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A population level analysis of mental health and non-communicable disease (NCD) in the Philippines using predictive modelling analysis

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ABSTRACT:

Abstract--- *The epidemic brought about by non-communicable diseases (NCD) and the lack of adequate data on the state of mental health (MH) in the Philippines have converged that threatens to overwhelm the health care infrastructure. Population level analysis is severely lacking that could otherwise provide a fundamental basis for critical analysis needed to address health policy interventions. The use of mathematical algorithm as a form of mixed-method analysis in population level studies in developing countries has the potential to elucidate associations between diseases. Our study looks into the Philippine national data on mental health and NCD from 2002-2016 to determine the association and predictive correlation between mental health and NCD using predictive modeling study; designed to expand current understanding on the developmental origins and trajectories of these diseases from a developing country perspective*

Keywords--- *Mental health, non-communicable diseases, behavior, dementia, diabetes, cardiovascular diseases*

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I. Introduction/Background:

The link between mental disorders and major NCDs are well established. In the Philippines, however, the lack of a unified approach to patients with mental health disease and patients with major NCD diseases are often overlooked. The prospect of premature mortality and disability can be mitigated if appropriate intervention with a greater focus on combined management is done. Insidiously the rise of non-communicable diseases (NCD) in developing countries have led to increase challenges on national governments to create strategic programs to mitigate the spread. As a developing country, the impact of NCD in the Philippines remains the top leading cause of morbidity and mortality.

The prevalence of stroke is 0.9% while the prevalence of age adjusted hypertension is 20·6%, diabetes 6·0%, dyslipidemia 72·0%, smoking 31%, and obesity 4·9% [1]. The disproportionate number of NCD related mortality belongs to developing countries and requires redirection towards mitigation and health policy promotion. Cardiovascular diseases, cancer, chronic respiratory diseases, and diabetes are the primary components of NCD related diseases accounting for an estimated 32.2 million deaths (80%) worldwide, while another 8.3 million (20%) were from other NCDs **[2,3]**. In Asia, NCD remains the leading cause of mortality, while its total number of cases accounts for 47% of global deaths related to NCD **[4].**

The cause of NCD in developing countries has been attributed to lifestyle and nutrition related transition. The dramatic shift in cultural diet to increased consumption of processed food, behavioral & lifestyle related changes that favor sedentary activity are key determinants in poor health outcomes. Changes in dietary behavior from food selection to increase consumption of low nutritional substances are significant factors linked to premature cardiovascular diseases. Traditional causes of diabetes have been attributed to high caloric density food, low nutrition, increase BMI, and older age **[5].** Sedentary behavior and poor mental health **[6,7]** have also been implicated as key factors in the development of malignancy (colorectal, ovarian).

While the problem of NCD has well studied, the problem of mental health disorder (MH) remains a long-neglected categorical disease worldwide and continues to be under reported in developing countries. World health studies on the prevalence of mental health revealed that approximately 450 million or 1 in four individuals are affected by the disorder. Problems related to mental health can occur during the entire lifespan while taking various forms that affect cognition, behavior, and psychological competencies. Cognitive difficulties (i.e. dementia, schizophrenia) can present with language and memory problems.

Nutritional perturbation is an important factor in the developmental process of neuropsychiatric and metabolic related diseases in developing countries. For instance, fetal exposure to malnutrition during pregnancy plays a critical role in altered developmental outcomes. This process of environmental exposure can induce genomic modification which leads to mental health disorders such as depression **[8],** ADD/ADHD, dementia [9]**,** cardiovascular diseases **[10],** and diabetes [11]. The link between pregnancy related changes with diet, activity, and lifestyle is based on the epigenetic modification that takes placed and increases the individual's susceptibility to poor health **[12,13]**. The epigenetic change and modification that occurs has the potential to be carried through the entire lifespan if no significant intervention is made. This fetal programming elucidates an important translational mechanism in the development of NCD and partly mental health based on environmental exposure and subsequent genomic imprinting.

