Food security and nutrition competencies diminish the role of GDP in predicting stunting variations among countries

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ABSTRACT

Purpose: Stunting as an indicator of human wellness deserves global attention. Lack of Income (Gross Domestic Product-Per Capita; GDP-PC) is a key factor for explaining all the variations in stunting, but refining its role calls for a close examination of other drivers. This study explored the role of GDP, food security, and nutrition competence in explaining the international variation in stunting.

Design/Methodology/Approach: Univariate and multivariate associations between stunting and predictors (GDP, Food Security, and Nutrition competence) were explored. The data required for this study was available from 90s countries.

Findings: Food security status (as assessed by the Impact Economist Food Security Index) and Nutrition Research Activity (estimated by Human Nutrition Research output of countries in the past five years) diminished the association between GDP and stunting and explained 74% of the variation in rates of stunting between countries.

Conclusion: These results concluded that an increase in income can assure improvements in human wellbeing only if it leads to an improvement in food security and nutrition competences, which appear to be important drivers of that process.

Research Limitations: This study only focused on stunting brought on by malnutrition. While genetic make-up, regional location, and pathological disorders all affect height, these elements are not the main focus of this study.

Practical Implications: This study highlighted the key determinants of food security and nutritional competence that are linked to stunting among the studied nations in the hopes that focusing attention on these issues will help to end the problem.

Contribution to Literature: No literature is available that presents worldwide data on the impact of countries' GDP on their rates of stunting. This study is one of its kind and provides reliable global data (113 countries) to find the association among the relative roles of Income, Food Security, and Nutrition Competence in the determination of global variations in stunting rates.

Keywords: *Countries, Food security, GDP, Income, Nutrition competence, Stunting, Variations.*

1. INTRODUCTION

While the usefulness of stunting as an indicator of the nutritional status of populations has recently been questioned (Leroy & Frongillo, 2019), it does have value in estimating the state of development and human wellness of populations (Kraemer, 2016). A large proportion of stunting's prevalence could be attributed to unfulfilled human needs. Stunting is associated with the income level of populations and households, but the cause-and-effect relationships are bilateral. Stunting often accompanies limitations in neurological wellbeing and is found to be associated with limited capacity for generating resources (De Sanctis et al., 2021). It is estimated to influence a country's economy if there is a high prevalence of people with disabilities due to impairments in the neurodevelopmental process; therefore, productivity would be compromised (Galasso & Wagstaff, 2019). Hence, the determinants of stunting need to be explored and controlled.

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Achieving successful growth requires an adequate environment and all its components: water and sanitation, nutritious and sufficient foods, access to health care, education, and recreation opportunities. Thus, height has the accumulated effects of living conditions, positive or negative, to which an individual is exposed, particularly in the early years of life (Tanner, 1992).

Globally, progress in diminishing the prevalence of stunting has not been equally distributed. Prior to the COVID pandemic, a WHO report (World Health Organization, 2018) stated that child stunting diminished more in urban locations than in rural areas in Asia-Pacific, Latin America, and the Caribbean regions and reported that countries experiencing long-term crises were out of track to meet the established targets of the World Health Assembly in the regions where this reduction was supposed to be a priority (Mates, Shoham, Khara, & Dolan, 2017).

Stunting appears to be negatively associated with GDP (Mary, 2018), and so at the international level, the decision-making process for accessing resources to implement programs is done based on GDP (Costanza, Hart, Talberth, & Posner, 2009). Efforts to reduce stunting are often directed towards increasing income without assurance or monitoring the utilization of added income at the population, family, or individual level, even though GDP is found to be only a modest predictor of stunting (Gaiser, Winkler, Klug, Nkurunziza, & Stelzle, 2023; Mary, 2018). In consequence, interventions for reducing human wellness disparities need to explore mediators that are more directly related to human wellness. A recent review by experts concludes: "Our ability to truly have an impact on the prevention and treatment of stunting will demand a different level of understanding to generate the data needed to improve our approaches to this complicated condition and its risks and to develop safe and effective programs, guidance, and standards of care" (Raiten & Bremer, 2020). This statement indicates the relevance of going beyond income in order to address a problem that shows multidimensional complexity, as shown by the accumulated effects of disadvantages over critical periods of growth (Tanner, 1992). As the discussion continues, the challenge is to have a perspective on stunting as an indicator of not only nutrition but the overall human wellness situation. Factors intertwined to limit the channeling of national income towards human wellness are the inappropriate distribution of national income and the lack of technical knowledge required to guide a healthy lifestyle and engage in nutrition education that translates into adequate diets; which can turn into food and nutrition security and influence human wellness. Evidence about the global association of the aforesaid factors with stunting has been limited.

