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Geospatial Analysis of Malnutrition among Under-Five Children: A Scoping Review

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Abstract

Nutritional status is one of the important factors that indicate children's proper development and growth. The geospatial analytic approach is useful in describing and analyzing the characteristics, depth, and coverage of the malnutrition burden among under-five children. This current scoping review was performed to systematically map the spatial analytical techniques and approaches applied in nutrition among under-five children. An organized online database search was conducted to identify articles published between 1995 and 2021 on under-five nutrition and spatial statistic in PubMed, Science Direct, Scopus, and Web of Science. A total of 80 distinct articles were identified, of which 34 articles were used for the final review. A spatial statistical correlation was mainly used ($n = 15$), followed by Bayesian spatial modelling ($n = 7$), Global Moran's technique ($n = 9$), and Getis-Ord ($n = 3$). Nine studies in India concerning spatial analysis and undernutrition were conducted based on a national-level demographic health survey. There is a need for future spatial studies related to nutrition and under-five children at the sub-national level in India.

Keywords
- ► geographic information system
- ► nutrition
- ► spatial methods

Introduction

The spatial analysis deals with application of various statistical methods for analysis of information related to area-specific, topographic-specific, and temporal and spatial correlation association between the available facts. The usage of spatial analysis in the field of public health provides enough base to plan for public health intervention based on geographic information and disease. As per United Nations member states, the agenda for Sustainable Development Goals (SDGs) 2030 is focusing mainly on ending poverty, eliminating malnutrition, and improving health and education.[1] Although many studies focus on national-level data for interpretation, to avoid diverseness at a sub-national level, the SDG targets the progress of targets at the sub-national level. Concentrating effectiveness and monitoring of data at the sub-national level will give more accurate information emphasizing on the usage of spatial tools to provide information at district and sub-district levels.[2]

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The spatial analysis tool Global Moran's I measures and evaluates the spatial autocorrelation based on both feature attributes, to find out if the patterns are clustered, dispersed, or random.[3] A LISA usually has two important features, the first one gives a statistic for each location with an assessment of significance and then initiates a corresponding relationship between the sum of the local and a global statistic.[4]

Globally, children under five (U5) were wasted to the tune of 45.4 million, and among the severely wasted were 13.6 million. The prevalence of acute malnutrition in South Asia is quite high (14.7%). As per the United Nations International Children's Emergency Fund (UNICEF) report 2021, nearly one-third of the children are still stunted and at least 30% of children were still affected by stunting in 2020. In 30 countries, at least 1 in every 10 children U5 is overweight, with the highest numbers in the Middle East and North Africa.[5] The update from the joint team of UNICEF, World Health Organization (WHO), and the World Bank of annual estimates of malnutrition among children U5 is expected to report further increase in all forms of malnutrition, especially in the vulnerable population—limited availability and affordability of nutritious food, disruptions in essential basic supply of resources due to worsening household income, and reduced physical activity.[6] In different parts of India, the study shows that underweight among U5 children ranged from 39 to 75%, wasting from 10.6 to 42.3%, and 15.4 to 74% of stunting.[7] In the field of health and epidemiological sciences, the spatial statistical method of approach has become a predominant statistical tool to study the geographical distribution with respect to health-related data and outcomes.[8,9]

In India, stunting is higher among children in rural areas (41% vs. urban, 31%). The prevalence of stunting is highest in Bihar (48%), Uttar Pradesh (46%), Jharkhand (45%), and Meghalaya (44%), and with the lowest in Kerala and Goa (20% each) among children below 5 years. Jharkhand has the highest levels of underweight (48%) and wasting (29%).[10] A valuable methodology can be utilized to understand the quality of literature through scoping review.[8] The application of spatial statistics in the field of nutrition has grown in recent times. The national-level data have been used for spatial analysis and the conclusion is also based on the results of these data, hence the subnational diverseness is not addressed.

A scoping review is a useful approach in evidence synthesis and identifying the knowledge gaps and clarify the concepts of the particular study. This scoping review is aimed to identify and describe the different methods of spatial analysis and its application in the field of nutrition.

Methods

Eligibility

Inclusion Criteria

All articles published in English during the period of 1995 to 2021 which used spatial statistic methods such as Moran's indexing technique, LISA analysis, and geographic information system (GIS) were included to analyze nutritional status among children U5.