In the Philippines problems related to mental health disorders parallel those of many low/middle income countries; characterized by poor resources and epidemiological study constructs that are often limited. For instance, mental health infrastructures are chronically under-funded and poorly resourced accounting for only 3-5% of the national budget **[14,15].** The burden of mental health is severely underestimated though national survey studies that have been conducted **[16],** revealing 14% prevalence in the general population. Recent sampling survey (>1300 participants) in the country looking at the prevalence of dementia revealed that approximately 10.6% (95% CI 9.0 to 12.4) had dementia with the breakdown 85.5% Alzheimer, 11.7% vascular dementia, and 2.7% other dementias. Furthermore approximately 82.0% of men and 70.4% of women had at least one cardiovascular risk factor (hypertension, diabetes, dyslipidemia, smoking) associated with vascular dementia but not Alzheimer.

With the projected rise of NCD and MH in developing countries, the need to further elucidate their association and predictive correlation is an important step towards improved outcome through mitigation and health policy adjustments. Determining future trajectories based on the association of NCD to MH can lead to health policy changes by leveraging data linkages while redirecting strategy and budget allocations. To better understand this association, examining common or shared determinants based on mixed-method analysis serves a fundamental purpose in addressing healthcare outcomes.

Analyzing large data sets involving these diseases through a well-designed modelling studies has the capability to analyze data architecture and create opportunities **[17,18]** based on association. Individuals with diabetes often have a comorbidity of depression or dementia. Rapid changes in blood glucose can present with elements of depression or worsening of memory loss. However, dementia and/or depression can lead to alteration in behavior with detrimental effects on blood sugar level. Developmental research studies looking at the link and correlation have been inconclusive and lacking. Health outcome studies can benefit from using predictive modeling to better understand this interlocking relationship. The use of predictive modeling can provide deep insight into the possible correlation and future trajectories of diseases. The limited scope and available quantitative data in the Philippine setting presents an opportunity to better understand the correlation of NCD with mental health given the shared key determinants (environment, lifestyle, nutrition) between the two.

II. DATA COLLECTION:

Data Source:

This was a population level, longitudinal study from 2002 to 2016 using the annual Philippine health statistics and data published by the national Department of Health [19-21]. The annualized data was derived through an open-source platform. The annualized, national data represented compiled raw data sourced from local health units, private & public hospitals, mental health registry, emergency department attendances, and death registers. Data was classified based on age, sex, and cause of death (mortality). The age classification was group into age range (i.e. 20-24, 25-29, 30-34, etc.). The cause of death was classified into cardio- and cerebro-vascular diseases, diabetes, and malignancy (NCD); while mental health data represented a compilation of psychoses, dementia, and other non-categorized mental disorders. The underlying cause was defined as the disease or injury which initiated the train of morbid events leading directly to death; or the circumstances of the accident or violence which produced the fatal injury.

Data Analysis (Chi-2 test):

A chi square test analysis was done using the variables age and gender as categorical variables. The mortality data-based on disease classification (mental health, cardiovascular, diabetes, malignancy)- were used as continuous variables to create a cross-tabulations (contingency tables) of MH disorders against every other disease and then calculated the observed counts and the expected counts for age and gender. (Table 1, below).

		Count			Expected		
Age	**Gender**	**Diabetes**	**MH disorders**	**Row sum**	**Diabetes**	**MH disorders**	**Row sum**
15-29	Female	1948	340	**2288**	2180	108	**2288**
	Male	1812	1065	**2877**	2742	135	**2877**
30-49	Female	15574	847	**16421**	15648	773	**16421**
	Male	22404	3601	**26005**	24781	1224	**26005**
50 above	Female	157291	5178	**162469**	154819	7650	**162469**
	Male	140630	5752	**146382**	139490	6892	**146382**
	Column sum	**339659**	**16783**	**356442**	**339659**	**16783**	**356442**

		Count			Expected		
Age	Gender	Cardiovascular	MH disorders	Row sum	Cardiovascular	MH disorders	Row sum
15-29	Female	39945	340	**40285**	40005	280	**40285**
	Male	42990	1065	**44055**	43748	307	**44055**
30-49	Female	104385	847	**105232**	104499	733	**105232**
	Male	227142	3601	**230743**	229137	1606	**230743**
50 above	Female	911637	5178	**916815**	910433	6382	**916815**
	Male	1068116	5752	**1073868**	1066393	7475	**1073868**
	Column sum	**2394215**	**16783**	**2410998**	**2394215**	**16783**	**2410998**