In this paper, we have tried to explore the relative importance of 1) Countries' GDP, 2) Food security status, and 3) Nutrition Competence in predicting Stunting.

2. METHODS

This study aimed at exploring the relative roles of Income, Food Security, and Nutrition Competence in determining global variations in the rate of stunting. All the countries from which the required data was available were to be included in the study.

2.1. Data

Data about the prevalence of stunting and Countries' Per Capita GDP in US $, was retrieved from the World Bank website (World Bank, 2022a, 2022b).

2.2. Food Security

The Global Food Security Index (GFSI) (Impact Economist, 2022) provided data on the state of food security. The Global Food Security Index (GFSI) analyses 113 nations' levels of food affordability, availability, quality, and safety, as well as their levels of natural resources and resilience. The index is a dynamic benchmarking model that combines quantitative and qualitative analysis and is built from 58 distinct indicators that assess the factors that influence food security in both underdeveloped and wealthy nations.

Agricultural import tariffs, food safety-net programs (presence, funding, coverage, and operation), market access, and agricultural financial services (access to finance and financial products for farmers, access to diversified financial products, and percentage of the population living below the global poverty line) were among the indicators used to estimate affordability. Agricultural research and development (Public expenditure on agricultural research and development, Access to agricultural technology, education, and resources), agricultural infrastructure (Crop storage facilities, Road infrastructure, Airports, and rail infrastructure, Irrigation infrastructure), and volatility of agricultural products were among the indicators used to estimate availability. (Armed war, political instability risk, corruption, gender inequality, and food loss) Political and societal hurdles to entry commit to food security and access policies

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(food security agency, food security plan). Dietary diversity, nutritional standards (national dietary guidelines, national nutrition plan or strategy, nutrition labelling, nutrition monitoring and surveillance), micronutrient availability (dietary availability of vitamin A, dietary availability of iron, dietary availability of zinc), protein quality, and food safety (mechanisms for ensuring food safety, access to clean water, capacity for food storage safely) were among the indicators used to gauge quality and safety. The following indicators were used to estimate natural resources and resilience: exposure (increased temperatures, droughts, floods, and sea levels), land (Land degradation, Grassland, Forest change), Oceans, Rivers, and Lakes (Eutrophication, Marine Biodiversity, Sensitivity (Food Import Dependence, Dependence on Natural Capital), Water (Agricultural Water Risk—Quantity, Agricultural Water Risk—Quality), early-warning strategies/climate-smart agriculture, managing exposure, national agricultural adaptation strategy, disaster risk management, and demographic stress (projected population growth, urban absorption capacity) are all examples of political commitment to adaptation.

2.3. Nutrition Competences

Various indicators were used to estimate potential nutrition competences, like the presence of a country in international nutrition organizations, research output related to human nutrition in the past five years, and the overall scientific ranking of countries. Overall Scientific Status: A country's overall scientific standing was used as an indicator, as it is one of the factors that determine scientific excellence in nutrition. Information on national scientific rankings was obtained from the World AD Scientific Rankings website (AD Scientific Index, 2020). Four criteria are used to rank countries: (i) Number of scientists in the top 10,000 list; (ii) Number of scientists in the top 100,000 list; (iii) Number of scientists listed in the AD Scientific Index; and in case of a tie after applying all three criteria, (iv) the world ranking of qualified scientists from that country will be used. Higher points indicate a country's higher scientific standing in this study because the index's developers converted the ranks into points.

Nutrition Research Activity Index (NRAI): Research output was estimated by comparing the number of scientific publications in the past 5 years in the area of human Nutrition, which was used to develop the Nutrition Research Activity Index (NRAI). It was calculated for a Google Scholar search using the term "Diet, Nutrition and country's name". The ratio of population to number of publications was calculated to find out the number of people per publication. The Nutrition Research Activity Index (NRAI) was generated by converting this information to normal scores, where a higher score meant higher nutrition research activity.

Nutrition Professional Activity Index (NPAI): Information about members of the "International Union of Nutrition Sciences" (IUNS) and "The International Confederation of Dietetic Associations" (ICDA) was taken from relevant websites and used to develop the Nutrition Professional Activity Index (NPAI). No membership in any of the two organization indicted at the lowest level and membership in both organizations indicted at the highest levels.

2.4. Data Analysis

Univariate associations between variables were explored by estimating correlations. A linear regression analysis was done to identify the predictors of Stunting.

3. RESULTS

3.1. Characteristics of the Data

Out of 218 countries in the world, data about stunting and food security was available for 144 and 113 countries, respectively. Data for both stunting and food security was available for 90 countries. Thus, the analysis is based on observations from 90 countries Table 1.

