ISSN: 2424-8150 (Print)
ISSN: 2424-8606 (Online)
Volume 5 · Issue 2
December 2019

INTERNATIONAL JOURNAL OF POPULATION STUDIES

WHIOCE PUBLISHING PTE. LTD.

International Journal of Population Studies

Print ISSN: 2424-8150 Online ISSN: 2424-8606

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Volume 5 • Issue 2 • December 2019
ISSN 2424-8150 (print) ISSN 2424-8606 (online)

INTERNATIONAL JOURNAL OF POPULATION STUDIES

Editor-in-Chief
Danan Gu
United Nations, New York, United States

WHIOCE PUBLISHING PTE. LTD.

International Journal of Population Studies

ISSN: 2424-8150 (print)

ISSN: 2424-8606 (online)

Editorial and Production Credits

Publisher: Whioce Publishing
Article Layout and Typeset: In-house Production

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RESEARCH ARTICLE

Worry about eldercare in China: The role of family relations, socio-economic resources, and community services in 2000 and 2010

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Abstract: Using the survey on aged population in urban/rural China from 2000 and 2010, we aim to achieve the following three objectives: First, to document the general trend in older adults' worry about eldercare, their family relations, socio-economic resources, and the availability of community services; second, to assess if improving socio-economic resources and availability of community services reduce older adults' worry about eldercare; and third, to examine if family relations are still important during such social changes. Results show that older adults' improving socioeconomic conditions and expanding community services are associated with less worry about eldercare. Meanwhile, family relations, measured by the number of children, living arrangements, and children's filial piety, remain important. Our findings demonstrate that while building social welfare programs, including providing community services, certainly alleviates older adults' worry about eldercare; they are no substitute for family ties, which should be facilitated rather than overlooked by public policies.

***Keywords*:** China; Eldercare; Family; Social services

ARTICLE INFO

Received: February 22, 2019
Accepted: April 16, 2019
Published: April 27, 2019

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CITATION

Sun R, Wang H (2019) Worry about eldercare in China: The role of family relations, socio-economic resources, and community services in 2000 and 2010. *International Journal of Population Studies*, 5(2):1-13.
doi: 10.18063/ijps.v5i2.1046

1. Introduction

1.1. Research Questions

Provision of eldercare, which includes financial or material assistance, personal care, and emotional support to older adults (Chen, 2002; Knodel, 2012), has become a contested issue in China, as the country has undergone dramatic demographic changes in the past decades. On the one hand, with unprecedented fertility decline, there are fewer children per family, meaning fewer family caregivers to elderly parents when needs arise. In addition, more Chinese older adults live alone, separately from their adult children (Hu and Peng, 2015; Zeng and Wang, 2003). These trends may prompt older adults' worry about receiving care in old ages. On the other hand, the recent development of the welfare state in China seems to alleviate such a concern and to make independent living an increasingly viable option (Du, 2013). More older adults have benefited from expanding social programs that provide income or medical care coverage. Community services to older adults have been growing and playing a more important role in eldercare in China (Zhang, Yeager, and Hou, 2016). Against such a backdrop, this paper uses the survey on aged population in urban/rural China from 2000 and 2010 to explore the following three research questions: (1) What is the general trend in older adults' characteristics in their family relations, socio-economic resources, availability of community services, and their worry about eldercare in the first

decade of the 21st Century? (2) Do the improving socio-economic resources and availability of community services play a positive role in reducing older adults' worry about eldercare? and (3) In such a backdrop, is the role of family relations still important in older adults' worry about eldercare?

1.2. Population Aging and Changes in Family Structure in China

Population aging in China results from both low fertility rate and rising life expectancy. The one-child policy in the past few decades since 1979 has contributed to a declining portion of the young in the general population. Meanwhile, rising life expectancy allows more people to live to old ages. There are currently more than 200 million older adults in China aged 60 or older, more than 20 million of whom were oldest old, or over the age of 80. In 2019, one in 11 people worldwide was aged 65 or over. It is projected to grow to one in six by 2050, and at the same time, the number of those aged 80 or above will reach 426 million (United Nations, 2019). In the past few decades, China's fertility rate has been on a downward track. It has started declining since the 1960s, when total fertility rate was around 6.0. It had dropped from 5.8 in 1970 to 2.8 in 1979 before the implementation of the one-child policy (Jiang and Liu, 2016). With the one-child policy in full swing, fertility fell below replacement in the early 1990s and was around 1.5 by 2010 (Cai, 2013). As a result, the average number of children per family is lower and the average size of the family is shrinking. The average number of family members declined from 3.96 in 1990, to 3.46 in 2000, and to 3.09 in 2010 (Hu and Peng, 2015).

Meanwhile, decades of social and demographic changes have gradually eroded the traditional ideal of having multiple generations living under the same roof. More Chinese older adults are increasingly living alone or with a spouse only. Using Chinese Census data, Hu and Peng (2015) documented that the percentage of parents living with married or unmarried children in two- or three-generation households has steadily declined from 74.2% in 1990 to 65.3% in 2000 and 53.0% in 2010. They found 40% of older adults living in empty-nested households, i.e. living alone or with spouse only. Such a change can be attributed to the growing number of one-child families that makes the multi-generation living arrangement demographically difficult, and rising incomes for both the young and old and housing availability that make living independently possible (Du, 2013; Meng and Luo, 2008).

