

1 **Epidemiological Patterns of HIV/AIDS and NCDs in developing countries: A**
2 ***cluster analysis***

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25 **Abstract**

26 **Introduction:** HIV/AIDS and NCDs are the major health threats of developing countries.
27 Analysis of joint epidemiological patterns of these diseases will help in designing and
28 implementing appropriate interventions to mitigate their impacts.

29 **Objectives:** The overall aim of this study was to analyse Epidemiological patterns of
30 HIV/AIDS and NCDs in developing countries by considering diabetes as a prototype NCD.

31 **Methods:** Country level HIV and Diabetes prevalence data at four time points, between
32 2000 and 2010, for 68 countries in Sub-Saharan Africa, Southern and South Eastern Asia
33 were transformed and analysed. Joint Geographic and temporal trends were described using
34 numerical and graphic summaries. The level of Covariation between HIV and Diabetes
35 prevalence was measured by Pearson correlation. K-means cluster analysis was conducted
36 after the appropriate number of clusters was determined using scree plot. Analysis of
37 variance was used to identify factors that differentiate the clusters.

38 **Results:** Diabetes had higher mean prevalence with increasing trend while HIV had higher
39 disability adjusted mean prevalence with a decreasing trend during the study period. The
40 prevalences of HIV and diabetes have negative Covariation at all four time points of the
41 study. Four clusters of countries with size 29, 12, 12 and 14 countries were identified. These
42 clusters were found to have significant variation with respect to their mean HIV and Diabetes
43 prevalences as well as time trends in their mean prevalences.

44 **Conclusions:** Diabetes and HIV are heading in reverse directions during the study period in
45 the study regions. The identified clusters were found to describe these patterns of variation
46 across geography and time.

47 **Key words:** *Epidemiological patterns, HIV/AIDS, Diabetes, cluster analysis*

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49 **Introduction**

50 The prevalence of Diabetes has been continuously increasing in developing countries during
51 the last decade. Developing countries currently bear the largest share of magnitude and
52 burden of diabetes mellitus. The current increase in the magnitude of diabetes is attributed
53 to both population growth and actual increase in the incidence of diabetes. Most of diabetes
54 related deaths also occur in developing countries as health systems in these settings are
55 weak and most cases are left undiagnosed or diagnosed at near-miss stage. Currently,
56 southern and South Eastern Asia regions have highest diabetes prevalence. Sub-Saharan
57 Africa is expected to have the highest increase in its diabetes magnitude in the
58 upcoming years (1-6).

59 Developing countries, especially those in sub-Saharan Africa and Southern and South
60 Eastern Asia, have also been severely affected by the HIV pandemic. Due to the intensified
61 and multi-sectoral response, the HIV prevalence in these regions is currently stabilizing. HIV
62 Deaths and new HIV infections has dramatically decreased in these regions. However, a few
63 countries are still having an increasing number of new HIV infections (7-10).

64 Recent evidences suggest that there are important relationships between HIV and Diabetes.
65 These relationships are mainly expressed in three forms: Epidemiological overlap, clinical
66 interaction and Health system parallels. The epidemiological overlap indicates that there is a
67 co-occurrence of HIV and Diabetes, double-burden, in developing countries while the clinical
68 interaction addresses the effect of HIV in the risk, management and complications of
69 Diabetes. The parallels in the Health system responses to HIV and Diabetes warrant
70 possible integration of the responses (11-16).

71 Although Sub-Saharan Africa, South and South Eastern Asia regions are presumed to have
72 Epidemiological overlap of Diabetes and HIV/AIDS, little is known about the joint patterns of
73 HIV and Diabetes in these geographical regions. The joint time and geographical trends, and
74 the relationship in these trends are not well clearly understood. Whether countries with high
75 prevalence or changes in prevalence of diabetes also have the same or opposite patterns in
76 HIV are not well established. Thus, countries which have similar patterns in the joint
77 epidemiological pattern of HIV and Diabetes need to be identified for coordinated responses.

78 In light of these, the overall aim of this study was to analyse the Epidemiological patterns of
79 HIV and Diabetes in developing countries. The specific objectives were to describe the
80 trends, to determine the level of co-variation, to identify operational clusters of countries and
81 to describe the factors of that differentiate the identified clusters.