In this analysis, Table 2, the prevalence of stunting ranged from 57.60% in Burundi to 1.60% in Chile, Germany, and the Netherlands, and the recent GDP per capita ranged from 63206.52 in the United States to 238.99 in Burundi. The results showed that Botswana ranked high in Nutrition research index, i.e., 89, and Congo ranked lowest, i.e., 1. The Nutritional Professional Activity Index showed countries like Argentina, Australia, Brazil, Germany, India, Indonesia, Malaysia, Mexico, Netherland, Nigeria, Pakistan, Philippines, Portugal, Singapore, South Africa, and the United States scored high, i.e., 3, and countries like Algeria, Angola, Azerbaijan, Bahrain, Belarus, Bolivia, Botswana, Burundi, Cambodia, Chad, Colombia, Congo, Ecuador, Ethiopia, Guatemala, Honduras, Jordan, Malawi, Mali, Mozambique, Myanmar, Nepal, Nicaragua, Niger, Panama, Qatar, Romania, Tajikistan, Togo, Ukraine, Uruguay, Uzbekistan and Zambia scored low, i.e., 0. It is worthy to note that Burundi, with its high prevalence of stunting and lowest GDP among the analyzed countries, has scored zero in the Nutritional Professional Activity Index. The

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Scientific Excellence Index ranked the United States in the highest position (score 09) and Angola in the lowest (score 01). Similarly, the Food Security Score among these countries showed the Netherlands scoring highest, i.e., 80, and Burundi scoring lowest, i.e., 35. In the Food Affordability Score, countries like Belgium, Germany, Japan, and the Netherlands ranked high (score 90), whereas countries like Burundi and Malawi scored lowest, i.e., 24. Singapore scored the highest, i.e., 83, in Food Availability, and Mozambique scored the lowest, i.e., 30. Mozambique also scored lowest (score 34) in Food Quality, whereas the United States ranked highest (score 94). Food Resilience Score data suggest the Czech Republic is in the highest position (score 71) and Indonesia is in the lowest (score 33).

3.2. Association of Stunting with GDP, Food Security Status, and Nutrition Competence among Countries

The univariate results revealed a strong association between stunting and GDP per capita. Table 3 showed a significant inverse relationship between the percentage of stunting and GDP per capita among countries. The correlation between Nutrition competence and stunting also revealed a significant relationship, as shown in Table 3. All the analyzed parameters of Nutrition competence, i.e., Nutrition Research Index Rank (NRI), Nutrition Professional Activity Index (NPI), and Scientific Excellence Index (SEI), showed an inverse relationship with stunting. Similar results were obtained with indices of Food security, i.e., Food Security Score (FS), Food Affordability Score (F.Af), Food Availability Score (F.Av), Food Quality Score (F.Q), and Food Resilience Score (F.R), with stunting in the same table. It is worthy to note that the association was strongest for Food Security (r=-0.875), followed by Food Quality score (r= -0.861) and GDP per capita (r=-0.858). In multivariate analysis (Linear regression), where all the indicators were included, GDP had no association with stunting Table 3. Food security and NRI had a significant role in predicting stunting. When dimensions of Food security were included as separate variables, Affordability, food quality, and Nutrition Research Activity played a significant role in predicting stunting Table 3. About 73.9% and 72.5% of the variation in stunting was explained by the models, respectively.

Table 1. Description of data used in this study.

Parameter	Number of countries with data
No of countries listed in the world	218
Countries with stunting information	144
Countries with food Security information	113
Countries with scientific ranking information	216
Countries with nutrition research information	218
Countries with nutrition professional information	218
Countries with all of the above information	90*