		Count			Expected		
Age	Gender	Malignancy	MH disorders	Row sum	Malignancy	MH disorders	Row sum
15-29	Female	14496	340	**14836**	14497	339	**14836**
	Male	15621	1065	**16686**	16305	381	**16686**
30-49	Female	81504	847	**82351**	80472	1879	**82351**
	Male	62913	3601	**66514**	64996	1518	**66514**
50 above	Female	246403	5178	**251581**	245841	5740	**251581**
	Male	297841	5752	**303593**	296666	6927	**303593**
	Column sum	**718778**	**16783**	**735561**	**718778**	**16783**	**735561**

Tables 1-3: Mortality data based on disease classification with cross-tabulation

Based on the differences between the observed counts and the expected counts of each disease, the Chi-2 tests was calculated for the datasets. After the Chi-2 tests was done, a linear regression analysis was completed.

Data Analysis using linear regression:
Regression analysis was applied to identify the relationship between MH disorders and NCD, after controlling for other variables related to MH disorders as age and gender. In regression analysis, historical data of a dependent variable (in this case mental health disorders, MH) is regressed against an explanatory variable (NCD) and control covariates (age and gender):

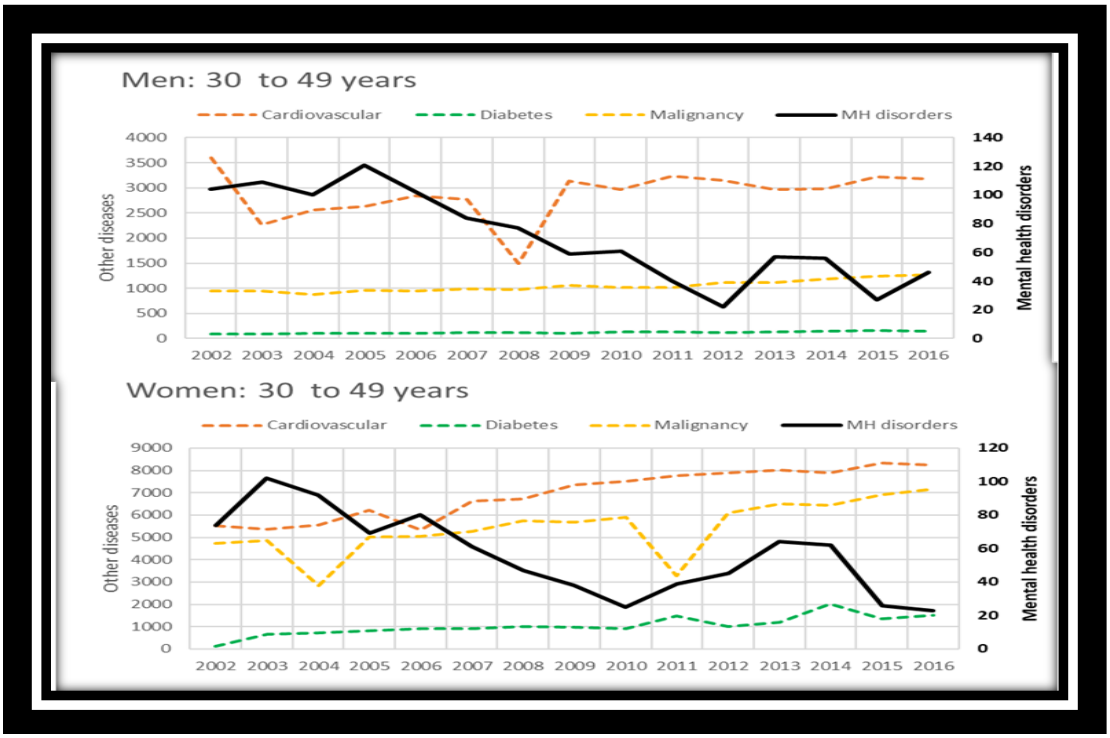
$$MH = \beta 0 + \beta 1\ NCD + \beta 2\ age + \beta 2\ gender + \varepsilon$$