82 **METHODS**

83 **Study design**

84 This study on the Epidemiological patterns of HIV and Diabetes in developing countries was
85 a time-series cross-sectional study, with cross-sectional dominance on country level
86 prevalence of HIV and Diabetes. Besides the comparison across time and geography for
87 each, HIV and Diabetes prevalence data were also compared at four major time points
88 during the study period.

89 **Study period**

90 The analysis period considered for this study was the period from 2000 to 2010. Four time
91 points were considered in this study period. These were 2000, 2003, 2007 and 2010. These
92 points were selected based on the availability of complete HIV and Diabetes prevalence data
93 for the selected countries. This analysis was conducted from Jan to Mar 2012.

94 **Sample and sampling**

95 Three regions (based on the UN classification) were purposively selected for this study. The
96 regions were Southern Asia, South Eastern Asia and Sub-Saharan Africa. The purpose of the
97 selection was based on magnitude of HIV and Diabetes. Morbidity and Mortality statistics of
98 HIV and Diabetes in these regions showed that the regions already have high burden of HIV
99 and currently are bearing rapid emergence of diabetes. This study took in to account all
100 countries in the selected regions as units of analysis during the study period. A total of 68
101 countries with a total population of nearly 3 billion were included in the analysis.

102 **Data sources**

103 Country level HIV and Diabetes prevalence data were retrieved from relevant secondary
104 sources including World Health Organization (WHO), Joint United Nations Program on
105 HIV/AIDS (UNAIDS), and International Diabetes Federation (IDF) documents. Other relevant
106 background variables were also collected along with the prevalence data. The background
107 and prevalence data were matched for each country. To ensure completeness of the
108 prevalence data, relevant country level data sources were explored.

109 **Study variables**

110 The main study variables used in this study were the prevalence of HIV among the 15-49
111 years of age group population, and the prevalence of diabetes in the 20-79 years of age
112 population in 2000, 2003, 2007 and 2010 for those selected countries. The rest of the

variables were background characteristics of the countries like development category, income group, population size, and Human Development Index (HDI).

Data quality issues

Country level data for those indicators were obtained for the majority of the countries from UNAIDS and IDF data tables and reports of the specific years. For some countries, their Diabetes prevalence (for the year) 2000 was calculated from their estimated number of diabetes cases reported by WHO. For a few countries having only the upper limit of the HIV prevalence, that upper limit was considered in this study. For one country with HIV prevalence reported in intervals only, the mid-point of that interval was taken.

Data transformation

As HIV and Diabetes prevalence data were proportions bounded between 0 and 1, they didn't fit with or couldn't be approximated by the normal distribution. Besides, the majority of the data were close to zero making arcsine transformation less appropriate. Therefore, the logit transformation [$Y = \log(X/(1-X))$] was applied to the data before any statistical analysis. Descriptive measures were back-transformed to original data form, i.e. the anti-logit ($X = \text{Exp}(Y) / (1 + \text{Exp}(Y))$).

Data analysis

Description of trends

Prevalence data were first described using both numerical and graphical summaries of geographical and time trends. After logit transformation, confidence intervals were used to test the statistical significance of the difference between paired values of prevalence figures across groups of countries. HIV and Diabetes prevalence data were also compared across time and geographic regions. The mean prevalence of HIV and Diabetes were adjusted by their respective disability weights to take in to account the severity of the diseases during the comparison.

Assessment of Covariation

In order to assess the level of co-variation between the prevalence of HIV and Diabetes across countries at the study time points, Pearson product moment correlation coefficient was used. This was applied on pairs of HIV and Diabetes data at the four time points of analysis. The trend of the Covariation across time was observed. The correlation was also determined at regional and income group levels. The correlation between ratios of Diabetes

prevalence to HIV prevalence among the different years was analysed to see if there were consistencies in the ratio across time. The serial correlation in HIV and Diabetes prevalence was also analysed. P values less than .05 were considered to indicate statistical significance of the correlation.

Cluster analysis

K-means cluster analysis was used to explore patterns of the prevalence of HIV and Diabetes among the study countries. This method was chosen due to small number of time points involved in the study, a cross-sectional dominance data. The number of clusters was determined by scree plot and its explained variance in the transposed dataset. Iterate and classify method with convergence criterion of zero was used in the cluster analysis. The resulting clusters were described in terms of their geographical location, development category and income groups.

Analysis of variance was used to determine which variables differentiate between the clusters identified in the cluster analysis. Actual tests of the differences in the mean prevalence of diabetes and HIV at those points of time among the clusters were conducted by multiple comparison (post-hoc) tests. Variables that significantly vary across clusters were considered to be predictors of those specific clusters.