Exclusion Criteria

The articles that have not used the spatial statistical method and those published outside the 1995 to 2021 period including systematic review and meta-analysis articles were excluded from the review.

Search Method

This review was conducted based on the guidelines of the Preferred Reporting Items for Systematic Review and Meta-analyses (PRISMA) extension for scoping review (PRISMA-ScR).[11] The articles published within 1995 to 2021 using the spatial statistical method were organized for literature search, which was done through PubMed/Medline, Scopus, Science Direct electronic database, and Web of Science. The search strategy for the articles was using the following keywords: spatial statistic, spatial modeling, Moron's indexing technique, GIS, LISA analysis, nutritional status, children under five years. Boolean operators "AND/OR" with keyword combinations such as "Spatial Statistics" OR "GIS" OR "Moran Index" AND "Nutrition among under five children" were used for literature search.

Study Selection

All possible studies retrieved were first imported to Zotero and duplicates were removed. Using pre-established inclusion criteria, we screened the titles along with their abstracts. After meeting the inclusion criteria, the full-text article assessment was done, followed by extraction of information fulfilling the objectives of the scoping review from the articles.

Data Extraction

A master template was prepared using Microsoft Excel, which involved information on spatial statistical technique, spatial software used, study focus, and main findings. The categories were made based on spatial application techniques. The summary of study findings was determined using counts and proportions.

Results

Study Features

Overall, 80 distinct articles were identified. Twenty articles were duplicates, hence excluded. Further, based on abstract and titles, six articles were excluded for not fulfilling the eligibility criteria. For the final review, the 34 articles were identified (►**Fig. 1**).

Spatial Tool Used

Out of 34 articles, 15 articles used spatial statistical clustering/autocorrelation for analysis, 9 articles used Moran's index, LISA, and global Moran's index technique, and 7 implemented a Bayesian spatial statistical model. The details of spatial techniques employed among U5 children are shown in ►**Table 1**.

Data extracted from the publications on nutritional status among U5 children have used several spatial methods. Moran's I measures spatial autocorrelation of dataset by

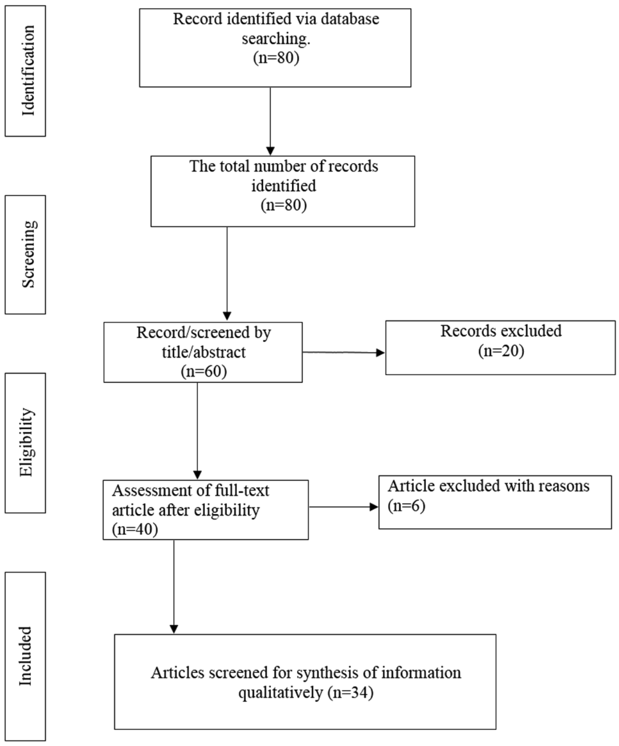

Fig. 1 Flow diagram of the article selection process using PRISMA guidelines.

correlation coefficient, Getis-Ord statistic gives information on how spatial autocorrelation varies over study location for each area, and local spatial autocorrelation analysis (hotspot analysis) is used to identify the local clusters of high, low, or high–low clusters. These methods are used with the GIS network, which observes the nutritional status U5 by location to estimate values for unobserved locations. Generally, stunting, wasting, underweight, overweight, and obesity are considered nutritional-related problems among children. To detect the status among children, WHO growth standards of measurement were used by calculating the Z-score value of "weight for age" (WAZ), "height for age" (HAZ), and "weight for height" (WHZ).[12] In this scoping review, articles fulfilling the eligibility criteria for nutritional status U5 using various methods of spatial analysis at different locations were selected. The stunting value (HAZ) of −2 standard deviation (SD), the wasting value (WHZ) is −2 SD, and the underweight value (WAZ) is −2 SD is considered moderately malnourished. To assess the children's anthropometric failure, the Global Moran's I was used to find out whether it is clustered, dispersed, or distributed randomly in the study.