Note: Countries included in the current analysis:
Algeria, Angola, Argentina, Australia, Azerbaijan, Bahrain, Bangladesh, Belarus, Belgium, Benin, Bolivia, Botswana, Brazil, Bulgaria, Burkina Faso, Burundi, Cambodia, Cameroon, Chad, Chile, China, Colombia, Congo, Costa Rica, Cote, Czech Republic, Dominican Republic, Ecuador, Egypt, El Salvador, Ethiopia, Germany, Ghana, Greece, Guatemala, Guinea, Haiti, Honduras, India, Indonesia, Japan, Jordan, Kazakhstan, Kenya, Kuwait, Lao PDR, Madagascar, Malawi, Malaysia, Mali, Mexico, Morocco, Mozambique, Myanmar, Nepal, Netherlands, Nicaragua, Niger, Nigeria, Oman, Pakistan, Panama, Paraguay, Peru, Philippines, Poland, Portugal, Qatar, Romania, Rwanda, Saudi Arabia, Senegal, Serbia, Sierra Leone, Singapore, South Africa, Sri Lanka, Sudan, Tajikistan, Tanzania, Thailand, Togo, Tunisia, Uganda, Ukraine, United States, Uruguay, Uzbekistan, Vietnam, Zambia.
Countries excluded from this study because of the non-availability of Food Security data are:
Afghanistan, Albania, Armenia, Barbados, Belize, Bhutan, Bosnia and Herzegovina, Brunei Darussalam, Cabo Verde, Central African Republic, Comoros, Congo, Rep., Djibouti, Equatorial Guinea, Estonia, Eswatini, Fiji, Gabon, Gambia, The, Georgia, Guinea-Bissau, Guyana, Iran, Islamic Rep., Iraq, Jamaica, Kiribati, Korea, Rep., Kyrgyz Republic, Lebanon, Lesotho, Liberia, Libya, Maldives, Mauritania, Mauritius, Moldova, Mongolia, Montenegro, Namibia, North Macedonia, Papua New Guinea, Samoa, Sao Tome, Seychelles, Solomon Islands, Somalia, St. Lucia, Suriname, Timor-Leste, Tonga, Trinidad and Tobago, Vanuatu, West Bank and Gaza, Zimbabwe.
Countries with Food Security data but missing Stunting Data are:
Austria, Canada, Denmark, Finland, France, Hungary, Ireland, Israel, Italy, Korea, Dem. People`s Rep., New Zealand, Norway, Russian Federation, Slovak Republic, Spain, Sweden, Switzerland, Syrian Arab Republic, Turkey, United Arab Emirates, United Kingdom, Venezuela, RB, Yemen, Rep.,
Countries excluded from this study because of missing both Stunting and Food Security data:
American Samoa, Andorra, Antigua and Barbuda, Aruba, Bahamas, Bermuda, British Virgin Islands, Cayman Islands, Channel Islands, Croatia, Cuba, Curaçao, Cyprus, Dominica, Eritrea, Faroe Islands, French Polynesia, Gibraltar, Greenland, Grenada, Guam, Hong Kong SAR, China, Iceland, Isle of Man, Kosovo, Latvia, Liechtenstein, Lithuania, Luxembourg, Macao SAR, China, Malta, Marshall Islands, Micronesia, Fed. Saint Petersburg, Monaco, Nauru, New Caledonia, Northern Mariana Islands, Palau, Puerto Rico, San Marino, St Maarten (Netherlands), Slovenia, South Sudan, St Kitts and Nevis, St Martin (French), St Martin Martin Island, Grenadines, Taiwan, China, Turkmenistan, Turks and Caicos Islands, Tuvalu, US Virgin Islands.

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Table 2. Characteristics of the studied countries.

Country	Country income group*	Stunting %	GDP.PC	Nutrition research index rank	Nutrition professional activity index	Scientific excellence index	Food security score	Food affordability score	Food availability score	Food quality score	Food resilience score
Algeria	LMI	9.30	3306.86	17	0	53	64	78	58	62	51
Angola	LMI	37.70	1776.17	23	0	1	41	33	43	49	46
Argentina	UMI	7.80	8579.02	25	3	74	64	66	59	90	46
Australia	HI	2.10	51680.32	65	3	88	72	85	64	88	45
Azerbaijan	UMI	16.30	4221.41	43	0	18	63	82	58	59	38
Bahrain	HI	5.10	20409.95	88	0	36	69	79	68	80	39
Bangladesh	LMI	30.20	1961.61	7	1	46	49	49	58	46	37
Belarus	UMI	3.90	6424.15	60	0	61	71	86	57	83	56
Belgium	HI	2.30	45205.34	78	1	84	76	90	71	85	51
Benin	LMI	31.30	1291.04	67	1	20	45	42	51	48	38
Bolivia	LMI	12.70	3133.10	63	0	19	60	73	53	61	47
Botswana	UMI	22.80	6404.90	89	0	27	56	70	48	60	40
Brazil	UMI	6.10	6796.84	6	3	83	61	69	46	90	42
Bulgaria	UMI	6.40	10079.20	80	1	57	71	83	59	82	57
Burkina Faso	LI	25.50	857.93	52	1	13	48	42	56	48	46
Burundi	LI	57.60	238.99	53	0	3	35	24	34	46	45
Cambodia	LMI	29.90	1543.67	42	0	22	53	69	49	44	41
Cameroon	LMI	27.20	1537.13	39	1	25	46	46	42	52	45
Chad	LI	35.00	659.27	47	0	2	41	38	42	42	42
Chile	HI	1.60	13231.70	45	1	68	73	82	67	84	57
China	UMI	4.70	10434.78	3	1	87	71	77	78	71	47
Colombia	UMI	11.50	5334.56	19	0	71	64	70	57	72	58
Congo	LI	40.80	543.95	1	0	11	39	38	42	36	40
Costa Rica	UMI	8.60	12140.85	84	1	49	74	85	61	82	67
Cote	LMI	17.80	2325.72	40	1	17	48	46	54	42	48
Czech Republic	HI	2.50	22933.50	71	1	64	78	88	69	81	71
Dominican Rep.	UMI	5.90	7268.20	57	1	24	65	75	62	70	50
Ecuador	UMI	23.10	5600.39	50	0	50	60	71	51	71	44
Egypt	LMI	22.30	3569.21	12	1	70	61	67	60	61	52
El Salvador	LMI	11.20	3798.64	74	2	21	60	66	59	63	46
Ethiopia	LI	35.30	936.34	11	0	39	38	25	48	42	39
Germany	HI	1.60	46252.69	44	3	89	79	90	69	88	66

