Spatial Clusters of Double Burden of Under-five Malnutrition in the Province of Marinduque

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As underweight among children under-five years old continues to be a major public health concern along with the increasing overweight, Philippines is now facing the problem known as the double burden of malnutrition. Local spatial cluster detection provides a spatial perspective in understanding this phenomenon, specifically in which areas the double burden of malnutrition occurs, which eventually can be used for focused targeting of interventions. This study aimed to determine and evaluate spatial clusters of different forms of under-five malnutrition across the province at the individual level using household location. Data from a province-wide household-based census conducted in 2014–2016 were utilized. Weight-for-age z-score was used to categorize the malnourished children into severely underweight, moderately underweight, and overweight. The Kulldorff's elliptical spatial scan statistic using the multinomial model was used to locate clusters with high or low risk of different forms of malnutrition, stratifying by age and membership to Pantawid Pamilyang Pilipino Program (4Ps). Three significant clusters across municipalities of Boac, Buenavista, and Gasan were found to have high-risk of over and undernutrition simultaneously, indicating existence of double burden of malnutrition within these communities. Therefore, specific programs and interventions should be focused on the identified high-risk clusters to maximize resources.

Keywords: Kulldorff's elliptical spatial scan statistic, multinomial model, under-five malnutrition, Marinduque, Philippines

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Introduction

Despite the efforts of the government and non-government organizations in fighting childhood malnutrition in the Philippines, the progress has been slow. The results of the updating of 8^{th} National Nutrition Survey (NNS) in 2015 showed that prevalence of under-five malnutrition in the form of underweight (21.5%), and stunting (33.4%) was almost the same as it was a decade ago, while prevalence of wasting (7.1%), and overweight (3.9%) were even higher. As undernutrition continues to be a major concern along with the increasing overnutrition, Philippines is now facing the problem known as the double burden of malnutrition. This phenomenon is also becoming evident across regions and provinces in the country. The World Health Organization (WHO) describes the double burden of malnutrition as a phenomenon in which there is a "coexistence of undernutrition along with overweight and obesity, or diet-related noncommunicable diseases, within individuals, households and populations, and across the life course" (WHO, 2017).

The Philippines is one of the countries which committed to the elimination of under-five malnutrition and all its forms by 2030 through the Sustainable Development Goals (SDGs). Therefore, understanding the double burden of malnutrition in all possible aspects is important in achieving this goal. The role of spatial context in health and well-being has long been recognized, but only in the past two decades in which the use of spatial analysis has been incorporated in different studies (Clarke, McLafferty, & Tempalski, 1996). This is primarily due to advancements in technology such as the computerization of spatial data through Geographic Information System (GIS), which has made the collection, storage, and utilization of spatial data easier and cheaper (Moore & Carpenter, 1999; Auchincloss, Gebreab, Mair, & Roux, 2012; Kirby, Delmelle & Eberth, 2017).

Central to spatial analysis is Tobler's First Law of Geography (TFL), which states that "everything is related to everything else, but near things are more related than distant things'' (as cited by Miller 2004, p.284). Particularly, public health phenomenon at locations close together are more likely to be similar than those further apart, which could be due to some underlying similarity in the physical and social environment, among others. In the case of malnutrition, nutritional status of children in neighboring units may tend to be alike, leading to spatial clusters. One of the commonly used spatial analysis methods is the detection of local spatial clusters (Auchincloss, Gebreab, Mair, & Roux, 2012). A spatial cluster is defined as an unusual number of cases that occurs within a population in a geographic area over a time period (Knox, 1989,Miller, 2004; Jacquez, 2008). Identifying the clusters where double of burden of malnutrition exists is vital in the formulation of programs and interventions tailored on specific forms of malnutrition and targeted in specific areas. Given that resources are limited, geographic targeting ensures that benefits from interventions or programs are maximized.

In the Philippines, only a few studies have applied cluster detection techniques in public health (Pangilinan, Gonzales, Leong, & Co, 2017; Duncombe, Espino, Marollano, Velazco, & Ritchie, 2013; Garcia & De las Llagas, 2011), adult obesity and overweight (Dahly, Gordon-Larsen, Emch, Borja, & Adair, 2013), and Respiratory Syncytial Virus (RSV) (Root et al., 2012). On under-five malnutrition, one study was conducted to investigate global and local spatial clustering of underweight children at the village level in the Province of Marinduque (Salvacion, 2017). Yet, no studies have applied local spatial cluster detection methods, specifically at the individual or household level and on double burden of under-five malnutrition. This study aimed to determine and evaluate spatial clusters of double burden of malnutrition among under-five malnourished children across the province at the individual level using household location by employing the Kulldorff's elliptical spatial scan statistic in multinomial model.