Focus of the Study

Among 34 articles screened, 12 studies have focused on understanding the spatial patterns of stunting, wasting, and underweight ($n = 12$). Then, 9 studies ($n = 9$) focused on the spatial distribution of risk factors and the determinants of malnutrition. Five studies focused on under-nutrition and over-nutrition among children U5 and four studies each focused on the mothers' nutritional dependency on children nutritional status and the intake of diet content and nutritional status (►**Table 2**).

The articles ($n = 34$) that were included for full-text assessment after fulfilling the eligibility criteria are from Asia and Africa continents (47.1% and 35.3% respectively), followed by South America (8.8%) and North America (2.9%). Two articles (5.9%) were conducted multi-centric (►**Table 3**).

Table 1 Types of spatial analysis technique adopted for data extraction

Application technique	Analysis method (references)	Number of studies	Percentage
Spatial statistical clustering/autocorrelation	Spatial statistical clustering/autocorrelation[16–30]	15	44.1
	Spatial analysis including Moran's index[10,31–34]	5	14.7
	LISA analysis and Global Moran's index technique[35–37]	3	8.8
	Getis-Ord spatial statistics[38–40]	3	8.8
	GIS spatial analysis[41]	1	2.9
Spatial modeling and prediction	Bayesian spatial statistical models[42–48]	7	20.6

Table 2 Main focus of the study.

Study focus (references)	Number of studies	Percentage
Patterns of stunting and wasting[16,19,21,26,28–30,34,44,46–48]	12	35.3
Under-nutrition and over-nutrition[20,22,23,33,38]	5	14.8
Mothers' nutritional dependency to children's nutritional status[10,18,35,36]	4	11.7
Diet content and nutritional status[25,27,42,45]	4	11.7
Spatial distribution of risk factor of malnutrition[17,24,31,32,37,39–41,43]	9	26.5

Table 3 Continents covered in the studies

Continent (references)	Number of studies	Percentage
Africa[17,18,21,25–27,29,31,39,40,46,47]	12	35.3
Asia[10,19,22,23,28,30,32,33,35–37,42–45,48]	16	47.1
North America[38]	1	2.9
South America[16,20,24]	3	8.8
Multi-country[34,41]	2	5.9

►**Table 4** depicts the aims of the study and the findings of each article. Most of the studies have focused on spatial distribution of risk factors and their association with malnutrition. Furthermore, most of them focused on spatial patterns of stunting, wasting, and underweight. Only few studies explained the dependency of mother's nutritional status on child's nutrition and intake of diet content with its effect on the status of nutrition among children U5. The

Table 4 Study aims and outcomes

Sl. No.	Reference	Country	Study focus	Software used	Main findings
1	Campos et al[16]	Brazil	Spatial dependence between dental Caries and nutritional status of under 5 children	SPRING software	There is no spatial dependence between decayed missed filled teeth (DMFT) and nutritional status among under 5 years children
2	Abdalla et al[42]	India	Geospatial variations in trends of RMNCHN indicators at the block level on an adaptation of Ananya Program in Bihar.	Hierarchical Bayesian spatiotemporal modelling	There are trends of variation in all blocks except in three indicators of facility delivery, public facility delivery, and age-appropriate initiation of complementary feeding.
3	Aheto et al[29]	Ghana	To explore and forecast spatiotemporal patterns in childhood of chronic malnutrition under 5.	Spatiotemporal modelling software	There is substantial spatiotemporal variation in the prevalence of stunting.
4	Akseer et al[43]	Afghanistan	To comprehensively assess geographical disparities and nutritional status among women and children.	Winbugs and R-software	The result found that children in Afghanistan were on average shorter and underweight and slightly more emaciated.
5	Amir-ud-din et al[34]	Multicenter (73 developing countries)	To analyze the geographic patterns in the child under 5 years for undernutrition inequalities in developing countries.	ESDA—exploratory spatial data analysis	South Asia has the highest prevalence of under-5 malnutrition, Europe and Central Asia have the lowest rate.
6	Benedict et al[44]	Mali	To examine the geospatial dependence of factors associated with stunting and wasting	ArcGIS software	Bayesian geospatial model estimation of stunting and wasting in a 2-year survey in Mali. It found out that children's diet, mothers'