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Country	Country income group*	Stunting %	GDP.PC	Nutrition research index rank	Nutrition professional activity index	Scientific excellence index	Food security score	Food affordability score	Food availability score	Food quality score	Food resilience score
Ghana	LMI	14.20	2205.53	37	1	43	52	60	49	58	37
Greece	HI	2.20	17647.23	76	2	80	73	89	60	90	54
Guatemala	UMI	42.80	4603.34	49	0	7	54	58	48	57	51
Guinea	LI	29.40	1194.04	70	1	23	43	33	53	40	46
Haiti	LI	20.40	1272.37	51	1	4	38	28	40	44	45
Honduras	LMI	19.90	2389.01	61	0	48	59	53	64	64	58
India	LMI	30.90	1927.71	2	3	81	57	50	66	59	53
Indonesia	UMI	31.80	3869.59	4	3	60	59	75	64	49	33
Japan	HI	5.50	40193.25	18	1	85	79	90	76	83	62
Jordan	UMI	7.30	4282.77	77	0	55	65	80	55	64	54
Kazakhstan	UMI	6.70	9122.23	38	1	45	69	83	59	81	52
Kenya	LMI	19.40	1878.58	24	1	41	47	48	46	55	40
Kuwait	HI	6.00	24811.77	82	1	44	72	80	72	86	43
Laos	LI	40.20	471.49	24	1	14	40	36	41	40	47
Madagascar	LI	40.20	471.49	33	1	15	40	36	41	40	47
Malawi	LI	37.00	636.82	58	0	32	37	24	41	37	56
Malaysia	UMI	20.90	10412.35	32	3	69	70	86	64	76	47
Mali	LI	25.70	862.45	55	0	28	55	44	65	61	49
Mexico	UMI	12.10	8329.27	13	3	78	67	74	61	81	51
Morocco	LMI	12.90	3058.69	26	1	62	63	75	52	72	49
Mozambique	LI	37.80	448.54	34	0	30	36	43	30	34	35
Myanmar	LMI	25.20	1467.60	15	0	5	57	59	52	63	55
Nepal	LMI	30.40	1155.14	36	0	37	54	48	65	54	44
Netherlands	HI	1.60	52396.03	68	3	86	80	90	74	92	61
Nicaragua	LMI	14.10	1905.26	72	0	9	56	66	48	58	50
Niger	LI	46.70	567.67	56	0	8	48	37	53	52	53
Nigeria	LMI	35.30	2097.09	8	3	58	41	33	45	49	41
Oman	HI	12.20	14485.39	81	0	54	70	89	57	84	45
Pakistan	LMI	36.70	1188.86	5	3	65	55	53	63	56	42
Panama	HI	14.70	12509.84	83	0	34	71	83	67	72	55
Paraguay	UMI	4.60	5001.07	69	1	31	62	78	48	75	45
Peru	UMI	10.80	6126.87	31	1	66	65	80	55	71	48
Philippines	LMI	28.70	3298.83	9	3	51	60	74	54	62	44