1.3. Expanding Older Adults Welfare Programs

As population aging places an ever-growing constraint on family's ability to provide eldercare, the state has launched a series of social programs to address such a challenge. The National Committee on Aging was established in 1999, and the state has made substantial progress in establishing a social safety net for the elderly population (Feng *et al*., 2012). In 1997, the State Council passed a decree to set up a uniform old age security system for urban employees, who contribute to their personal account, which is managed by the local government. By the end of 2012, 304 million urban employees had participated in this program. Monthly benefit for the pensioners has been on the rise in the past decade (Zhang, 2017). In rural areas, China initiated the New Rural Pension Program (NRPP) in 2009, aiming at covering all the rural older adults. The new program is funded by contributions from individuals and subsidies from local and central governments. By the end of 2011, about 200 million rural residents had participated in the program (Du, 2013). In addition, the minimum security program is set up for those with low or no income. It had provided coverage for 74 million urban/rural residents by 2012, among whom 3.4 million were older adults in the cities and 20.2 million older adults in rural areas, which accounted for 15.7% and 37.8% of older adult population, respectively (Yang, 2013).

China's network of medical care currently covered both urban and rural areas, with more than 1.3 billion beneficiaries (Wu and Luo, 2013). While urban residents are covered by the Urban Employee Basic Medical Insurance (UEBMI), which provides insurance to urban employees and retirees, and Urban Resident Basic Medical Insurance (URBMI), which covers self-employees, employees in informal sectors, and the unemployed. Rural residents are covered by the New Cooperative Medical Scheme (NCMS). Under this coverage, part of the patient's medical expenses is reimbursed. The treatment for some major diseases, such as lung cancer and stomach cancer, is covered by up to 90%. The personal share of all medical expenses had gone down from 58% in 2002 to 35% in 2011 (Wu and Luo, 2013).

Meanwhile, the state steps into promoting community-based services aiming to supplement family care and help older adults remaining in the community (Xu and Chou, 2011). These services, both formal and informal supports available to older adults within the community provided by people other than family members (Shen and Yeatts, 2013), include household chores, health care at home, and meal services (Du, 2013). Various pilot projects and experiments have been conducted in both urban and rural areas since the 1990s (Lee and Kwok, 2006), from government-operated services to private enterprises. While some of the services are wholly funded or partially subsidized by the local government, some are paid out of pocket by individual customers (Lin, 2017).

1.4. Worry about Eldercare and Hypotheses

1.4.1. The impact of economic resources and community services

As reviewed earlier, the traditional practice of having adult children taking care of older adults has been under pressure from drastic demographic changes in the past decades in China. As both the number of children and the proportion of older adults coresidence with adult children are declining, it is becoming more infeasible to totally rely on families to provide eldercare. In light of these challenges, the state has increased investment in welfare programs to provide older adults with more resources in income and health-care coverage, which have started to show effect. For example, health insurance programs in urban and rural areas, mainly UEBMI, URBMI, and NCMS, have been found to be effective in booting health-care utilization, although rural area coverage is less generous (Zhang, Nikoloski, and Mossialos, 2017).

With expanding public pension and other welfare programs, older adults, especially those in urban areas, have more disposable income and become less dependent on others financially. Even for those living in rural areas covered by NRSP, which offers lower benefits than in urban areas, the benefit level has doubled between 2009 and 2013. The NRSP coverage is expanding rapidly with increasing government subsidies. Several studies have shown that pension from NRSP to rural residents has improved their sense of personal security, self-esteem, and ability to support themselves. Meanwhile, it reduced their worries about later life (Liu *et al*., 2015). The expanding health-care coverage makes medical treatment more affordable and accessible. Furthermore, the increasing availability of community services provides older adults with alternative options in seeking care. More older adults turn to affordable and responsive community services for help instead of relying on children (Leung, 2010). Such a trend has been observed in some other Asian societies. In Japan, which shares Eastern Asian traditional culture, there has been a shift from family care to socialization of care. Eldercare responsibilities have gradually been transferred from the family to the state (Hayashi, 2011). It has been reported that as pension programs were implemented in Taiwan, there was a substantial decline in older adults relying on private monetary transfers (Chan *et al*., 2003). A study in Thailand found that the financially better-off older adults were more likely to pay non-relatives for caregiving than those less wealthy (Knodel and Chayovan, 2012). By the same token, older adults with less power and fewer resources in Hong Kong showed a stronger expectation to be taken care of by their children because of limited choice (Ng, Phillips, and Lee, 2002). Similarly, in Spain, characterized by a high proportion of multigenerational households in Europe, it is the disadvantaged older adults with lower educational or financial status who are more inclined to coreside with relatives (Fernandez-Carro, 2016). Knodel (2012) predicted that with the expansion of state welfare allowance programs, such as pensions and social security type of benefits, there would be a reduction in reliance on children for eldercare, and an increase in the use of formal services to substitute for it.