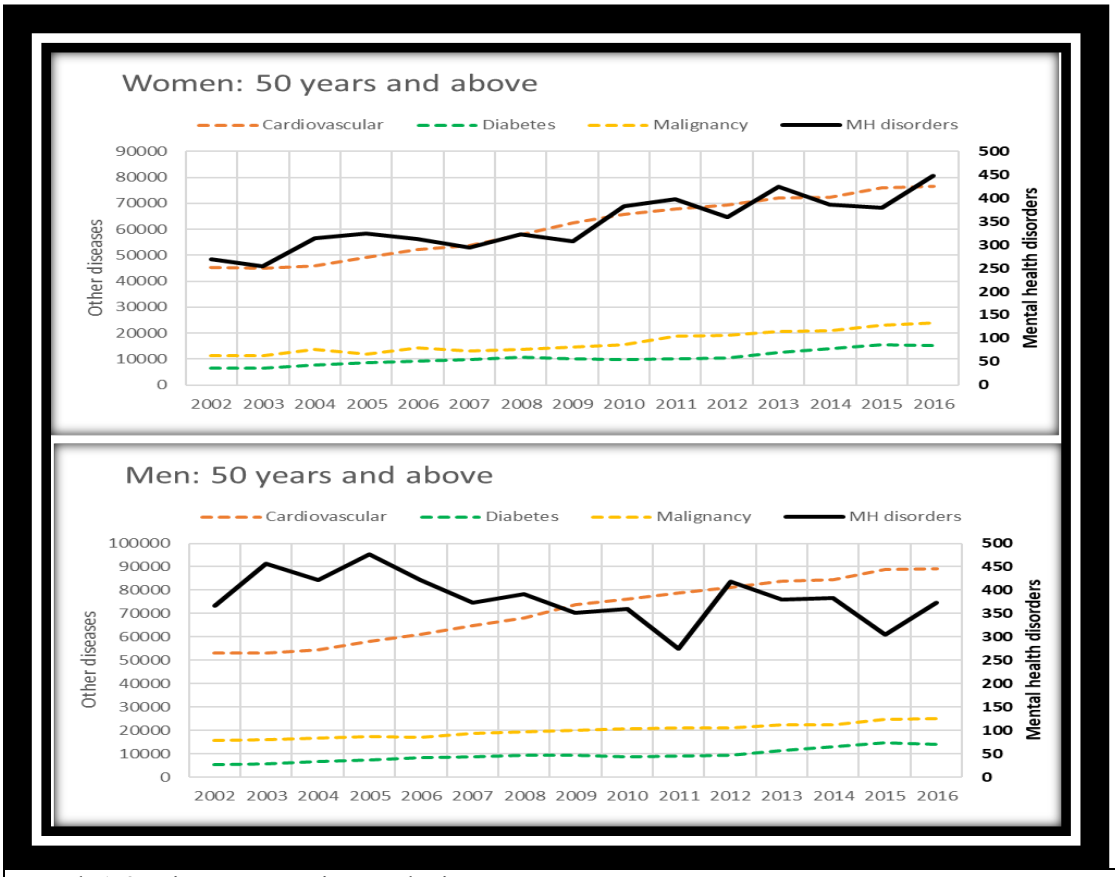
In the regression, $\boldsymbol{\varepsilon}$ is a disturbance term that is expected to capture other variables that affect mental health but are not explicitly being considered in the regression (formally, ε is an independent and identically distributed stochastic process following a Gaussian distribution). The importance of NCD for MH is measured with a weight $\beta 1$, a parameter that measures how strong is the relationship between NCD and mental health disorders. The value of $\beta 1$ can be estimated with Ordinary Least Squares (OLS), maximum likelihood or other techniques. The null hypothesis of no relationship between mental health disorders and NCD can be tested with:

$$H0: \beta 1=0$$

A rejection of the null hypothesis **H0** provides empirical evidence suggesting that there is a statistically significant relationship between an NCD and MH, after controlling for other variables that affect MH disorders. (Note the difference with a simple correlation coefficient: correlation measures the relationship between NCD and MH but does not consider the potential confounding effects of other variables affecting the trends in MH.)