Methods

The study is cross-sectional in design, utilizing secondary data from the Community-Based Monitoring System (CBMS) conducted by the Provincial Government of Marinduque in 2014 – 2016. CBMS is a household-based local census aimed to collect several information that would support local planning, program design and implementation. Detailed information on the CBMS methodology can be found elsewhere (CBMS, 2014). Approval on the use of secondary data was obtained from the Provincial Government of Marinduque and CBMS International Network Coordinating Team. The study population focused on malnourished children 0–59 months old residing in the province during the data enumeration, which included 1,084 children.

Study setting

Marinduque is an island province located southeast of Manila, between 121.80° to 122.18° East and 13.18° to 13.57° (Provincial Government of Marinduque, n.d.; Salvacion, 2017). The province is composed of 6 municipalities – Boac, Buenavista, Gasan, Mogpog, Sta Cruz, and Torrijos - with Boac as its capital. It is further subdivided into 218 barangays covering a total land area of 959.3 km^2. The terrain in Marinduque island is predominantly hilly and mountainous (Provincial Government of Marinduque, n.d.; Salvacion, 2017), with fishing and farming as the primary source of income (Provincial Government of Marinduque, n.d.).

Study variables

Malnourished children were identified based on their weight-for-age z scores according to sex and were classified into different types such as severely underweight, moderately underweight, and overweight. A child wa considered severely underweight if his/her weight-for-age z-score was greater than 3 standard deviations below the median of the WHO reference population (i.e., child's weight was severely low for his/her age). A child wa considered moderately underweight if his/her weight-for-age z-score was greater than 2 and less than 3 standard deviations below the median of the WHO reference population (i.e., child's weight was moderately low for his/her age). Otherwise, the child was considered overweight with weight-for-age z-score greater than 2 standard deviations above the median of the WHO reference population (i.e., child's weight was high for his/her age). Variables such as age and membership to *Pantawad Pamilyang Pilipino Program* (4Ps) (Bridging Program for the Filipino Family) were included as covariates. The age refers to the child's age at last birthday and grouped into either 0–24 or 25–59 months old. Membership to 4Ps refers to household's membership to the program in the past 12 months from the conduct of the data collection. This is a proxy variable to indicate household's social standing in terms of income or wealth, as members of this program are poorest of the poor. Using the two covariates, four subpopulations were created: 0–24 months old who are members 4Ps and those who are non-members and 25–59 months old who are members of 4Ps and those who are non-members.

Data processing and analysis

Non-spatial data were checked for completeness and consistency using Stata Software (Version 12, College Station, TX, USA). Notably, there were no missing non-spatial data. Spatial data were checked and visualized using QGIS version 2.18.19. All household locations in longitude and latitude decimal coordinates were converted to two dimensional Cartesian coordinates through planar map projection to facilitate data analysis. All spatial data used the same coordinate reference system (CRS) which is World Geodetic System (WGS) 84, European Petroleum Survey Group (EPSG): 4326.

Descriptive statistics such as frequencies and percentages were computed to describe the under-five children included in the study. Local spatial cluster detection at the province-level, regardless of municipal boundaries, was done using the multionomial model of Kulldorff's elliptical spatial scan statistic. The SaTScan™ software version 9.6, a freeware downloadable at www.satscan.org was utilized in all analyses. The spatial scan statistic considered each malnourished child as a case that is either belonging to severely underweight, moderately underweight or overweight. It therefore identified spatial clusters where the distribution of these types of malnutrition among malnourished children may be significantly different from the remaining areas of the study region. Relative risks for each type of malnutrition and stratified according to the identified subpopulation were computed. This is the ratio of the proportions of the number of children categorized in each type of malnutrition out of the total number of malnourished children inside the cluster versus the outside. For each of the size and location of these windows, the observed and expected cases inside and outside the window is compared using the likelihood ratio test. The null hypothesis is that the relative risk is the same inside and outside the window, while the alternative hypothesis is that there is an increased risk within the window as compared to outside. The log likelihood ratio test statistic for a window *z* is given below:

$$log\lambda_z = \sum_k \{ c_k(z)\log\frac{c_k(z)}{C(z)} + (c_k - c_k(z))\log\frac{c_k - c_k(z)}{C - C(z)}\} - \sum_k c_k log\left(\frac{c_k}{C}\right)$$

where c_k — the total number of observations in category k

C — total number of observations in the whole study area

The most likely cluster is the window associated with the maximum of log λ_z (Jung, Kulldorff, & Richard, 2010).