It seems that expanding welfare programs and community services provide older adults with an alternative and viable option of receiving care. Therefore, we hypothesize that older adults' socio-economic resources, mainly their income and health-care coverage, and the availability of community services will make them less worry about eldercare (Hypothesis 1).

1.4.2. Does the family still matter?

As older adults have more resources at their disposal and have more access to community services, an interesting and important question emerges: Is the family still relevant, or at least becoming less important? The picture is not as clear as evaluating the impact of the resource factors discussed above.

On the one hand, Cowgill and Holmes (1972) claimed that, in the process of modernization, one traditional function of the family of supporting its older members might fade away as a social welfare state gradually took its place. Older adults' increasing resources from outside the family, largely due to the establishment of public welfare programs, may make them less dependent on the family networks for support, such as seeking medical treatment and eldercare. Typical aspects of family structure, such as number of children and whether living with adult children, may become less critical. A comparative study of four Asian societies found that family size was not particularly important in determining the care older adults received when there was a remarkable decline in fertility. What mattered was children's character rather than the number (Asis *et al*., 1995). Living separately from children may not necessarily imply older adults being abandoned or an erosion of traditional family values. The practice of multi-generational coresidence might be partly attributed to housing shortage in the past (Zavoretti, 2006). Living in separate residence has been reported to be preferred by some aging parents and their children in China. Although living apart, parents and married children maintain frequent contact and offer support to each other (Whyte, 2003). As Taiwan experienced industrialization and growth in income before the end of the last century, many older adults expressed interest in independent living that provides privacy and freedom (Lee, Lin, and Chang, 1995). A similar trend was observed among Chinese older adults in Singapore (Mehta, Osman,

and Alexander, 1995). Living arrangements have become a result of each generation's needs, economic resources, health, and ability to provide (Asis, Domingo, Knodel *et al*., 1995). While coresidence with children was found to be beneficial to the psychological well-being of the widowed Chinese older adults, it did not make any difference for those who were married (Wang, Chen, and Han, 2014). Another study found that the daily maintenance dimension of filial piety, which includes the frequency of contact and assistance with daily activities, was not associated with life satisfaction or psychological well-being of Chinese older adults (Cheng and Chan, 2006). Following these findings, we hypothesize that the association of family relations, measured by the number of children, coresidence with at least one adult child, and children's filial piety, with older adults' worry about eldercare may become less significant from 2000 to 2010, when older adults' socio-economic resources and the availability of community services are taken into account (Hypothesis 2a).

On the other hand, it was found that even with dramatic economic development in recent decades, family-based care is still the backbone of care provision for older adults in China (Shen and Yeatts, 2013; Zavoretti, 2006). Families have been the bedrock of providing care to older adults in China and many Asian societies. The Confucian value of filial piety, where the younger generation is expected to respect and take care of their elderly parents, has been instilled for generations (Chow, 2004; Zhang and Yeung, 2012). "More children, more happiness" has been the conventional wisdom. Living with at least one married son has been the ideal living arrangement. Even though NRSP has improved the quality of life for many Chinese older adults in rural areas, the impact of family structure, such as the number of children, remains significant (Liu, Han, Xiao *et al*., 2015). Thus, the crucial role played by families, especially adult children, may not simply fade away as alternative options of care are available for at least two underlying reasons.

First, children are thought to provide better care than nonfamily caregivers. They know better the needs and habits of older adults, thus able to provide better care (Chen, 2002). In one study in Hong Kong, Chinese older adults gave a detailed account of the advantages of living with adult children (Ng, Phillips, and Lee, 2002). Living with children provided a sense of security. They felt happy and safe. They could count on getting help immediately once an emergency came up. Children gave the best emotional support.

The second reason may be tied to the strong value and practice of filial piety, which has been instilled in the collective consciousness. Adult children's provision of care for their parents does not only serve a practical function – meeting parents' material or other needs but it is also a manifestation of filial piety and moral obligation on the part of children. It is a symbol of adult children's appreciation and repayment of care and love received early in life from parents (Asis, Domingo, Knodel *et al*., 1995). The absence of such an act makes both parents and children "lose face," even though parents' needs may be met by other sources, such as paid workers or institutions. One qualitative study in Thailand is a case in point. Even though coresidence with children has declined, 80% of the respondents from a national survey in 2011 still regarded it as the most appropriate living arrangement, regardless of the respondent's age. About two-thirds of the respondents agreed that children should be the main provider of care for older adults. Children were viewed as the ideal personal care providers. Concern about having an outside person to fulfill such an intimate role was still common. While paid caregivers were acceptable when children were working or serving as children's assistant, full-time services that replaced care from children were viewed less favorably. As one respondent said, "No matter who will be caregiver they are not children," followed by another, "I don't think a paid caregiver can substitute for children for giving care to parents" (Knodel, 2012, p. 20). In Japan, family-based care is still central to eldercare in spite of the introduction of long-term care insurance scheme in 2000 (Kawakami and Son, 2015). Even in Spain, there is a strong intergenerational solidarity. Informal support provided by family members is pre-eminent in its culture. Taking care of older adults by younger generations is an expected duty rather than an option (Fernandez-Carro, 2016). Therefore, we develop an alternative hypothesis to Hypothesis 2a: The association of family relations with older adults' worry about eldercare remains significant in both years even when older adults' socioeconomic resources and the availability of community services are taken into account (Hypothesis 2b).