Table 4 (*Continued*)

Sl. No.	Reference	Country	Study focus	Software used	Main findings
					education, and BMI were key factors.
7	Bharti et al[10]	India	To examine and investigate the spatial clustering of childhood stunting and to determine factors determining it.	Spatial regression and Moran's I index	The "spatial analysis" reveals a high degree of clustering in childhood stunting in districts of India with Moran's I: 0.65 value.
8	Biswas[35]	India	To understand the place-specific spatial dependence and heterogeneities in the SES, demographic, and nutritional status.	Geographically weighted regression (GWR), spatial (leg/error) model	There is significant dependence between nutritional status and SES, demographic factors.
9	Di Cesare et al[45]	Pakistan	The spatial dependence of food security, SES, and maternal health to nutritional status.	ArcGIS software Mixed-effect linear model	Findings show dependences of food insecurity and large social and geographical disparities were associated with the nutritional outcome of mothers and children.
10	Dk et al[47]	Somalia	To find out the wasting trend and seasonal prevalence within 2007 to 2010 at a subnational level among children aged between 6 and 59 months.	"Stochastic partial differential equation" (SPDE) approach in "integrated nested Laplace approximations" (INLA)	Finding reveals significant year to year spatial variation wasting. Fluctuation of wasting seasonally at different times in different locations.
11	Gebreyesus et al[17]	Ethiopia	To evaluate the clustering of stunting and wasting among children under 5 through local spatial analysis.	Software SaTScan version 9·1·1	There is significant clustering of wasting and severe wasting in two of six villages and a single cluster for severe stunting, whereas the wasting and stunting distribution was structured partially.
12	Habyarimana et al[18]	Rwanda	Spatial distribution of risk factors of malnutrition under 5 years.	SAS 9.3 PROC GLIMMX SP (EXP) Exponential	Child's age, mothers' education, wealth index, drinking water, multiple births, and nutrition knowledge are determinants of children malnutrition.
13	Haile et al[39]	Ethiopia	To identify the factor associated with stunting in Ethiopia through spatial analysis.	Getis-Ord Gi* software	The hotspot and low hotspot stunting were found in the northern part and central, eastern, western parts of the country, respectively.
14	Hasan et al[19]	Bangladesh	To examine malnutrition in children below 5 years through spatio-	PSU; geographical unit analysis	Finding reveals the changed between 1999 and 2011 in patterns of spatial clustering for underweight, stunting,

(*Continued*)

Table 4 (*Continued*)

Sl. No.	Reference	Country	Study focus	Software used	Main findings
			temporal heterogeneity.		and wasting at subnational and national level, which exceeds the prevalence threshold of WHO.
15	Hernández-Vásquez et al[20]	Peru	It identifies the degree of overweight and obesity spatial patterns in districts for children below 5 years.	ArcGIS software	It was found that the prevalence of overweight in 126 urban and 73 rural, then 136 urban and 48 rural for obesity.
16	Hernández-Vásquez et al[24]	Peru	To assess and determine regional changes in prevalence of malnutrition (CCM in 2010 and 2016)	Information system nutritional status. ArcGIS software.	In 2010, Peruvian districts have prevalence of 20% (379/1,834) and in 2016 17.2% (316/1,834) of malnutrition cluster are identified by spatial analysis.
17	Khan and Mohanty[37]	India	To find out malnutrition in 640 districts of India by spatial heterogeneity and mesoscale.	Spatial leg model and error model Moran's I and LISA statistic. Arc/GIS software.	There is a spatial heterogeneity of malnutrition in India.
18	Lemessa et al[21]	Ethiopia	To examine spatial dependence among individuals and between clusters in nutritional status in children under 5. To identify socio-economic factors.	Spatial statistic software	The spatial variability of malnutrition is observed. There is heterogeneity between clusters obtained for stunting, underweight, and wasting. A significant difference in malnutrition in individual households and regional clusters.
19	Leyso and Palatino[22]	Philippines	To find out cluster forms of malnutrition and identify their potential risk.	QGIS version 2.18.19 Spatial SaTScan analysis	All children within a cluster are 2.9–13.7 times more likely overweight than those outside a cluster.
20	Mishra[23]	India	To study the spatial variation of nutritional status among preschool-going children.	ArcGIS software	The spatial analysis shows spatial variation exists for the prevalence of underweight children in the socially disadvantage group.
21	Muche et al[31]	Ethiopia	Geographic heterogeneity and predictors of undernutrition among children under 5.	ArcGIS version 10.5 software SaTScan version 9.6 version	There are zonal level geographical variations. The spatial distribution showed clustered and high-risk areas of undernutrition.
22	Pérez et al[38]	Salvador	Application of spatial analysis to understand distribution of overweight and obesity.	"Getis-Ord Gi* statistics" and "Moran's indexing."	Cluster of overweight and obesity are found in 29 municipal areas.
23	Sartorius et al[25]	South Africa	The spatial-temporal dependence	Stata software V.15 GeoDa software	There is a high geographical variation with