Default collection of cluster sizes in the SaTScan™ was utilized, with maximum geographical cluster size for all analysis set to 50% of the total population. Default parameters were also employed to define the angle and shape of the ellipse. To avoid long and narrow clusters and favoring compact clusters, a medium strength non-compactness penalty was used. The multiple data sets feature was utilized to adjust for covariates. P-value was generated based on 999 Monte Carlo simulations (Kulldorff, 2018). Clusters with p-value less than 0.05 were identified as statistically significant clusters. Only all significant clusters were reported. The results of the data analysis done in SaTScan™ were imported in QGIS, and all cartographic displays were carried out in the same software.

This study was reviewed and approved by the University of the Philippines Manila (UPM) Research Ethics Board.

Results

A total of 1,084 under-five children who are malnourished – either underweight or overweight - was included in the study. Moderately underweight was the most prevalent which constituted 75 percent of the malnourished children. The prevalence of overweight and severely underweight were 13.7 percent and 10.9 percent among malnourished children, respectively (Table 1). Underweight classified as moderate seemed to be a common concern across municipalities, with proportion among malnourished ranging from 66.2 percent in Boac to as high as 84.3 percent in Santa Cruz. In terms of number, Torrijos had the highest number of cases as reflected inTable 2. Children who are overweight was prevalent in Gasan and Boac, where one in every five malnourished children was classified as overweight. On the other hand, prevalence of severely underweight was high in Boac (13.6%), Buenavista (13.4%) and Torrijos (13.2%).

Table 1. Prevalence of types of malnutrition among malnourished children under-five years old in the Province of Marinduque, 2014–2016

Nutritional Status	No.	%
Overweight	148	13.7
Moderately underweight	818	75.5
Severely underweight	118	10.9
Total	1,084	100.0

Table 2. Prevalence of types of malnutrition among children under-five years old, by municipality, Province of Marinduque, 2014–2016

	Severely underweight		Moderately underweight		Overweight		All	
Municipality	No.	%	No.	%	No.	%	No.	%
Boac	31	13.6	151	66.2	46	20.2	228	100
Buenavista	25	13.4	149	79.7	13	7.0	187	100
Gasan	14	7.0	143	71.1	44	21.9	201	100
Mogpog	8	8.6	72	77.4	13	14.0	93	100
Sta Cruz	9	6.4	118	84.3	13	9.3	140	100
Torrijos	31	13.2	185	78.7	19	8.1	235	100
Province of Marinduque	118	10.9	818	75.5	148	13.7	1,084	100

Figure 1 is a dot density map displaying the geographic distribution of malnourished children according to type of malnutrition. Although the map shows more moderately underweight children scattered throughout the province, it also suggests select areas that exhibit concurrence of two or more types of malnutrition. In particular, there seems to be a clumping of both underweight and overweight in northern Boac, southern Gasan that borders Buenavista, and in the town center of Torrijos. However, it should be recognized that the identification of these clusters by just using the dot density map is subjective in nature and may vary in terms of perspective.