2. Data and Methods

2.1. Study Population

We will use the survey on aged population in urban/rural China to describe the general trend of eldercare in China and test the research hypotheses. The survey is conducted by China Research Center on Aging, which is a consulting branch of China National Committee on Aging. All survey procedures meet the ethical standard of the committee. So far, four waves of data have been collected in 2000, 2006, 2010, and 2016, respectively, whereas the data from the most recent wave are currently unavailable. The survey covers all geographical regions: North, Northeast, East, Southcentral,

Southwest, and Northwest. Out of 31 provinces and national metropolises, 20 are selected. The survey follows a stratified, multistage sampling design to randomly interview those 60-year-old or older. This analysis is based on data from two waves in 2000 to 2010.

2.2. Measurement of Worry about Eldercare

Worry about eldercare is measured by older adults' response to the question of whether they are worried about getting care when needed. There are five response options: (1) Not worried at all; (2) almost not worried; (3) so-so; (4) a little worried; and (5) very worried. It is recoded into two categories: Either worried (4 or 5) or not worried (1, 2, and 3).

2.3. Covariates

Family relations are measured by the number of children, living arrangements, and older adults' perception of their children being filial or not. The living arrangements have three categories: Living alone or with spouse only, living with children, and living with others. As a subjective measure to gauge family relations, older adults were asked in the survey about whether they had any worry about children being unfilial, which is coded as yes or no.

Older adults' socio-economic resources mainly refer to income and medical coverage, including both objective and subjective measures. Two objective measures are whether an older adult receiving any income from public sources (yes or no), including pension from state insurance programs or enterprises, security income for the poor, and any income from other public sources; and whether an older adult receiving any public medical care coverage coded as yes or no. Two subjective measures include whether an older adult having any worry about insufficient income or unaffordable medical care, coded as yes or no.

There are questions about eight kinds of community services asked in both years: Household work, personal care, doctors' home visits, companionship (having someone to chat), older adults' hotline, meals to home, as company to see a doctor or to go shopping. For each service, older adults were asked about the availability in the community, their need, and their use of the service. Since the availability and need for the last four types of services are low in both years (under 10% for all in 2000), we will only include the first four types of services in the analysis. Preliminary results indicate that the sheer availability of these services is not significant. Instead, we construct an unmet need variable for each service: If there is a need for a specific service but unavailable in the community, it is coded as yes, otherwise no.

Among the control variables, there are age, sex (male, female), and residence (urban and rural). Since the percentage of being divorced or never married is <2%, marital status is coded as a dummy variable: Currently married or not. Education is coded at three levels: Illiterate, elementary school, and middle school or higher. An older adult's health status is measured by their difficulty in performing an array of activities of daily living (ADL), which include six basic activities: Eating, clothing, toileting, getting in/out of bed, bathing, and walking. Each activity is measured by a score at three levels: No difficulty, a little difficulty, and unable to perform. Since more than 70% of older adults from both years reported no difficulty in any of the six activities, we recode it into a binary variable: Having any ADL difficulty or no difficulty at all. Home ownership is a dummy variable: Yes or no.

2.4. Analytical Strategies

In the following analysis, we will first present descriptive statistics to illustrate the changes in older adult population between 2000 and 2010. Next, we will adopt three logistic regression models for each year to test the two hypotheses. Model 1 will only include family relations variables in addition to the control variables to show the effect of family relations without socioeconomic resource variables. Socio-economic resource variables will be added to Model 2, which will partially test Hypothesis 1, and Hypothesis 2a and b. Community service variables will be added to Model 3 to completely test all hypotheses.

3. Results

3.1. Description of Older Adults in 2000 and 2010

Table 1 presents descriptive statistics of the two elderly samples in 2000 and 2010, respectively. Although the dependent variable – worry about eldercare – remained virtually the same between 2000 and 2010, family relations, older adults' socio-economic resources, and unmet need for community services had undergone dramatic changes during the same time period.

Table 1. Socio-demographic characteristics of the surveyed older adults in 2000 and 2010.

