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Title: Understanding Seasonal Risks of Poor Health in Cross-Sectional Data Sources

Research Aims: A seasonally adjusted measure is needed to help account for seasonal variation in health outcomes in survey data. To understand how health outcomes and associated risk factors vary throughout the year, this research has leveraged multiple pooled large-scale cross-sectional surveys, using Bangladesh as a case study. Using this dataset, a Seasonal Risk Index (SRI) has been developed, comprising of three domains in which health may be influenced seasonally, including food security, disease environment and economic pathways. The SRI aims to address a knowledge gap by capturing the cumulative effect of multiple seasonal risk factors in each of the seasonal dimensions. This index explores evidence to test the hypothesis that poor health is most pronounced during the monsoon season in Bangladesh. This study has captured the concept of seasonality through human behaviour and socio-economic activities that may increase the seasonal risk of poor health, rather than focusing solely on variation in climatic conditions. Finally, previous literature generally focuses on rural livelihoods varying seasonally given the high dependence on agricultural livelihoods, this study contributes new knowledge about seasonal patterns also observed in urban areas.

Background: In areas with concentrated periods of rainfall, such as Bangladesh, people are often at their most disadvantaged and experience the poorest health during the monsoon season. During this time, infections and malnutrition are high, food availability and access are low and income-generating opportunities are scarce (Devereux et al., 2013). It is believed that the simultaneous occurrence of multiple seasonal risk factors for poor health can have a compounding negative impact on health and nutrition at certain points within the year (Vaitla et al., 2009; Devereux et al., 2013). However, there is a lack of understanding of how such risk factors coincide and interact.

A dearth of large-scale, high-frequency survey data has hindered the study of seasonal variation in health outcomes and associated risk factors in low- and middle-income countries (LMICs). Cross-sectional data sources, such as Demographic Health Surveys (DHSs) are commonly used to measure progress in health outcomes. Yet data collection generally spans 3-6 months, which does not depict the varying seasonal conditions across all the year. This prevents summary statistics of variables that vary seasonally from being generalisable beyond the months in which sampling occurred, hence, surveys sampled at different points in the year may produce very different findings (Pullum, 2008; icddr,b & UNICEF, 2021). Few studies comment on the timing of survey implementation and how this may impact the generalisability of annual averages (WHO et al., 2020). Caution is therefore needed to measure progress over time in health outcomes (and associated determinants) for the 2030 Sustainable Development Goals (SDGs) if seasonality is not accounted for. Additionally, as seasons are shifting due to human-driven climatic changes, understanding how seasons influence health has never been so critical.

Various sources have highlighted that a seasonally adjusted measure is needed to study seasonality in cross-sectional data (Pullum, 2008; icddr,b & UNICEF, 2021; Devereux et al., 2013; WHO et al., 2020). To date, no existing literature has attempted to develop such a measure or to study when multiple risks of poor health are highest during the year, particularly using cross-sectional data.

Numerous studies have found seasonal variation in a selection of general health outcomes. These include infectious illnesses, such as diarrhoea, ARI or malaria (Otte im Kampe et al., 2015; Buchner & Rehfuess, 2015; Pullum, 2008; Few et al., 2013; Bandyopadhyay et al., 2012; Carlton et al., 2014; Pinfold et al., 1991). Non-communicable illnesses, such as acute undernutrition, and hypertension, alongside accidents and injuries also vary seasonally (Mertens et al., 2021; Branco et al., 2018; Goyal et al., 2018; Rohwerder, 2016). Finally, seasonal variations in maternal and newborn health outcomes such as low birthweight and pre-term births are also observed (Strand et al., 2011; Grace et al., 2015; Dorélien, 2016). Yet even with these seasonal variations known, conceptual frameworks (such as the UNICEF framework (UNICEF, 1998) on maternal and child nutrition) does not account for seasonality.

Previous research studying intra-annual variation in health outcomes tends to focus on a specific dimension of seasonality, for example, food security, income (and the ability to smooth consumption), or water quality and infection risk. No previous studies have looked holistically at dimensions of seasonality and their impacts on health outcomes, thereby ignoring the multiple drivers and their interactions that may lead to seasonal patterns in the outcome variable of interest.

Marshak et al., (2021) highlights that local populations describe seasons based on the pattern of human activities and access to resources, rather than describing climatic conditions. Previous literature has focused on associations between meteorological conditions and health outcomes, rather than understanding the proximate changes in risk factors by studying human behaviours and socio-economic activities.