Table 4 (*Continued*)

Sl. No.	Reference	Country	Study focus	Software used	Main findings
			between malnutrition and associated risk factors among children under 5 years.		obesity more pronounced in the east of the country. Male gender, LBW, low SES, rural, and food insecurity are associated risk factors.
24	Schwinger et al[26]	Bwamanda, DR Congo	The spatial variation toward patterns of child growth.	SPSS (Statistical Package for Social Sciences) V.19.	There is significant dependence of seasonal and spatial factors on the patterns of growth of children.
25	Seboka et al[40]	Ethiopia	Spatial dependence between anthropometric failure of children under 5 years.	Getis-Ord spatial statistical tool	The spatial analysis revealed that the northern part of the country is at higher risk of anthropometric failure.
26	Singh et al[32]	India	The spatial analysis to identify key determinants of malnutrition.	"GeoDa software (version 1.14)." "STATA (version 15.1MP)"	There is positive autocorrelation with the predictors of diarrhea, drinking water, breastfeeding, LBW, and toilet facility to malnutrition.
27	Spray et al[33]	Haiti	Spatial analysis to characterize the nutrition and health situation of children under 5 years.	Global Moran's index statistical tool. OLS regression and GWS regression.	The result shows partial autocorrelations of undernutrition.
28	Striessnig and Bora[30]	India	A geographical variance of status of nutrition among children below 5 years in districts of India.	R-statistical software (Facto-mine R package)	A significant strong geographical clustering among the districts of India.
29	Tiruneh et al[27]	Ethiopia	A spatial dependence between iron-rich food and its associate factors among children.	Kulldorff's SaTScan version 9.6 software. ArcGIS version 10.7 software	Spatial scan statistics show 21% of children in a cluster are more dependent on iron-rich foods.
30	Muche et al[46]	Ethiopia	Bayesian multilevel analysis of predictor of stunting among children under 5 years.	Win BUGS version 1.4.3 software	The result shows that male children are more prone to stunting compared to female children.
31	Singh and Menon[36]	India	Geospatial dependence among stunting, wasting, underweight, and anthropometric failure.	Bivariate LISA maps and spatial error model	There is significant dependence of anthropometric failure to mothers' education and income. Mostly the clusters of stunting and underweight were found in 144 districts.
32	Hossain and Khan[48]	Bangladesh	The spatial dependence between household livestock ownership and childhood stunting in Bangladesh.	Hierarchical Bayesian spatial logistic tool	The northern and northeast regions of Bangladesh have the highest spatial variation of childhood stunting.

(*Continued*)

Table 4 (*Continued*)

Sl. No.	Reference	Country	Study focus	Software used	Main findings
33	Gupta and Santhya[28]	India	To understand and explore geospatial patterns and their correlations to childhood stunting in India.	GeoDa 1.6.0 version	In central and eastern states, districts of India have high and several hot spots of childhood stunting.
34	Almasi et al[41]	Multicentric	The spatial pattern of malnutrition (stunting, wasting, underweight, and overweight)	Arc/GIS 10.6 version software	The result shows there is a spatial variation of malnutrition all over the world with the highest cluster in African and Asian countries.

