidirectional relationship between substance use disorders and IPV [40]. Some studies indicated that substance use issues might start after exposure to IPV while others indicated substance use issues might put the person at increased risk for IPV victimization [40]. Both propositions found evidence in the literature to indicate the complex interaction between substance use issues and IPV. It is important to note that the condition that exhibited the strongest indirect association with IPV was Substance Abuse in our study, thus investigation of the similarity of co-occurrence profiles of IPV and Substance Abuse may shed further light on the complex relationship between IPV and Substance Abuse.

An important limitation of this observational study is that the associations identified do not provide information on the directionality of the relationships. In future studies, it would be of particular interest to understand which disorders occurred following IPV vs. those that occurred prior, e.g., to what extent substance substance abuse could be considered a consequence vs. one of the predisposing conditions to IPV. To answer such questions, incorporation of time into the analysis of EHR data is essential.

In conclusion, comprehensive investigation of the associations between mental health conditions and IPV provided important insights into the etiology of mental health conditions in IPV survivors. In particular, consideration of co-occurrence and similarity of co-occurrence profiles provided information that complemented each other in dissecting direct and indirect associations. In future research, our findings, which are based on mining of structured EHRs, can also be compared to associations obtained using text mining [41].

In order to diminish the debilitating effects of IPV, it is important to understand the patterns of IPV victimization and its link to multiple simultaneous mental health issues. In the future, to improve the effectiveness of treatment strategies treatment models can be customized to reflect the variability in mental health issues.

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