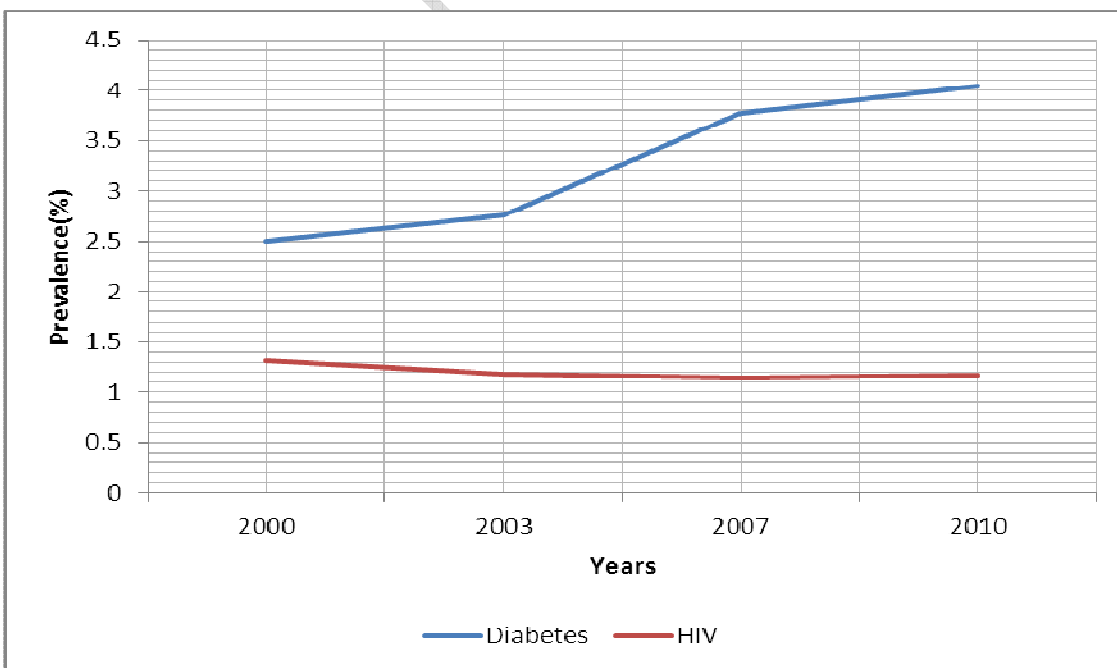
RESULTS

Description of Joint trends

Persistently high Diabetes prevalence during the study period was observed in Singapore, Seychelles, Mauritius, Brunei, and Reunion. Persistently high HIV prevalence was observed in Swaziland, Botswana, Zimbabwe, Lesotho, Zambia, and South Africa. On the other hand, persistently lower Diabetes prevalence was observed in Eastern Africa region while constantly lowest HIV prevalence was observed in Southern Asia region. As to the overall change in prevalence between 2000 and 2010, Sri Lanka and Reunion had the highest increase in diabetes while Zimbabwe and Namibia had the highest decrease in HIV prevalence.

The overall time trend of HIV and Diabetes prevalence indicates that the HIV prevalence is getting stabilized in the study regions while diabetes prevalence is continuously increasing during the study period. The increase in the mean prevalence of diabetes looks to follow exponential pattern while the decrease in the mean HIV prevalence fits better with the logarithmic pattern. The difference between the mean prevalence of Diabetes and HIV is also getting higher across time. This difference had increased by more than two-fold during the study period. The trends in the mean prevalence of diabetes and HIV in the study area is shown in [Figure 1](#).