Abbreviations: BMI, body mass index; CCM, chronic childhood malnutrition; LBW, low birth weight; SES, socio-economic status; WHO, World Health Organization.

spatial analysis findings explain that the nutrition status among children U5 and clusters of stunting, wasting, and underweight are mostly dependent on the mother's literacy, income, food security, household income, seasonal factor, and rural areas with poor facilities. Most of the studies suggest the need of interventional programs from governments to invest and act toward improvement of health of children U5.

Discussion

This review focuses on the application of spatial analysis techniques on nutrition among U5 children across the globe. Spatial autocorrelation and cluster detection using GIS software were the predominant methods applied. Articles in this review used demographic health survey data conducted nationwide, and in India, they used NFHS (National Family Health Survey) data. These data are analyzed using various versions of the Arc/GIS software.

Only 2.9% of review articles focus specifically on the intake of nutritional content in their diet, like iron, vitamins, etc. The review found that there are limited articles (5.8%) describing the association of nutritional status among children and maternal health, food security, and household economy, which is significant toward the child's nutritional status. Furthermore, there is a lack of evidence of programs on interventional evaluation on nutritional status among children U5 in different places in the world. Many articles apply spatial analysis of Moran's I correlation coefficient, Getis-Ord statistic, LIZA, and Z-score. All spatial autocorrelations are measured by Moran's index, its values lie within $+1$ and -1, wherein the value of -1 is perfect clustering of dissimilar values and the value of $+1$ shows perfect clustering of similar values.[13] LISA was used to identify local clustering under four categories; high–high and low–low autocorrelation, which comes under positive spatial autocorrelation, then high–low and low–high autocorrelation as negative autocorrelation.[14] The study in India focuses on identifying and assessing the various key factors and determinants among children below 5 of their anthropometric failure and their spatial dependencies across India. Thereby, to plan a specific program that focuses on the influencing determinant to intervene malnutrition in India, there are limited articles focusing on the evaluation of nutrition programs and redesigning the interventions after finding out the key influencing factors. Overall, articles related to spatial analysis need bio-statistical expertise and innovative research with skills in managing, analyzing, and using GIS to predict spatial patterns from observed patterns to notify implementers and policymakers as much concerned.[15]

Limitations

Even after following the guidelines of PRISMA-ScR, we might have overlooked those articles focusing on the application of spatial analysis of nutritional status among children U5 in India as well in other countries. This review had excluded studies that focus on nutritional status other than children, like maternal health, household income, and food security. Most studies have different forms of result presentation and different utilizations of spatial techniques. For example, some have only used Z-score and Moran's I, but others made use of all the techniques, such as Moran's I, LISA, Getis-Ord, and Bayesian model, to come up with an outcome. A few papers were excluded as they were published in a language other than English.

Strength

This review provides the best available knowledge on nutritional status among children U5, with the application of different techniques like spatial analysis to analyze health demographic data in India and other countries. It also focuses on the use of spatial analysis techniques predominated by the spatial autocorrelation method. The review included articles covering almost 26 years (1995–2021) where spatial analytical methods were used to determine the U5 nutrition.

Conclusion

In this descriptive and analytical analysis, there is a need for a standard statistical package for estimating the population's parameters to provide results approximately equal to those obtained from the software. Most of the studies have used R-software, ArcGIS version, and Kulldorff's SaTScan version, etc., in which the detailed information about the characteristics of the software is unknown, leading to a potential pitfall.

Advanced analytical skills are needed to manage and analyze available data to notify policymaker and implementers. Most of the studies have focused on the anthropometric failure of children U5, and only a few studies were meant to assess and identify key indicators of nutritional diet content, maternal health, household income, and food security toward malnutrition among preschool-going children. The spatial analysis is according to a grouping unit that may unintentionally misrepresent or overlooked actual risk variation. To avoid the misrepresentation of the sample and distortion of spatial inference, all studies have utilized demographic health survey data at the national level for the correct interpretation of spatial patterns toward nutritional status among children U5.

Ethical Statement

The study did not require the approval of an ethics committee as it was a review of the articles published available in the public domain.

Conflict of Interest

None declared.

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