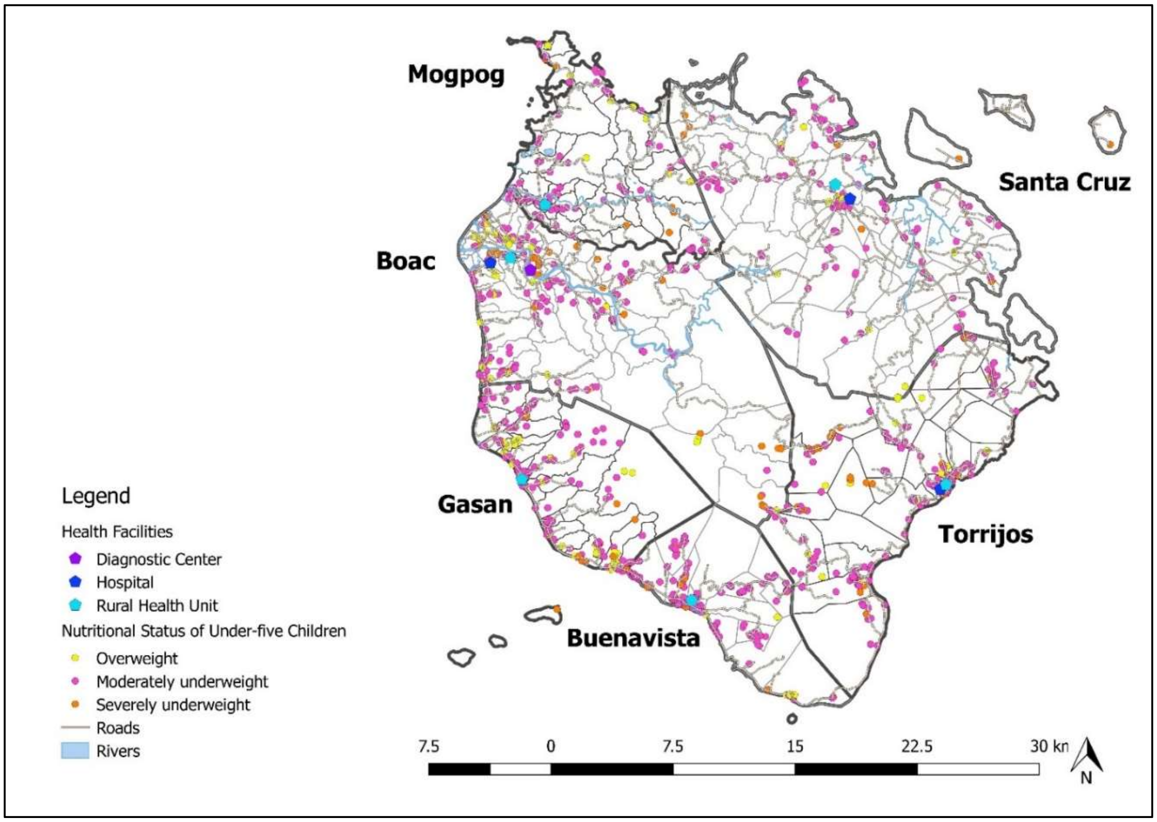

Figure 1. Location of children under-five years old, by type of malnutrition, Province of Marinduque, 2014–2016

As malnutrition has many forms such as underweight (moderate or severe) and overweight, it is relevant to identify spatial clusters where the distribution of these forms of malnutrition among malnourished children may be significantly different from the remaining areas. For instance, it is possible for some forms of malnutrition to be simultaneously prevalent in a given area which could characterize presence of double burden of malnutrition in a community. Table 3 shows the results of the purely spatial SaTScan™ analysis using the multinomial model stratified by age and 4Ps membership, respectively. Five clusters were identified — a primary cluster and four secondary clusters — which in all these clusters, the distribution of the types of malnutrition was significantly different from the remaining province (Figure 2). The most likely cluster or primary cluster (*LLR* = 59.81, *p* = .001) was found in Gasan covering east of Barangay Pingan, south of Barangay Dawis, and west of Barangay Banuyo. The cluster had a radius of 0.9 kilometers and included 31 malnourished under-five children. In this cluster, the risk of being overweight was the highest, while the risk of moderately underweight was the lowest across both age groups and 4Ps membership. However, among 0–24 months old children, this cluster exhibited a high risk of being overweight (*RR* = 4.5) and being severely underweight (*RR* = 1.7) simultaneously. Among non-members of 4Ps, overweight (*RR* = 4.5) and severely underweight (*RR* = 1.1) also posed risks at the same time. Furthermore, there were subgroups that exhibited exceptionally high risk of being overweight. For instance, among 0–24 months old children, the risk of being overweight was 4.5 times higher inside the cluster compared to outside, but among children 25–59 months old, the risk of being overweight was 6.6 times higher inside versus outside the cluster. Although the relative risks were high, those who are non-members of 4Ps (*RR* = 10) inside the cluster had even higher risk of being overweight than non-members (*RR* = 4.5) inside the cluster.