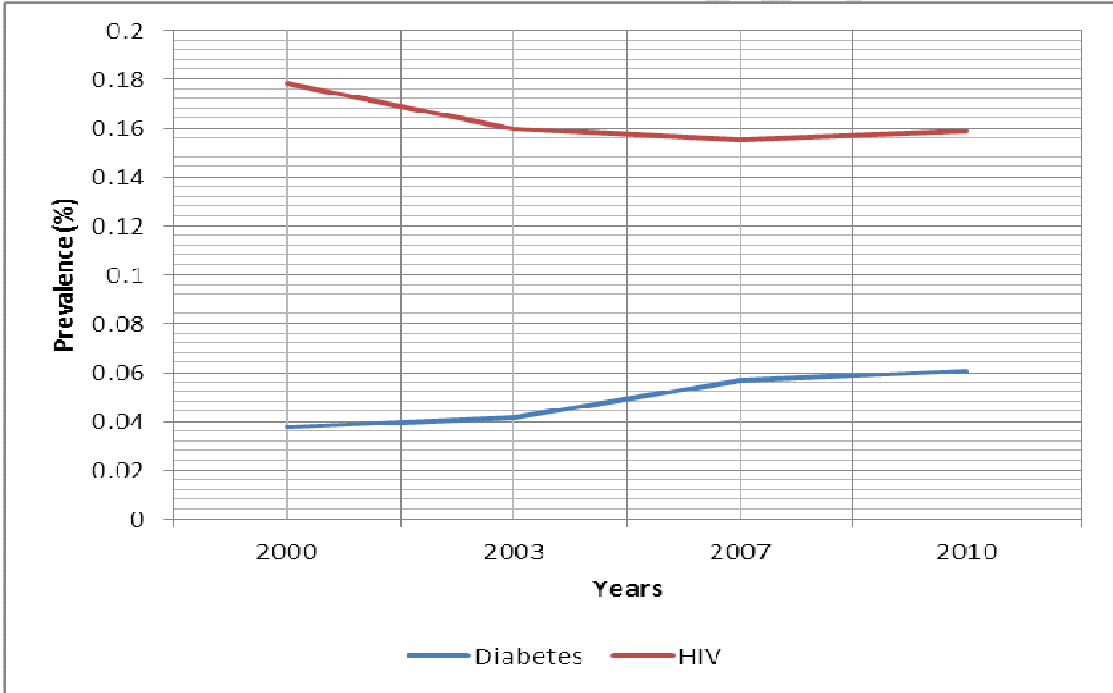
Fig 1: Trends in the mean prevalence of HIV and Diabetes in the study region (2000-2010)



The mean prevalence of HIV and Diabetes across time, separately calculated for the Africa and Asia study regions shows that the Asia region has a wide disparity between prevalence of HIV and Diabetes while the Africa region had narrow disparity between HIV and Diabetes prevalence. The prevalence lines of both HIV and Diabetes for the Africa region lies between the prevalence lines of diabetes and HIV for the Asia region. Besides, there were reversals at two points between the mean prevalence of HIV and Diabetes in the African region.

Adjusting the mean prevalence of HIV and Diabetes by the average disability weights of the two diseases, which are 0.135 and 0.015 for HIV and Diabetes respectively (17), has reversed the trends in the mean prevalence of HIV and Diabetes. This suggests that burden of HIV is still much higher than that of Diabetes even though the prevalence figures inform the opposite in terms of proportions of people with the disease (Figure 2).

Fig 2. Disability weight adjusted mean prevalence of HIV and Diabetes (2000-2010)



Disaggregated analysis of adjusted prevalence of HIV and Diabetes for the Africa and Asia regions indicated that the African HIV burden is more than 3-fold of the Asian Diabetes burden which has been demonstrating a rapid increase in the recent years. The Asian HIV and the African Diabetes burden were relatively lower. However, these prevalence figures are showing an increasing pattern in the more recent years.

Association between HIV and Diabetes prevalence

The serial correlations between subsequent time points for diabetes prevalence have shown an increasing pattern suggesting persistence in countries' diabetes prevalence. The average serial correlation for Diabetes was 0.624 (0.498 for Asia and 0.655 for Africa). The serial correlations for HIV prevalence has stabilized at higher level and shown minimal increment across time. The average serial correlation for HIV prevalence was 0.955 (0.843 for Asia and 0.953 for Africa).

On the other hand, the serial correlations among the ratios of Diabetes prevalence to HIV prevalence at all the four time points was very high (each more than +0.90 and $P=0.000$) indicating that the ratio of diabetes to HIV prevalence in countries is persistent across time, i.e. countries which had high ratio in 2000 are still having high ratio in 2010 and vice versa.

The findings of this study suggest that HIV and Diabetes were negatively correlated throughout the study period indicating that countries with higher prevalence of diabetes tend to have lower prevalence of HIV and vice versa. However, the level of correlation is relatively lower though it attained statistical significance at all-time points. The correlation between HIV and Diabetes prevalence has shown a decrement between 2000 ($r=-0.434$, $P=0.000$) and 2003 ($r=-0.281$, $P=0.021$). After this decrement it was showing a constant increase in 2007 ($r=-0.346$, $P=0.004$) and 2010 ($r=-0.440$, $P=0.000$) indicating that the disparity between the prevalence of HIV and Diabetes the study countries is getting higher and higher.