After estimating the regression, the null hypothesis **(H0: β1=0)** was only rejected for diabetes **(p-value: .004)**, suggesting that this NCD is related to the trends in MH disorders. The sign of the estimate **(βˆ1= .629)** further suggest a positive relationship between diabetes and MH disorders, after controlling for age and gender

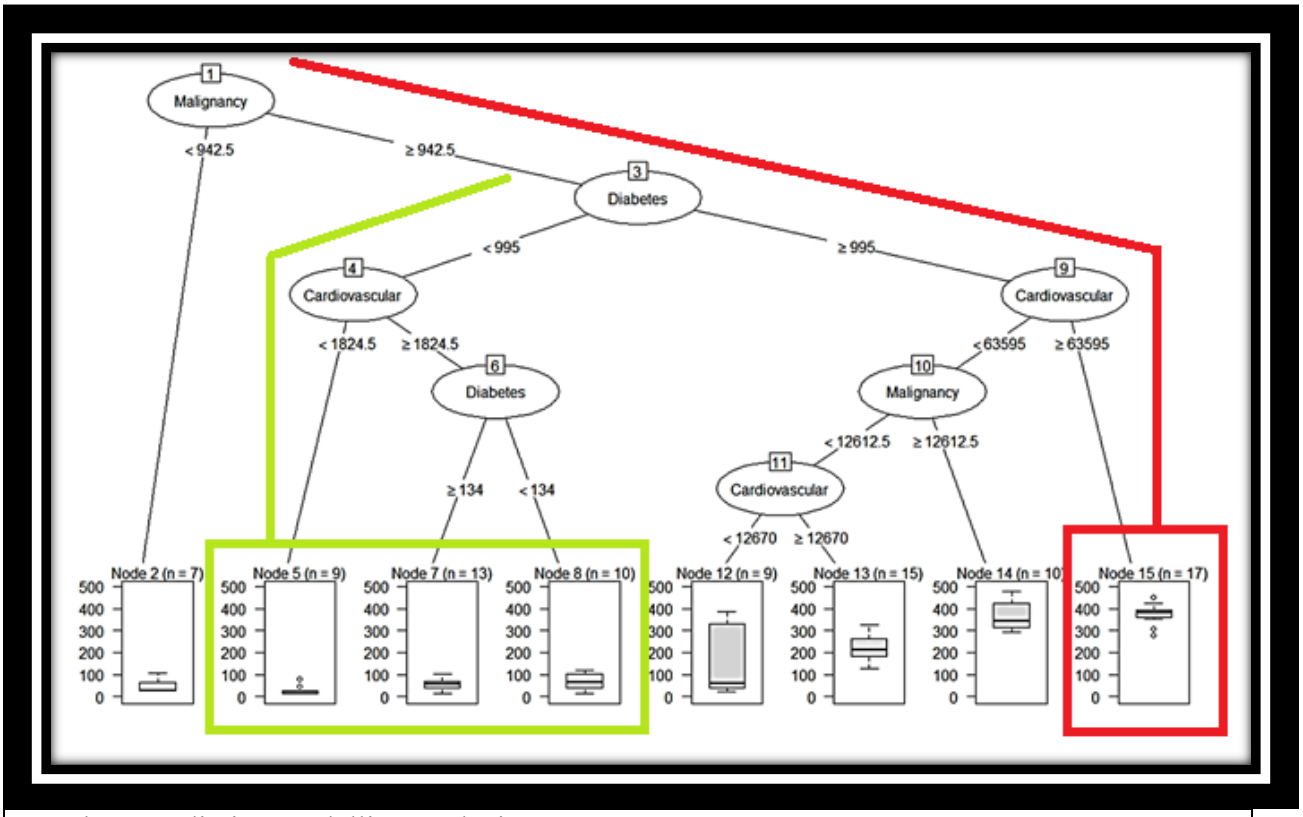




Graph 1-2: Linear regression analysis

Data Analysis using predictive modeling:
Regression trees were used as a modelling tool to predict potential mental health problems originated from NCD. Regression trees are a common supervised learning technique applied in predictive modelling [22,23].