Variable	2000	2010
Worry about eldercare (%)	39.8	38.7
Age	69.1 (6.8)[a]	72.2 (7.4)[a]
Sex (%)		
Male	53.0	51.7
Female	47.0	48.3
Residence (%)		
Urban	50.2	50.2
Rural	49.8	49.8
Marital status (%)		
Currently married	62.6	65.8
Currently not married	37.4	34.2
Education (%)		
Illiterate	43.1	29.0
Elementary	34.3	38.9
Middle and high school	22.6	32.1
Number of children	4.0 (1.8)[a]	3.2 (1.6)[a]
Living arrangements (%)		
Alone or with spouse only	38.4	53.8
With children	55.5	40.4
Other	6.1	5.8
No worry about children's filiality	68.8	75.8
ADL difficulty	18.7	25.8
Home ownership	53.1	72.5
Receiving any public income	50.6	73.7
Receiving medical care coverage	63.3	95.7
No worry about income	56.2	61.4
No worry about medical care	46.8	49.9
Unmet need for housework work	11.2	16.9
Unmet need for personal care	13.1	25.0
Unmet need for doctors' home visits	12.8	21.7
Unmet need for companionship	17.5	23.0
Sample size	20,255	19,986

[a]Mean and standard deviation (in parentheses), ADL: Activities of daily living.

The average number of children had dropped from 4.0 in 2000 to 3.2 in 2010. Since the lower age limit of the survey is 60 years old, the youngest members of those surveyed in 2000 would have been 40 in 1980, when the one-child-policy started to be enforced, and the impact would be minimal. In contrast, some of the older adults interviewed in 2010 were in their 30s in 1980 and could be impacted by the policy. Therefore, the reduction in the number of children could be substantial. There was a marked increase in the percentage of older adults living alone or with spouse only (from 38.4% to 53.8%) and correspondingly a decrease in the percentage of living with children (from 55.5% to 40.4%). However, the proportion of older adults who did not worry about children being unfilial went up, suggesting stronger ties between generations.

The increasing coverage of pensions and other public sources of income was evident between 2000 and 2010. Whereas only half of the older adult population received any income from public sources in 2000, about three-quarters did so in 2010. Correspondingly, the percentage of not worrying about income increased from 56.2% to 61.4%. The improvement

in receiving medical care coverage was more significant: Increased from 63.3% to 95.7%, though the change in the percentage of not worrying about medical care was less impressive: From 46.8% to 49.9%.

As shown in Table 1, there was a substantial increase in the unmet needs of all the four types of services included in this study. Data suggest (not shown) that there were growing demands for all the services in the same decade, even though there was greater availability of these services except for a slight decrease in doctor's home visit.

Among the control variables, what is worth noting is that the educational profile of Chinese older adults was improving. The share of illiterate older adults declined from 43.1% in 2000 to 29.0% in 2010, whereas the shares of those educated went up. Home ownership within the same decade had grown from 53.1% to 72.5% for the older adult population.

3.2. Regression Analysis of Worry about Eldercare

Table 2 shows the results of logistic regression of having any worry about eldercare in 2000. In Model 1, all three measures of family relations are highly significant. An additional child is associated with a nearly 10% reduction in the

Table 2. Odds ratios of logistic regression of worry about eldercare, 2000 (n=20, 255).

Variable	Model 1	Model 2	Model 3
Age	0.988***	1.007	1.007
Sex			
Male	1.124**	1.043	1.043
Female (ref.)			
Residence			
Urban	1.274***	0.986	1.023
Rural (ref.)			
Marital status			
Married	0.754***	0.729***	0.732***
Currently not married (ref.)			
Education			
Illiterate (ref.)			
Elementary	0.902*	0.976	0.976
Middle school or higher	0.947	1.297***	1.292***
ADL difficulty	1.470***	1.234***	1.227***
Home ownership	1.129**	1.115*	1.117*
Number of children	0.909***	0.916***	0.914***
Living arrangements			
Alone or with spouse only (ref.)			
With children	0.770***	0.732***	0.732***
Other	1.041	1.022	1.024
No worry about children's filiality	0.056***	0.112***	0.112***
Receiving any public income		1.051	1.050
Receiving medical care coverage		0.979	0.976
No worry about income		0.367***	0.368***
No worry about medical care		0.174***	0.175***
Unmet need for housework work			0.966
Unmet need for personal care			1.041
Unmet need for doctors' home visits			1.178*
Unmet need for companionship			1.135*

*P<0.01, **P<0.01, ***P<0.001 for Wald Chi-square test. ADL: Activities of daily living.

odds of worry about eldercare. Similarly, living with at least a child reduces 23% of the odds of worry about eldercare. The subjective measure of family relations, worry about children's filiality, is also highly significant. Those who had no worry about children's filiality were only 5% as likely as those who had such a concern to worry about eldercare.

In Model 2, when older adults' socio-economic resource variables are added, the effects of the three family relations variables remain robust. Although the two objective measures of receiving public income and medical care coverage were not significant, the two subjective measures were highly significant. Those who had no worry about income were only 37% as likely as those who had such a concern to worry about eldercare, and those who had no worry about medical care coverage were only 18% as likely as those who had such a concern to worry about eldercare. In Model 3, of the four types of community services, having unmet need for doctors' home visits and unmet need for companionship is associated with higher odds of worry about eldercare, while the effects of family relation variables and older adults' socioeconomic resource variables remained virtually unchanged.

Table 3 shows similar results for 2010. All three family relation variables remain highly significant even when all other variables are controlled for. Older adults' socio-economic resource variables are significant, as well. Among the

Table 3. Odds ratios of logistic regression of worry about eldercare, 2010 (n=19, 986).