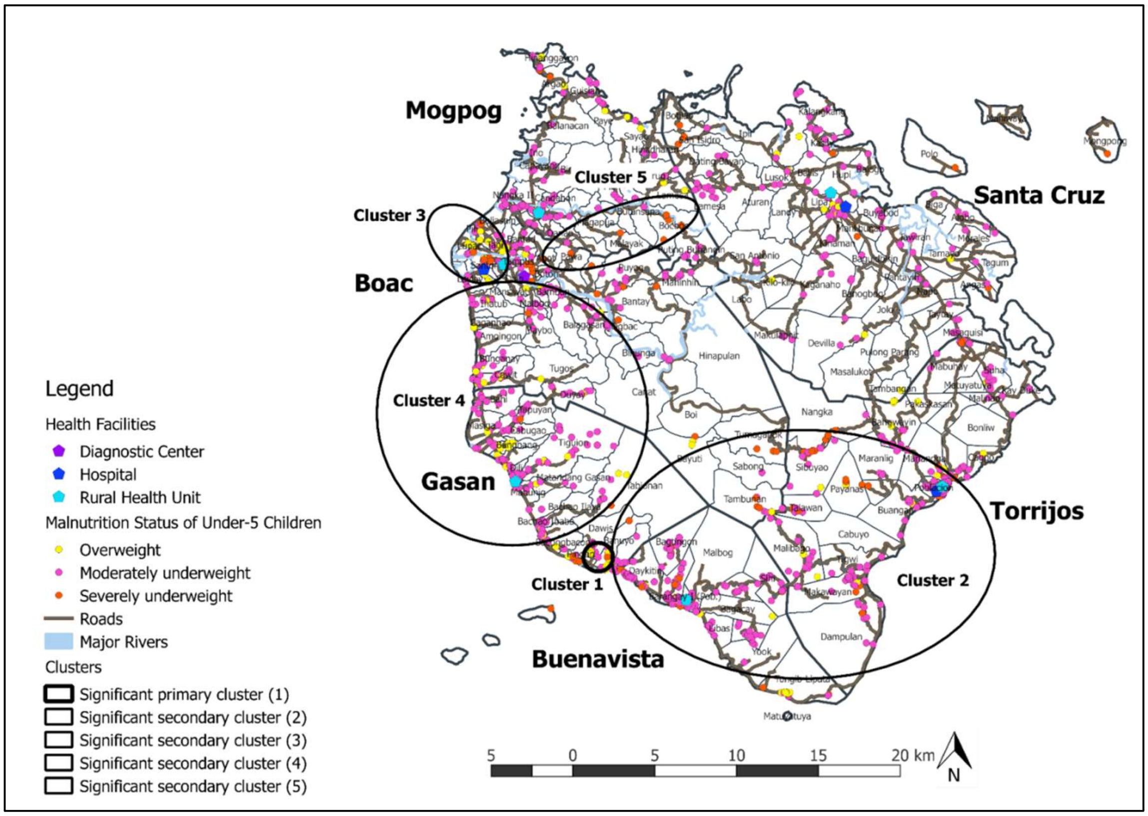

Figure 2. Location of clusters of type of malnutrition among malnourished under-five years old children stratified by age and 4Ps membership status, Province of Marinduque, 2014–2016