Disaggregated analysis of the correlation between the prevalence of HIV and Diabetes for the Africa and Asia regions indicated no statistically significant correlation except for the Africa region in the year 2000 when the correlation was -0.382 ($P=0.008$). Examination of the correlation between changes in HIV and Diabetes prevalence between 2000 and 2010 indicated that there is no statistically significant correlation between the changes in Diabetes prevalence and the changes in HIV prevalence across countries ($r=-0.102$, $P=0.428$).

Comparison of the correlation between the prevalence of HIV and Diabetes between low income and *non-low income* (middle plus higher income) countries indicated that the level of correlation in the low income countries is higher than the overall correlation and the correlation for *non-low income* countries at all of the time points. The correlation for the years 2000, 2003, 2007 and 2010 were -0.0402, -0.530, -0.472 and -0.475 respectively all with $P=0.000$. The correlation between prevalence of HIV and Diabetes in *non-low income* countries was statistically significant for the years 2000 ($r=-0.361$, $P=0.000$) and 2010 ($r=-0.424$, $P=0.000$) only. In 2003 and 2007, the correlation between HIV and Diabetes

prevalence for the non-low income countries was negative but hasn't attained any statistical significance.

Cluster analysis

The scree plot on the transposed data using the principal component analysis extraction method indicated that the eigenvalues start to level off at about four components. Hence, the number of clusters was determined to be four. The K-means cluster analysis has thus resulted clusters with cluster sizes of 29, 12, 12 and 14. The cluster analysis is based on the logit transformed prevalence of HIV and Diabetes at the four time points considered in this study.

Profiles of the clusters

Cluster I: This cluster is composed of three countries from South Eastern Asia (Cambodia, Myanmar and Thailand), five countries from Eastern Africa (Brundi, Djibouti, Eritrea, Ethiopia and Rwanda), six countries from middle Africa (Angola, Chad, Congo, Democratic Republic of Congo, Equatorial Guinea and Gabon), and fifteen countries from western Africa (Benin, Burkina Faso, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone and Togo). Based on their income groups, this cluster consisted of 18 lower income, 10 middle income and 1 high income countries.

Cluster II: This cluster encompasses three countries from South Eastern Asia (Indonesia, Lao PDR and Philippines), three Island countries from Africa (Cape Verde, Comoros and Madagascar) and six countries from Southern Asia (Bangladesh, Bhutan, Maldives, Sri Lanka, Afghanistan and Iran). Four of these countries are in the low income group while the rest six are in the middle income group.

Cluster III: This cluster had three countries from Southern Asia (India, Mauritius and Nepal), four countries from Eastern Africa (Reunion, Seychelles, Somalia and Sudan), and five countries from South Eastern Asia (Brunei Darussalam, Malaysia, Singapore, Timor-Leste and Vietnam). In this cluster two countries are high income and two countries are low income while the rest were middle income groups.

Cluster IV: All the members of this cluster are entirely African countries. Two countries from middle Africa (Cameroon and Central African Republic), five countries from Southern Africa (Botswana, Lesotho, Namibia, South Africa and Swaziland), and Seven countries from Eastern Africa (Kenya, Malawi, Mozambique, Uganda, Tanzania, Zambia and Zimbabwe)

were the members of this cluster. Half of the countries in this cluster are in low income groups while the rest half are in the middle income groups.

Comparison of the Human Development Index (HDI) for the year 2011 among the clusters indicate a statistically significant difference between cluster I and II which have mean HDI of 0.42 and 0.56 respectively.

Patterns of HIV and Diabetes in the clusters

Analysis of variance indicated that the clusters vary significantly with respect to all HIV and Diabetes prevalence variables. By categorizing the trend in the mean HIV and Diabetes prevalence of the clusters in to high, medium, low and very low, the pattern of HIV and diabetes prevalence in the clusters can be characterized as follows.

Cluster I had *low* Diabetes and *medium* HIV prevalence. The mean prevalence of Diabetes in this cluster has increased from 1.54% to 3.30% between 2000 and 2010. In the same cluster the mean prevalence of HIV has decreased from 3.19% to 1.76% between 2000 and 2010. In this cluster, there was reversal of mean HIV and Diabetes prevalence between 2000 and 2003.