In the regression tree, the target variable is mental health disorders. The goal of the model is to obtain a function that allows to predict MH disorders, from predictor variables (NCD). The algorithm finds partitions of the independent variable (NCD) that best separates the data of the target variable (MH). Then, for each separation, the process is repeated to find other NCD variables able to predict MH disorders.



Graph 3: Predictive modelling analysis

III. Data Analysis:

Chi-2 test results:
Results from the Chi-2 test revealed that age and gender were not independent of other diseases (since the null of independence can be rejected in all cases with a significance level of less than 1%). The value of the Chi-2 test was higher for the cross-tabulation of diabetes and mental health with age and gender, compared to the cross-tabulation of mental health with cardiovascular diseases and malignancy, which suggests that diabetes and mental health disorders are less independent compared to other diseases.

In the correlation analysis, negative correlation coefficients were obtained for mental health disorders and cardiovascular diseases, diabetes and malignancy in men and women between 15 to 49 years. In contrast a positive and statistically significant relationship between mental health disorders and cardiovascular diseases, diabetes and malignancy were found for women of 50 years and above. However, there was zero correlation found for men of 50 years and above. The negative correlation indicates that the trend of mental health disease has (in some age

categories) an opposite direction compared to NCD. This is particularly true (statistically significant) for women and men between 30 to 49 years.

In the cases for which mental health diseases have an opposite direction compared to NCD, the trends show that as mental health goes down, NCD increase over time. (Graphs 1). The previous trends however are not enough evidence in favor or against the hypothesis that NCD could be an intermediate towards the development of mental health disorders.

Linear Regression Analysis:
In the regression analysis, ordinary least squares were used to estimate the relationship of mental health disorders (dependent variable) with cardiovascular diseases, diabetes and malignancy (independent variables). Control covariates were included in the regression to account for age and gender, as well as fixed effects to account for the dynamics of the diseases across years. The estimated regression has a R2 (R-squared) of 90%, with an adjusted R square of 87.4%. The estimates of the regression coefficients suggest a positive and statistically significant relationship of diabetes with mental health disorders. Cardiovascular diseases and malignancy (cancer) were not statistically significant to explain mental health disorders at conventional significance levels. Gender (women) and age (30 to 49 years, 50 and above) were also found statistically significant for mental health disorders with a significance level of less than 1%.

Predictive Modelling analysis:
The algorithm finds that the presence of the three NCD diseases has the highest predictive power to anticipate mental health problems. The risk of mental health disorders is low in the presence of malignancy alone; however, the risk of mental health disorders was found to be high when malignancy is followed by diabetes and cardiovascular diseases ***(red square in the graph below)***. The results of the analysis with predictive modelling also indicate that diabetes plays a central role in the interaction of other diseases with mental health disorders. When diabetes interacts only with cardiovascular diseases the risk of mental health disorders is low (**green square in the graph below**), but when diabetes interacts with cardiovascular diseases and malignancy the risk of developing mental health disorders is high.

IV. Discussion:

A population level analysis of the Philippine mental health and non-communicable diseases (NCD) is crucial to determine the association and predictive correlation between the two. Previous population level studies looking at the association of mental health and diabetes indicated a dependent relationship exists. Diabetes was associated with an increased likelihood of anxiety disorders [24,25]. In addition, there was a strong correlation between mental disorders, diabetes, and glycemic control as important variables that determines this relationship. Furthermore, the prevalence of diabetes in MHC (mental health clients) compared to non-MHC individuals was significantly higher **(**9.3% vs 6.1%, respectively, $P < 0.001$) [26,27]. The results of this study revealed similar findings suggestive of a more interdependent association between diabetes and mental health. Categorical variables of age and gender strongly influences the level of association. Other recent studies [28,29] on geriatric population with or without diabetes revealed similar findings of increasing prevalence of mental health disorders ranging from depression, generalized anxiety disorder (GAD), and cognitive impairment. Poor mental health conditions in geriatric population must be reminded of the possibility of metabolic disorders, particularly diabetes.