The first secondary cluster (Cluster 2) was elongated in shape with an area of 285.7 square kilometers which contained almost the whole of Buenavista, majority of Torrijos, and southern parts of Boac and Gasan. A total of 379 malnourished under-five years old children was within the cluster. In this cluster, both moderately and severely underweight had high relative risk and overweight had the lowest relative risk across subpopulations. The risk of being moderately underweight was almost the same, ranged from 1.1 to 1.2 relative risk, across age groups and 4Ps membership status. On the other hand, the risk of being severely underweight inside Cluster 2 compared with the rest of province was higher among those non-members of 4Ps (*RR* = 2.0) than those who are members (*RR* = 1.3), and higher among 0–24 months old children (*RR* = 1.9) than among 25–59 months old (*RR* = 1.6). The secondary Cluster 3 spanned 22 barangays in the north of Boac. The cluster resembles an ellipse with an area of 17.5 square kilometers. There were 59 malnourished children under the age of five within it. The two dominant types of malnutrition inside the cluster across all subpopulations were overweight with relative risk ranging from 3.0 to 4.1, and severely underweight with relative risk ranging from 1.4 to 1.9, except for those aged 0–24 months. However, risks of being moderately underweight inside the cluster compared with outside the cluster were lower which ranged from 0.4 to 0.6 across subpopulations. The secondary Cluster 4 had a radius of 8.2 kilometers covering majority of Gasan and areas west of Boac. It included 238 malnourished children. Although the relative risk ranged from 1.1 to 1.3 only, this cluster indicated a region where the foremost risk was being moderately underweight across all subgroups. Inside the cluster the risk of being severely underweight was also lower across all subpopulations. Furthermore, inside the cluster in subgroups such as among 0–24 months and among non-members of 4Ps, there was a risk of being overweight and moderately underweight at the same time. Lastly, secondary Cluster 5 was located mostly in Mogpog but also covered some parts of east Boac. The elongated-shaped cluster covered an area of 26.2 square kilometers with only 6 malnourished cases. Within this cluster, all subgroups had high risk of being severely underweight ranging from 7.3 to 11.1, with aged 0–24 months having the highest risk. Under-five children inside the cluster also had low risk of being moderately underweight and no risk of being overweight as there were no overweight children inside the cluster.

Table 3. Results of multinomial* cluster detection analysis showing the significant clusters for types of malnutrition among malnourished children stratified by age, Province of Marinduque, 2014–2016

		Overweight			Moderately underweight			Severely underweight			p-value
Cluster	Area (km^2)	n	No. of cases	RR	n	No. of cases	RR	n	No. of cases	RR	
Primary cluster (1)	2.5										0.001
Age group											
0–24 months old		57	10	4.5	205	1	0.1	27	2	1.7	
25–59 months old		91	12	6.6	613	5	0.4	91	1	0.5	
Membership to 4Ps											
Member		43	9	10.0	326	1	0.1	59	1	0.7	
Non-member		105	13	4.5	492	5	0.3	59	2	1.1	
Secondary cluster (2)	285.7										0.001
Age group											
0–24 months old		57	5	0.2	205	78	1.2	27	13	1.9	
25–59 months old		91	9	0.2	613	231	1.1	91	43	1.6	
Membership to 4Ps											
Member		43	7	0.2	326	156	1.1	59	30	1.3	
Non-member		105	7	0.2	492	153	1.1	59	26	2.0	
Secondary cluster (3)	17.5										0.001
Age group											
0–24 months old		57	8	4.1	205	3	0.4	27	0	-	
25–59 months old		91	17	3.6	613	21	0.6	91	10	1.9	
Membership to 4Ps											
Member		43	7	3.0	326	13	0.6	59	6	1.8	
Non-member		105	18	3.9	492	11	0.4	59	4	1.4	
Secondary cluster (4)	214.0										0.001

Age group											
0–24 months old		57	16	1.1	205	56	1.1	27	3	0.4	
25–59 months old		91	18	1.0	613	143	1.2	91	2	0.1	
Membership to 4Ps											
Member		43	2	0.2	326	71	1.3	59	2	0.2	
Non-member		105	32	1.3	492	128	1.1	59	3	0.2	
Secondary cluster (5)	26.2										0.003
Age group											
0–24 months old		57	0	-	205	0	-	27	1	11.1	
25–59 months old		91	0	-	613	2	0.3	91	7	7.3	
Membership to 4Ps											
Member		43	0	-	326	0	0.0	59	3	7.6	
Non-member		105	0	-	492	2	0.4	59	5	8.6	

Note. RR = Relative risk of being either overweight, moderately or severely underweight among malnourished under-five children in the cluster compared with outside the cluster; *Elliptical scan window; medium non-compactness penalty.

Discussion

An emerging issue in childhood malnutrition has been the existence of both undernutrition and overnutrition at the same time across different levels, either at the individual, household or community, or across the life course (WHO, 2017). The results revealed presence of double burden of malnutrition within the community in three of the five statistically significant clusters. Two of these clusters exhibited simultaneous existence of overweight and severely underweight but affected different population groups. Within the primary cluster covering lowland areas of coastal barangays of Banuyo, and Pingan, and upland areas of barangay Dawis, children two years old and below or those non-beneficiaries of 4Ps had high risk for both overweight and severely underweight. All these barangays within the cluster were classified as rural. Poverty incidence was more pronounced in three barangays with Banuyo and Dawis having low access to sanitary toilet, and Dawis among the highest proportions of households who experienced hunger due to food shortage. Intuitively, the profile of the barangays within the cluster suggests presence of undernutrition, however, there could also be other factors that related to overnutrition among under-five children in the cluster especially among the non-poor or non-beneficiaries of 4Ps. Poor feeding practices or limited access to food could also result to either under or overnutrition among under-five children within the cluster (WHO, 2017).