Variable	Model 1	Model 2	Model 3
Age	0.977***	1.000	1.000
Sex			
Male	1.148***	1.138*	1.133**
Female (ref.)			
Residence			
Urban	0.947	1.058	1.140*
Rural (ref.)			
Marital status			
Married	0.730***	0.757***	0.759***
Currently not married (ref.)			
Education			
Illiterate (ref.)			
Elementary	0.907*	1.003	1.017
Middle school or higher	0.767***	1.219**	1.236***
ADL difficulty	1.514***	1.153**	1.137*
Home ownership	1.035	1.044	1.039
Number of children	0.888***	0.873***	0.872***
Living arrangements			
Alone or with spouse only (ref.)			
With children	0.850***	0.813***	0.813***
Other	0.941	1.000	0.998
No worry about children's filiality	0.048***	0.104***	0.105***
Receiving any public income		1.184***	1.181***
Receiving medical care coverage		1.040	1.030
No worry about income		0.362***	0.365***
No worry about medical care		0.129***	0.128***
Unmet need for housework work			1.208**
Unmet need for personal care			1.075
Unmet need for doctors' home visits			1.033
Unmet need for companionship			1.092

*P<0.01, **P<0.01, ***P<0.001 for Wald Chi-square test. ADL: Activities of daily living.

community service variables, having unmet need for housework service is associated with higher odds of worry about eldercare.

Among the control variables, older adults who were married and those with less ADL difficulty were less likely to worry about eldercare than their counterparts.

4. Discussion

In light of drastic changes in family structure and rapid socio-economic development in China, this study used data from a national survey to explore the presence of worry about eldercare among Chinese older adults between 2000 and 2010. Within one decade, living separately from children had become the way of life for the majority of Chinese older adults. On the other hand, the socio-economic conditions of older adults have been improving, with more covered by pensions and medical care programs, thus, resulting in less worry about income and seeking medical care. Furthermore, the availability of community services is on the rise. In the end, a little surprisingly, worry about eldercare among Chinese older adults remained virtually unchanged during that decade, which could be a result of the competing effects of the two tracks of changes aforementioned.

Our results clearly support Hypothesis 1 regarding the association between socio-economic conditions of older adults and worry about eldercare. Those older adults who did not worry about their income or medical care coverage showed significantly less worry about eldercare. Furthermore, those who lived in communities where available services could meet their particular needs of daily living tended to have less worry about eldercare. These findings are consistent with the health-care utilization model developed by Anderson and others (Andersen and Newman, 2005), where enabling conditions are a set of critical factors that determine individuals' access to health care. They include family resources such as income, health care coverage, and other financial sources. In addition, the amount of health facilities and personnel in a community is another dimension of enabling conditions. These also correspond to the affordability (ability to pay) and availability (of services) factors within the framework of accessibility to health-care developed by Levesque, Harris, and Russell (2013). Zhu (2015) found that, among Chinese oldest old, those who were economically independent and had family members as the primary caregiver were less likely to experience long-term care unmet needs, which we assume to be related to reduce worry about eldercare. Therefore, access to more resources and the provision of community services do alleviate the concern of older adults about eldercare.

Meanwhile, between the two competing hypotheses regarding the effect of family relations when older adults' socio-economic resources and the provision of community services are taken into account, Hypothesis 2b is supported, which predicts that family relations are still important and relevant. It is confirmed by the fact that the number of adult children of older adults, older adults' living arrangements, and their children's filial piety are highly significant in both 2000 and 2010. This finding confirms the prominent role of the family in providing eldercare in many Asian societies, including China. Having more children, living with at least one adult child, and children's filial piety all provide higher possibility and security for older adults to receive care from them. As discussed by Knodel and other scholars (Asis, Domingo, Knodel *et al.*, 1996; Knodel, 2012), receiving care from children is valued highly among many Asian older adults. It serves not only a practical function but also as a symbol of children's affection and the appreciation of the traditional value of filial piety. This finding suggests that family relations remain a crucial element of the equation when older adults assess their prospect of receiving eldercare.

China's population aging happens at a time of rapid urbanization and industrialization, which have weakened the functions of traditional family support (Jackson, 2010). The traditional mode of family care faces serious challenges. Longer life expectancy comes with a rapidly growing older adult population and more non-communicable, chronic diseases, which are related to functional impairments and disability. The demographic reality makes it impossible for all older adults to live with their adult children. More older adults live alone or with their spouse only. All these points to a pressing dilemma: On the one hand, there is an ever-growing demand for care and services to older adults; on the other hand, individual families, the traditional care providers, are increasingly incapable of fulfilling their functions. Therefore, the role of the public sector, including state welfare programs and community services, becomes increasingly prominent in dealing with these challenges by providing income security, medical care, and social services.

Against such a backdrop, the results show some positive development for Chinese older adults. Overall, the personal and economic circumstances of Chinese older adults have been improving. The results show that during the first decade of this century, Chinese older adults became more educated, enjoyed higher home ownership, received more pension or other public income, and more medical care coverage. These changes certainly reduce older adults' worry about eldercare.