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Country	Country income group*	Stunting %	GDP.PC	Nutrition research index rank	Nutrition professional activity index	Scientific excellence index	Food security score	Food affordability score	Food availability score	Food quality score	Food resilience score
Poland	HI	2.30	15742.45	35	1	75	75	87	65	81	65
Portugal	HI	3.30	22194.57	73	3	72	75	89	67	88	52
Qatar	HI	4.60	50124.39	85	0	63	74	84	74	84	43
Romania	HI	9.70	12915.24	46	0	73	72	82	67	85	53
Rwanda	LI	32.60	797.86	62	1	16	40	26	46	52	45
Saudi Arabia	HI	3.90	20110.32	28	1	77	68	75	68	80	44
Senegal	LMI	17.20	1471.83	59	1	12	47	44	48	56	44
Serbia	UMI	5.30	7730.69	79	1	47	61	83	38	81	45
Sierra Leone	LI	26.80	509.38	75	1	29	38	34	32	37	58
Singapore	HI	2.80	59797.75	86	3	82	77	88	83	79	47
South Africa	UMI	23.20	5655.87	20	3	76	58	63	49	72	49
Sri Lanka	LMI	16.00	3680.67	41	1	52	54	63	51	52	46
Sudan	LI	33.70	486.42	27	1	35	37	32	32	52	41
Tajikistan	LI	15.30	859.14	48	0	6	52	53	51	56	46
Tanzania	LMI	32.00	1076.47	22	1	38	48	40	57	51	44
Thailand	UMI	12.30	7186.87	16	1	67	65	82	57	60	51
Togo	LI	23.80	914.95	66	0	10	44	41	47	35	55
Tunisia	LMI	8.60	3521.59	64	1	79	63	74	54	72	48
Uganda	LI	27.90	822.03	29	1	33	44	42	38	49	54
Ukraine	LMI	15.90	3724.94	21	0	59	62	74	52	72	49
United States	HI	3.20	63206.52	30	3	90	79	89	71	94	61
Uruguay	HI	6.50	15438.41	87	0	40	68	75	53	81	69
Uzbekistan	LMI	9.90	1750.70	14	0	42	54	49	51	65	55
Vietnam	LMI	22.30	2785.72	10	1	56	61	69	60	64	45
Zambia	LMI	32.30	985.13	54	0	26	38	29	40	42	46

Note: *LI = Low income, LMI= Lower middle income, UMI = Upper middle income, HI= High income.

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Table 3. Correlation table for different antecedents and stunting.

Correlations (Spearman's RHO)											
		Stunting	**GDP**	**NRI**	**NPI**	**OSA**	**FS**	**F.Af**	**F.Av**	**F.Q**	**F.R**
Stunting %	Correlation	1.000									
	Sig. (2-tailed)										
	N	90									
GDP.PC	Correlation	-0.858**	1								
	Sig. (2-tailed)	0.000									
	N	90	90								
Nutrition research index rank	Correlation	-0.357**	0.286**	1							
	Sig. (2-tailed)	0.001	0.006								
	N	90	90	90							
Nutrition professional activity index	Correlation	-0.266*	0.324**	-0.213*	1						
	Sig. (2-tailed)	0.011	0.002	0.044							
	N	90	90	90	90						
Overall scientific excellence	Correlation	-0.637**	0.721**	1	0.545**	1					
	Sig. (2-tailed)	0.000	0.000	0.121	0.000						
	N	90	90	90	90	90					
Food security score	Correlation	-0.875**	0.939**	0.252*	0.278**	0.736**	1				
	Sig. (2-tailed)	0.000	0.000	0.017	0.008	0.000					
	N	90	90	90	90	90	90				
Food affordability score	Correlation	-0.848**	0.911**	0.281**	0.243*	0.682**	0.961**	1			
	Sig. (2-tailed)	0.000	0.000	0.007	0.021	0.000	0.000				
	N	90	90	90	90	90	90	90			
Food availability score	Correlation	-0.638**	0.741**	0.110	0.286**	0.643**	0.833**	0.722**	1		
	Sig. (2-tailed)	0.000	0.000	0.304	0.006	0.000	0.000	0.000			
	N	90	90	90	90	90	90	90	90		
Food quality score	Correlation	-0.861**	0.891**	0.250*	0.301**	0.722**	0.914**	0.862**	0.678**	1	
	Sig. (2-tailed)	0.000	0.000	0.018	0.004	0.000	0.000	0.000	0.000		
	N	90	90	90	90	90	90	90	90	90	
Food resilience score	Correlation	-0.402**	0.316**	0.183	1	0.288**	0.449**	0.361**	0.313**	0.390**	1
	Sig. (2-tailed)	0.000	0.002	0.084	0.987	0.006	0.000	0.000	0.003	0.000	
	N	90	90	90	90	90	90	90	90	90	90

Note: Stunting = Stunting %, GDP = GDP.Per capita, NRI = Nutrition research index rank, NPI = Nutrition professional activity index, OSA = Scientific excellence index, FS = Food security score, F.Af = Food affordability score, F.Av = Food availability score, F.Q = Food quality score, F.R = Food resilience score. Significance level: *p < 0.05; **p < 0.01.