This study will develop a Seasonal Risk Index (SRI) to understand when in a year the compounding risk factors of poor health are at their highest during the year. By doing so, the study aims to shift the focus of seasonality from changing climatic conditions towards variation in human experiences of seasonal variation that contribute to periods of poor health during the year. This can be used as a tool to help interpret summary statistics from a cross-sectional survey, based on when the survey took place within the year. Understanding the timing of seasonal risks and peaks in poor health will also facilitate well-timed policy interventions to mitigate the worst consequences of seasonality (Sabates-Wheeler & Devereux, 2013).

Data: This study used cross-sectional DHS data in Bangladesh. Six rounds of DHS were pooled together between 1999 and 2018. DHS data lacked information about food security and consumption, therefore monthly WFP rice food price data at the Division level was linked to observations given that 80% of calories consumed from rice in Bangladesh (FAOSTAT, 2018). Additional data sources to be linked are still being explored.

The data was pooled together, which required harmonization of variables that have changed over the multiple surveys. The dataset was required to have (relatively even) coverage over the year to study seasonality, with sampling in each DHS round simultaneously taking place in parallel in different regions to ensure it is representative over space and time. Comprehensive checks and geo-spatial plotting of PSU GPS coordinates was conducted to ensure this is the case.

Methodology: Variables for the SRI were selected based on a theory-driven approach, drawing on existing literature about seasonality and health. Three domains were defined signifying different pathways that seasonal variation may influence health: food security, disease environment and economic conditions. An important point is that a household's resilience to seasonal changes may be influenced by underlying variables that do *not* vary seasonally. However, this index has only selected variables where previous literature has shown seasonal variation and have a negative impact on health (to stop positive impacts cancelling out the effect in the index).

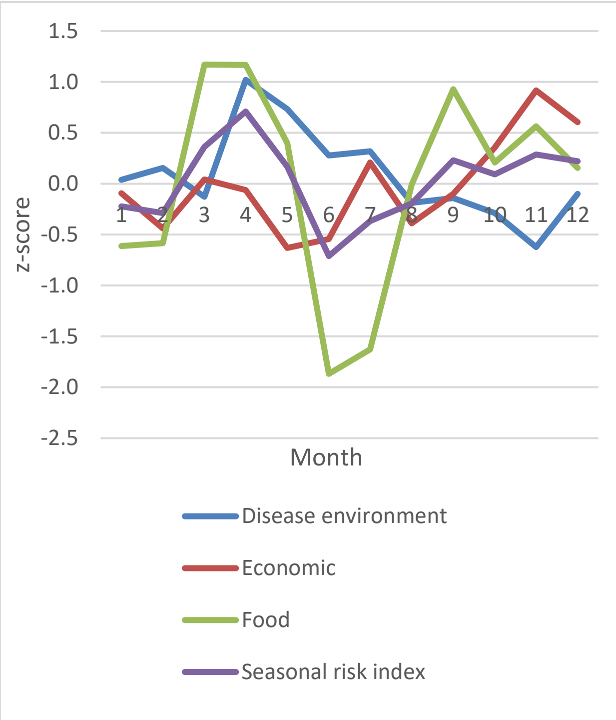
The SRI is constructed by aggregating individual-level responses from the pooled dataset (disaggregated by month), which were then normalized at Division-level (or national, urban, or rural levels). Monthly z-scores to measure the relative risk of poor health throughout the year were then calculated. A 1-month temporal lag is introduced for the economic and food domains. To combine the indicators within each domain, an unweighted mean was taken of the z-scores for each domain. To combine the domains into a singular index value for each month, the arithmetic mean score is calculated based on the mean domain value.

It is hypothesised that (to show causality), the risk of poor health (the SRI) may increase prior to a peak in poor health. The SRI was then compared with seasonal variation in selected child health outcomes from the DHS data, including wasting (an indicator for acute undernutrition), diarrhoea and Acute Respiratory Infections (ARI).

The SRI is calculated at various levels, including national, urban, rural, and Division levels, which helps uncover spatial and temporal variations in seasonal risk factors of poor health. Temporal variations were also explored using 10-day intervals (dekads) to shift away from a western conceptualisation of time through months. This study also utilized nightingale (radar) plots to visualise the results of the SRI to reflect the cyclical nature of seasonal variation.

Results: Descriptive statistics by month from the cross-sectional pooled dataset showed clear seasonal variation in many risk factors. The seasonal timing of some of the associations aligned with hypothesised seasonal patterns discussed in literature, while other patterns did not.