In addition, more and more people have recognized the necessity of getting support from the community to complement the provision of eldercare fulfilled by individual families (Du, 2013). Similar trends are seen in other Asian Countries as

well. Japan and South Korea, two leading industrialized countries coupled with rapid population aging, have witnessed a significant expansion of both public and market provisions of eldercare since the 1990s. Care burdens traditionally assumed by women in these societies are gradually shifted to the market and community (Peng, 2012). There has been discussion in China about the distinction between family care – the traditional practice where eldercare is entirely given by family members – and at-home care – where older adults use financial resources to acquire daily care and services from the community or neighborhood. The latter is considered a social eldercare model (Chen, 2002). Eldercare, which has been mainly limited to the family as the sole care provider, is gradually giving way in China to a shared responsibility of the family, state, and market. Boundaries are crossed between informal and formal, public and private sectors (Zhang and Yeung, 2012). As a result, more community services emerge in both urban and rural neighborhoods, such as household work, health care at home, companionship, and meal services. Although the development of these services is still at its early stage, the results show that the services that meet older adults' needs do reduce their worry about eldercare (Zhang, 2002). In the future, not only are more services in demand but also will be the kinds of services that suit local circumstances and satisfy the real needs of the elderly residents (Zhang, 2002).

The support of the first hypothesis seems to suggest that the constraints faced by older adults, such as smaller family size and less chance of living with adult children, can be compensated by their improving resources at disposal and greater presence of community services resulted from the ongoing socio-economic development. Some believe that in the process of modernization, the social model will ultimately replace the family eldercare model and become the dominant form of care (Chen, 2002). Our analysis, however, points to a different direction. Family ties between generations still matter to older adults. The finding that while fewer older adults were living with their adult children, the percentage of older adults not worrying about their children's filiality went up instead of going down during the same decade suggests that family bond remains strong China. The higher percentage of older adults living alone cannot be simply interpreted as evidence of the erosion of traditional values. Independent living of older adults is transitory in nature, which is one phase of the eldercare process. It has been found that Chinese older adults would like to live independently in their family as long as their health permits (Gu, Dupre, and Liu, 2007). Coresidence is still the ideal living arrangement when older adults' health deteriorates and need for daily assistance arises. This has been found in Taiwan, the Philippines, Thailand, and Singapore as well (Asis, Domingo, Knodel *et al*., 1996). Moreover, as discussed earlier, the prominent role of coresidence in Asian societies may not only lie in its practical function of providing eldercare but also in its compliance with traditional practice, which is viewed as an expression of filial piety.

This study has its limitations. First, since the survey from the two-time points does not follow the same cohort, it prevents a life course analysis of changes with age, such as the living arrangements and worry about eldercare, which would be more revealing about the dynamics of their relationship. Second, this study also has measurement shortcomings. The measurement of unmet need may not be accurate because the need for some older adults may not be met even if the community services are available. Other aspects, such as the quality of services, maybe at work as well. In addition, some of the variables on income and medical care coverage are still crude measures. For example, while the percentage of receiving health-care coverage increased from 63.3% in 2000 to 95.7% in 2010, the change in the percentage of not worrying about medical care was much less impressive: Only from 46.8% to 49.9%. This may reflect the disparity in benefit coverage among older adults between regions and urban/rural areas. There is also a wide variation in the cost of living. We attempted to address this by including subjective measures on worry about income or medical care in the paper. Third, since the development of community services for older adults is only at its early stage in China, the availability and usage of some types of services are still uncommon. Their full impacts remain to be seen. As reported earlier, we did find a distinction between the availability and unmet needs of certain services. It would be interesting to do a more in-depth analysis on this subject, which is beyond the scope of this paper.

Despite these shortcomings, the findings of this study clearly show that the family is still the ideal institution for eldercare in China, even as it has undergone profound socio-economic transformations. As the state increases investment in welfare programs to improve older adults' financial and medical care coverage and to provide more community services, what shall not be overlooked is polices that strengthen family ties between generations. It is unrealistic and counterproductive to expect to replace family eldercare with formal services. The value of filial piety and the responsibilities it entails should be upheld and encouraged (Chow, 2004). Measures should be taken to enable and facilitate increasingly shrinking and dispersed families to engage in eldercare in varying forms and shapes (Chan, 2005). Formal services should serve to crowd in, rather than crowd out, traditional family support (World Bank, 1994).

Acknowledgments

The authors would like to thank the two reviewers for their helpful comments.

Authors' Contribution

R Sun designed the study, performed part of the analysis, drafted and revised the manuscript. H Wang participated in data collection and preparation, performed part of the analysis, interpreted the results, and revised the manuscript.

Conflicts of Interest

No conflicts of interest have been reported by the authors.

Ethics Approval

No ethics approval was required for this study. The datasets were obtained from China Research Center on Aging, which are publicly accessible on request.

Funding

The authors declare that they have no financial support for this study.

Disclaimer

Views expressed in this article are solely those of the authors and do not necessarily reflect those of the Cleveland State University or China Research Center on Aging.