3.3. Regression Analysis for Stunting Predictors

Table 4a displays the results of a regression analysis conducted to predict the percentage of stunting in a population using multiple independent variables. The Model Summary indicates a strong positive correlation between the dependent and independent variables, whereas the ANOVA table confirms the statistical significance of the regression model. The Coefficients table provides insight into the individual impacts of each independent variable on the dependent variable, with the Food Security Score and GDP. The PC and Nutrition Research Index rank as having a significant impact on stunting%, while the Nutrition Professional Activity Index and Scientific Excellence Index do not have a significant impact on the dependent variable.

Whereas, Table 4b presents regression analysis to identify predictors of stunting, with the Food Resilience Score, Nutrition Professional Activity Index, Nutrition Research Index Rank, Food Availability Score, Food Affordability Score, GDP.PC, Scientific Excellence Index, and Food Quality Score all entered as variables. The model's R-squared value of 0.762 indicated that the predictor variables explained 76.2% of the variance in the stunting outcome. The variables that significantly predicted a decrease in stunting were the nutrition research index rank, food affordability score, and food quality score. The excluded variable, food security score, had a partial correlation of 0.079 and a tolerance value of 5.600E-6.

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Table 4a. Regression analysis

Variables entered/Removed[a]					
Variables entered			**Variables removed**		**Method**
Food security score, Nutrition research index Rank, Nutrition Professional activity index, GDP.PC, Scientific. excellence. index[b]			.		Enter
Coefficients[a]					
Model	Unstandardized coefficients		Standardized coefficients	t	Sig.
	B	Std. error	Beta		
(Constant)	69.734	4.652	-	14.990	0.000
GDP.PC	6.259E-5	0.000	0.069	0.799	0.426
Nutrition research index rank	-0.101	0.037	-0.198	-2.765	0.007
Nutrition professional activity index	0.504	0.895	0.041	0.563	0.575
Scientific excellence index	-0.092	0.055	-0.182	-1.664	0.100
Food security score	-0.749	0.106	-0.725	-7.048	0.000
R	0.861[c]		Adjusted R square	0.725	
R Square	0.741		Std. error of the estimate	6.90569	
ANOVA[c]					
Regression	Sum of squares	df	Mean square	F	Sig.
Residual	11445.068	5	2289.014	47.999	0.000
Total	4005.838	84	47.689	-	-
	15450.906	89	-	-	-

Note: [a.] Dependent Variable: Stunting %
[b.] All requested variables entered.
[c] Predictors**:** (Constant), Food security score, Nutrition research index rank, Nutrition professional activity index, GDP.PC, Scientifc. Excellence. Index.

4. DISCUSSION

This paper aimed to identify associations between stunting, income, food security, and nutrition-related technical expertise in countries. It is probably the first time that worldwide reliable data has been used to explore these associations, to the best of our knowledge.

Our study identified that Food security status, as identified by the Economist-FSI, is the strongest predictor of stunting in countries Nutrition expertise is also an important predictor of nutritional wellbeing. On the one hand, food security or insecurity in a household defines what an individual will be able to eat and whether that is nutritious or not, depending on the availability, access, and ability to utilize the foods and how stable these are over time (FAO, 1996). On the other hand, nutrition capacities impact wellbeing, particularly in vulnerable children, in terms of how early stunting can be identified and adequately treated (World Health Organization, 2018). Undoubtedly, children's health is significantly influenced by socioeconomic variables in many developing nations, including access to clean water, sanitary facilities, and a supportive regulatory and legal environment (Khan & Ali, 2023).

Being a multi-dimensional concept, food security includes economic elements that translate into food consumption and the nutrition status of the population. It is evident that individuals who possess the means to acquire and obtain food are more likely to experience food security and subsequently attain a state of sufficient nutritional status, in contrast to those who lack access to food (Farmery et al., 2021). On the contrary, people who are not able to economically access foods because they cannot afford the high food prices will then be exposed to insecure food conditions which in turn translate particularly for children under five, as referred to by some authors as nutritional deficiencies, acute severe under nutrition and, if chronic, stunting (Agostoni, Baglioni, La Vecchia, Molari, & Berti, 2023; Reinhard & Wijeratne, 2000).

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Table 4b. Regression analysis (B).