The data analysis also revealed an important finding on the level of association between mental health against cardiovascular disease and malignancy. Although the association between mental health and cancer (MH:cancer) [30-32] or cardiovascular diseases (MH:CVD) [33-35] has been well described in the literature, however, the results from the cross-tabulation analysis (observed counts vs. expected counts) indicate that there is a difference in the level of association. That the association between mental health and diabetes (MH:DM) is more dependent and closely linked when compared against either malignancy or cardiovascular diseases. This could indicate that diabetes plays a central role in the development of cardiovascular diseases or malignancy especially when combined with mental health problems. The role of diabetes shows the strongest relationship with mental health disorders, compared to other NCDs alone. Indeed, the results of the predictive modelling analysis shows that diabetes when combined with cardiovascular diseases ***and*** malignancy increases the risk of developing mental health disorders.

Alternatively, diabetes combined with cardiovascular alone (without malignancy) carries a lower risk of mental health problem.

Since the association between mental health and diabetes is more stringent when compared against malignancy/cardiovascular diseases, the results of correlation analysis further highlight the degree of relationship between these variables. Indeed, a positive correlation coefficient exist between mental health and the NCD spectrum (diabetes, cardiovascular disease, malignancy) but only for women 50 years old and above, while male population at 50 years old and above revealed zero (0) correlation. Although the expected outcome of the male population at 50 and above would have been positive correlation rather than zero correlation, there are specific factors that could have influenced this result. The amount of data variability and availability are factors that can affect the result of a Pearson correlation [36].

The negative correlation for both male and female between the ages of 15 years old to 49 years old indicate the important inverse relationship of NCD disease and mental health. The negative correlation indicates that the cases of mental health disease have an opposite direction compared to NCD. The trends show that as mental health goes down, NCD increase over time. **(Graphs 1-2)**. In addition, this relationship is significantly influenced by age. The results suggest that the risk of developing either diabetes, malignancy or cardiovascular disease at a young age is considerably lower when compared against the older age group; while the outcomes related to mental health (depression, bipolar, anxiety, behavioral disorders) are expected to be higher during the younger years, coinciding with higher rates of depression, suicide, and anxiety.

These trends however do not support the hypothesis that mental health could be an intermediate disease towards the development of the major NCDs. On the contrary, results of the predictive modelling analysis suggest that the trajectory of mental health disorder when combined with diabetes alone is predictive of poor health outcome. This correlation also has significant influence in the developmental outcome of cardiovascular diseases and malignancy. Indeed, the results also revealed that the efficiency of diabetes when combined with malignancy and cardiovascular disease has a strong predictive value in the developmental risk for mental health disorders. Moreover, the findings could further suggest that the future risk of mental health development from malignancy or cardiovascular disease is greatly determined by the presence or absence of diabetes. Without diabetes the hidden relationship between the development of mental health from malignancy (or cardiovascular disease) is less certain and less predictable. Future events looking at the risk of mental health with cardiovascular disease or malignancy must investigate further into the presence of diabetes particularly if the strength of correlation is limited or low.

V. Conclusion:

The integration of mental health and non-communicable diseases (NCD) is crucial in many low/middle income countries and in areas with poor resource settings. The threat from these complementary diseases requires further understanding not only through contemporary research models but also through future forecasting with the goal of improving healthcare design systems and policy development. These challenges can be addressed with the use of advance statistical designs on population level analysis which investigates the hidden relationships and correlations of these diseases.

The results of our population level study did not only support previous descriptions of the strong correlation between mental health and diabetes, but crucial to the outcome is the use of predictive modeling in forecasting hidden relationships from large data sets. Our findings did not support a more robust correlation between mental health and cardiovascular or malignancy type diseases, independent of diabetes. However, the value of predictive modeling becomes important when we look at the correlation of mental health with NCD (using diabetes as a central determinant). Here we can elucidate that future trajectories of mental health and NCD relies on the role of diabetes as a key determinant in health outcomes between them. Finally, when analyzing for future events and outcomes using predictive analysis our results suggest that an integrated approach of mental health combined with the major NCDs would be an important strategy in health policy concept and development.

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