Another cluster with presence of double burden of malnutrition covered the rural barangays along the Boac River extending to the coastline of Tablas Strait. It also covered several barangays within the business district of Boac including the urban barangay of Murallon. In this cluster, both children who are beneficiaries and non-beneficiaries of 4Ps aged older than two years old had high risk of developing overweight and severely underweight. The area in this cluster had good socio-economic profile in terms of income, access to potable water, access to sanitary toilet, and employment. Double burden of malnutrition in this community could have been shaped by differences in feeding practices and food access of mothers in poor and nonpoor households (WHO, 2017).

Lastly, the secondary cluster with existence of double burden of malnutrition at the community level was situated in the barangays along the coastline and within the interior, extending from Boac to Gasan. The cluster consisted mostly of rural barangays—some were situated in the town center—with only one urban barangay of Ihatub in Boac. Primary sources of livelihood inside the cluster were fishing for coastal barangays and farming in the upland barangays. In this cluster, children two years old and below or those non-beneficiaries of 4Ps had marginal risk of being overweight and moderately underweight at the same time. As this cluster covered a large area, profile of barangays within the cluster varied widely from barangays with good socio-economic conditions (e.g., Canat, Cawit, Ihatub in Boac, and barangays Bahi, I, II, and III in Gasan) to barangays with high proportion of households with makeshift housing (e.g., Libtangin and Masiga in Gasan), without access to safe drinking water (Balaring and Caganhao in Boac, and Masiga and Tabionan in Gasan), without access to sanitary toilet (Duyay in Boac, and Tiguin, Tabionan, Libtangin, Bahi and Cabugao in Gasan), and experienced hunger due to food shortage (e.g., barangays in Gasan), unemployment (Malbog in Boac) (CBMS Network Office, 2017).

In general, economic disparities within communities could have led to double burden of malnutrition in the identified clusters, with children in relatively high-income households developing overweight and children in low income households developing underweight (Tzioumis & Adair, 2014). In the Philippines, among children of households headed by fisherfolks, undernutrition is more pronounced but still overnutrition was observed (Capanzana, Aguila, Gironella, & Montecillo, 2018).

This study has several limitations that should be acknowledged. First, the cluster morphology such as its shape and size are complex, in which a specified geometric scanning window may not well represent its true morphology. In this study, the scanning window was limited to ellipse and circle (a special case of an ellipse) only, but true clusters may appear irregular in shape which might not be detected. However, based on the literature, elliptical scanning window has competitive power in detecting irregularly shaped clusters except for the extremely irregular ones. Second, the SatScan™ used for the analysis in this study does not provide the corresponding confidence interval for the relative risks computed for each cluster. It should also be noted that the current study is explanatory in nature in which results may not give a comprehensive picture of under-five malnutrition. It is then recommended to further investigate on factors affecting the double burden of malnutrition in the Province of Marinduque.

Conclusion and Recommendations

Using Kulldorff's elliptical spatial scan statistics in multinomial model, the study showed significant clusters of different forms of under-five malnutrition among malnourished children, within and across municipalities, where there are both high risk of either overweight and severely underweight, and overweight and moderately underweight. This manifests the existence of double burden of under-five malnutrition, particularly coexistence of under and overnutrition within communities in the Province of Marinduque. There were also differences in the patterns of risk of malnutrition across the clusters and subpopulations suggesting underlying local causes at work that warrant further investigation.

The detection of significant clusters reinforces the need to investigate the spatial perspective of double burden of malnutrition to uncover variations even in small geographic areas. It also has important policy implications as availability of this information at the lowest level supports a more decentralized decision-making and planning process. For one, it supports the use of geographic targeting and targeting of specific populations based on some measure of risk. This also enables policymakers to give priority to identified high-risk areas and populations through developing policies and programmes in line with local conditions and needs. This way benefits are maximized even with limited government resources.

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