Variables entered/Removed[a]						
Variables entered				**Variables removed**		**Method**
Food Resilience Score, Nutrition Professional Activity Index, Nutrition Research Index Rank, Food Availability Score, Food Affordability Score, GDP.PC, Scientifc.Excellence.Index, Food Quality Score[b]				.		Enter
Model summary						
R	R square			Adjusted R square		Std. error of the estimate
0.873[a]	0.762			0.739		6.73674
ANOVA[a]						
Model		Sum of squares	df	Mean square	F	Sig.
	Regression	11774.831	8	1471.854	32.431	0.000[b]
	Residual	3676.075	81	45.384	-	-
	Total	15450.906	89	-	-	-

Coefficients[a]				
Model	Unstandardized coefficients		Standardized coefficients		Sig.
	B	Std. error	Beta	t	
(Constant)	63.678	6.486	-	9.818	0.000
GDP.PC	2.236E-5	0.000	0.024	0.280	0.78
Nutrition research index rank	-0.076	0.037	-0.149	-2.056	0.043
Nutrition professional activity index	0.680	0.888	0.055	0.766	0.446
Scientific excellence index	-0.067	0.055	-0.133	-1.217	0.227
Food affordability score	-0.245	0.073	-0.383	-3.346	0.001
Food availability score	-0.026	0.102	-0.022	-0.257	0.798
Food quality score	-0.291	0.099	-0.369	-2.954	0.004
Food resilience score	-0.082	0.107	-0.047	-0.763	0.448

Excluded variables[a]						
Model		Beta in	t	Sig.	Partial correlation	Collinearity statistics
						Tolerance
	Food security score	16.318[b]	0.710	0.480	0.079	5.600E-6

Note: a. Dependent Variable: Stunting %.
b. Predictors in the Model: (Constant), Food Resilience Score, Nutrition Professional Activity Index, Nutrition Research Index Rank, Food Availability Score, Food Affordability Score, GDP.PC, Scientific Excellence Index, Food Quality Score.

Previous reports of country-wide associations between food security and stunting were not found to the best of our knowledge, particularly because of the difficulties in obtaining such data (Akseer, Vaivada, Rothschild, Ho, & Bhutta, 2020). However, a review of other studies indicates a strong positive association between Food Insecurity and stunting (Sihite, 2022) and shows advances in stunting prevalence decrease as improvements occur when economic growth exists, such as in the group of Exemplar countries (Akseer et al., 2020).

The current observations support the notion that food security indicators need to be used as the major tool for estimating nutrition risks, and intervention should target sustainable improvements in food affordability and quality. Observations about the role of nutrition expertise call for immediate attention to measuring and monitoring the status of nutrition education and research in countries.

Worldwide, treating and reducing stunting is an important challenge since its roots relate to structural problems compared to acute under nutrition treatment, which is more lifesaving-oriented. In terms of immediate effects, treating acute under nutrition might seem urgent and cost-worthy, while treating stunting as a consequence of chronic under nutrition as important as it is recognized, is always left behind since the cost associated with long term and structural intervention is large and not always possible to include in overall country health budgets.

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Once installed, stunting is difficult to treat. Improving food security at the household level and building capacity where there is none are long-term goals that need to be worked on over time. A note on stunting prevention is needed because reports on investments in early child nutrition, improving food security, and access to health and nutrition care show improvements in children's growth and are cost-effective actions that will reduce the burden of disability in the future (De Sanctis et al., 2021; Prasetyo et al., 2023).

5. STRENGTHS AND LIMITATIONS

Until now, to the best of our knowledge, the present study is the first to examine the prevalence of stunting among countries as a consequence of their economic status, food security conditions, and Nutrition competence. The main strength of this study is that it analyzed data from 90 countries on the above factors, and each was evaluated with an array of indicators to explain the stunting variations among these countries. Beside this, this study identified the main contributing factors of food security and nutrition competence that are related to stunting in these countries, so that focusing attention on these factors can eradicate its occurrence.

This study also has some limitations, like the fact that it only focused on stunting as a consequence of malnutrition. While height also depends on genetic makeup, geographical area, and pathological conditions, these factors are not the target of this study. In addition, some issues like implemented policies, governance, etc. also needed to be explored.

6. CONCLUSION

The results of this study confirm the findings that countries with strong economic status suffer less from stunting as compared to economically unstable ones. Beside this, it is also concluded that nutrition research and studies in the countries play a significant role in managing the onset of stunting among malnourished children.

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Not applicable.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors without undue reservation.

CONFLICT OF INTEREST

The authors declare that they have no competing interests.

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Coined the idea, searched and analyzed the data, and wrote the manuscript, R.H.; reviewed the manuscript and provided valuable suggestions, M.H.; wrote the conclusion and proofread the manuscript, M.J. All authors have read and agreed to the published version of the manuscript.

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