Cluster II has *medium* Diabetes and *very low* HIV prevalence. The HIV prevalence is constantly low in this cluster but with smaller increases across time, about 0.2% in 10 years. Though still at lower level the mean prevalence of Diabetes in this cluster has increased from 2.75% to 5.01% between 2000 and 2010.

Cluster III has *High* Diabetes and *low* HIV prevalence. The mean Diabetes prevalence for this cluster was above 5% in at all the points of the study period. The general trend in the mean prevalence for this cluster is also increasing. The HIV prevalence in this cluster, though still low, is higher than that of cluster II. The mean HIV prevalence for this cluster has an increasing trend. It has increased from 0.21% to 0.29% during the 10 years study period.

Cluster IV has *High* HIV and *low* diabetes prevalence. The mean HIV prevalence in this cluster is still above 10% though it has shown a declining trend between 2000 and 2010. The mean Diabetes prevalence in this cluster has shown an increasing trend from 1.64% to 3.22% between 2000 and 2010.

Mean diabetes prevalence significantly varies between clusters I and III at all-time points. It also significantly varies between cluster III and IV at all points. The difference in mean diabetes prevalence between cluster II and III was also significant for the years 2000 and

2003. All the cluster combinations at all the four years have differences mean HIV prevalence that varies significantly.

On the other hand, mean diabetes prevalence hasn't shown a statistically significant variation between clusters I and II, I and IV and II and IV at all-time points. Besides, the mean difference in diabetes prevalence between cluster III and IV hasn't attained statistical significance for the years 2007 and 2010.

DISCUSSION

The prevalence figures indicate that diabetes in the study area had higher magnitude as compared to HIV. The number of people with diabetes is also much higher than that of people living with HIV in the region. However, the burden of HIV, based on the disability weights, was much higher than that of Diabetes at all the time points. This paradox indicates that HIV is putting much burden even though diabetes is affecting more people. But this viewpoint changes when the Sub-Saharan Africa and the Asia study regions are seen separately. The Sub-Saharan Africa had higher magnitude and burden of HIV while Southern and South Eastern Asia had higher magnitude and burden of Diabetes (18, 19).

Looking in to the trends of prevalence across time, the prevalence of diabetes is increasing at a rapid rate while the prevalence of HIV is nearly stabilized. This implies that the incidence of diabetes is much higher than that of HIV in these study regions. Clearly, the prevalence of HIV in Sub-Saharan Africa is greater than that of Diabetes, while the prevalence of Diabetes in Southern and South Eastern Asia is greater than that of HIV. But in both regions the incidence of Diabetes is much greater than that of HIV.

The high level of serial correlation in HIV and Diabetes prevalences imply that the relative prevalence of HIV and Diabetes in the study countries has a *persistence* nature. This means countries tend to 'retain' their relative prevalence during the study period. This was also verified by the serial correlations in the ratio of diabetes to HIV prevalence across time. Both HIV and Diabetes prevalence tend to change in a similar manner among countries.

Thus study has indicated that correlation between HIV and Diabetes prevalence at all points was negative. This crudely suggests that countries with high HIV prevalence have relatively lower Diabetes prevalence and vice versa. This was partially explained by the high prevalence of HIV in Sub-Saharan Africa and a correspondingly low prevalence of diabetes

in the same region, and low prevalence of HIV in the Asian study region which had high diabetes prevalence.

The clusters identified in this study have several importances for public health policy and practice. It informs whether HIV, Diabetes or both should be major priorities among countries in the clusters. The classification also informs what models of integrating HIV and Diabetes services could be applicable for countries in the different clusters. Above and beyond, the cluster analysis has suggested international level focus countries for HIV, Diabetes and Both HIV and Diabetes.

There were a few limitations associated with this study. Firstly, the data used in this study were prevalence estimates and all the weaknesses of these data can affect the interpretations of the findings. Secondly, the K-means clustering method was applied as the dataset was very short time series data. The autocorrelation among the variables may to some extent affect the quality of the cluster analysis. Finally, the study addresses only three major regions of developing countries and thus the findings may not apply to other regions of the world.

In conclusion, this study has suggested that the joint epidemiologic patterns of prevalence of HIV and Diabetes tend to be heading in opposite directions suggesting that the incidences of the two diseases are also advancing in opposite direction. This pattern, however, varies from region to region.

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