Figure 1 shows that the SRI observed a peak in relative risk between March and May, at the end of the dry season when intense rainfall begins (from March to May). Conversely, the lowest risk of poor health was during the monsoon season (in June and July). Figure 2 shows that the SRI was highly associated with the prevalence of ARI, with a correlation coefficient of 0.86. The increase of risk in the disease environment domain coincides with a rapid increase in diarrhoea and wasting prevalence, suggesting that risk factors relating to disease environment are most important for determining seasonal variation for infections and undernutrition.



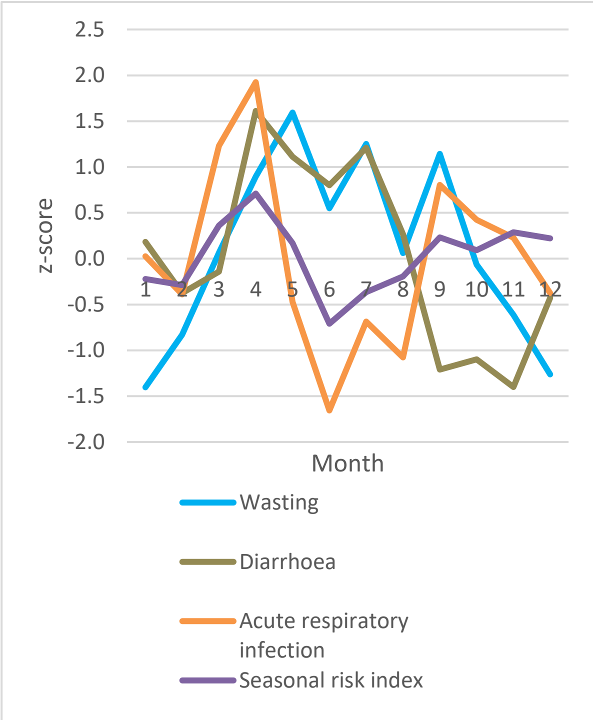


Figure 1: Seasonal Risk Index & Domains by Month (National-Level)

Figure 2: Seasonal Risk Index & Health Outcomes by Month (National-Level)

The seasonal variation within each domain has also been shown in the nightingale plots in figure 3. The plots show that each domain does not directly coincide with others, which contradicts existing literature about multiple risk factors coinciding during the monsoon period (June to October).

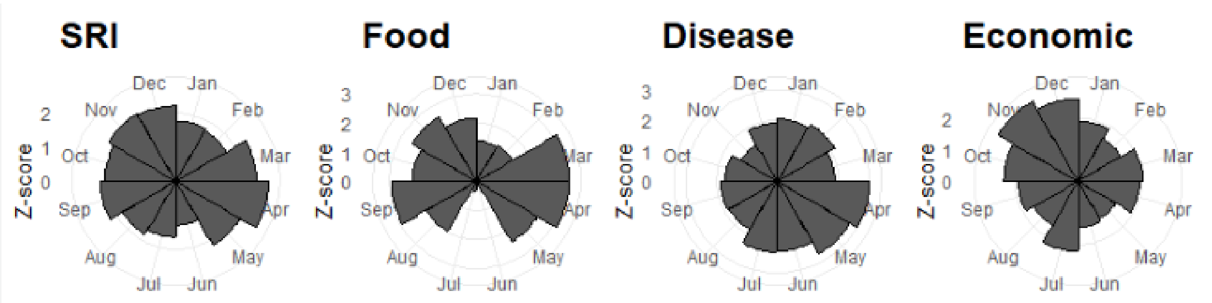


Figure 3: Nightingale Plots of Seasonal Risk Index & Domains by Month (National-Level)

A separate SRI for urban and rural areas showed very similar results, although slight differences in the risk associated with the disease environment pathway. This highlights the need to better understand intra-year variation in health in urban areas, particularly in relation to drinking water sources and sanitation facilities.

Conclusion: Country-level progress for SDGs is currently monitored using annual summary statistics, attention should shift towards monitoring and reducing intra-annual variation beyond 2030. The SRI developed in this paper helps to understand how multiple risk factors may coincide and interact seasonally to influence the health outcomes. This research serves as a proof of concept for studying seasonal risk factors with cross-sectional data that can be extended to other countries and regions to enhance our understanding of the complex relationship between seasonality and health with limited high-frequency data availability.

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