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International Journal of Population Studies

RESEARCH ARTICLE

Risk factors and socioeconomic inequalities in undernutrition among children 0-59 months of age in India

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Abstract: In the majority of low- and middle-income counties, child health-care dissimilarities are further aggravated by nutritional status (i.e., stunting, underweight, and wasting). In India, child malnutrition is the most important contributor to disease burden. The present study uses data from the 4th round of the National Family Health Survey (NFHS-4), conducted in 2015-2016. We considered anthropometric indicators of unit-level data of 2, 48, and 174 children aged 0-59 months. This study examines the socio-economic inequality in nutritional status and their determinants among under-5 year children. The factors considered in the analysis were categorized as child age in months, mother's educational status, mother's nutritional-status, type of caste, wealth index, birth order, and size of a child at birth. In this study, multivariate logistic regression and concentration index (CI) have been employed to explore the effect of various factors on the child's nutritional status. The binary logistic analysis has demonstrated a significant association between child nutritional status and mother's education, mother's nutritional status, type of caste, wealth index, birth order, and size of a child at birth. The results show that the CI for stunting, underweight, and wasting were −0.14, −0.16, and −0.08. Therefore, these factors were significantly high in poorer households. Our study suggests that the nutrition-specific programs to encourage nutritional adequacy, diversity, reduces the nutritional burden, and growth of child's in India.

***Keywords*:** India; Stunting; Wasting; Underweight; Logistic regression; Concentration index

ARTICLE INFO

Received: April 6, 2019
Accepted: May 28, 2019
Published: June 4, 2019

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CITATION

Mokalla TR, Mendu VVR. (2019). Risk factors and socioeconomic inequalities in undernutrition among children 0-59 months of age in India. *International Journal of Population Studies*, 5(2):14-23. doi: 10.18063/ijps.v5i2.1125

1. Introduction

Maternal and child undernutrition is highly prevalent in low- and middle-income counties (LMICs), resulting in substantial increases in morbidity, mortality, death, and overall disease burden (Black, Allen, Bhutta, *et al*., 2008; Hosangadi, Kaslow, Giersing, *et al*., 2019). It accounted for almost 97 million disability-adjusted years of life among under-five children, 98% of which occurred in LMICs (Islam, Rahman, Rahan *et al*., 2019). Child undernutrition in developing countries remains a significant cause for more than one-third of all child deaths under the age of five (United Nations Children Fund [UNICEF], 2011). Child malnutrition causes 3.5 million children under the age of five to die each year in the world at the third level in this age group's disease burden (Messelu and Trueha, 2016). Lack of food affects physical and intellectual growth, harms the immune system, increases morbidity and mortality possibilities (Uthman, 2012). Nutritional status stands as a result and impact indicator when assessing development in the direction of achieving the Sustainable Development Goal. Child mortality is remarkable in one of the world's problems, especially in the first 5 years of age, which is a problem for public health in African and Asian countries (Das, 2015).

India is the second largest populated country in the world. The country accounts for nearly a third of the global burden of stunting. Over 38%, or 46.6 million, children are stunted in India. While there are 51 million wasted children in the world, India alone houses 25 million (50%) of them. In 45% of under-five child mortalities, chronic malnutrition is the underlying factor (UNICEF, 2019). The term malnutrition comprises both undernutrition and overnutrition, and it is a significant factor causing child mortality around the world (Markos, 2014). Stunting, wasting, and underweight are three widely recognized indicators of a child's physical growth and to describe the nutritional status (Khan, Zaheer and Safdar, 2019; Akombi, Agho, Merom, *et al*., 2017). According to National Family Health Survey (NFHS-4), the percentage of children stunted, underweight, and wasting is 38%, 36%, and 21%, respectively, whose children aged 0-59 months (International Institute for Population Studies [IIPS], 2017).

Literature also indicates significant variations in specific risk factors for child malnutrition through the application of statistical models and several techniques (Kumar, Kumari and Singh, 2015; Messelu and Trueha, 2016; Mishra, Pandey, Chaubey, *et al.*, 2015; Corsi, Mejía-Guevara and Subramanian, 2015; Talukder, 2017; Boah, Azupogo, Amporfro *et al*., 2019; Kang and Kim, 2019; Alom, Amirul and Quddus, 2009). We have employed multiple logistic regression model(s) with binary outcomes and concentration index (CI) functions to examine the various determinants of under-nutrition and its associated risk factors in India using NFHS-4 data.

The three leading indices are used to measure the nutritional imbalance resulting in child undernutrition. Stunting (Short height for age) – is the reason for long-term nutritional inadequacy, which brings about reduced intellectual capacity, poor school execution, and delayed mental development. The results in exposure of a child to repetitive infections or diseases pose a higher risk for sickness and death, and it influences on financial productivity. In women, stunting leads to numerous obstetric intricacies as a result of a smaller pelvis. It makes them give birth to newborn children with low birth weights, and it causes infant growth which lean toward the shorter physical frame as adults (World Health Organization [WHO], 2010). Wasting (low weight for length/height) – is a symptom of acute undernutrition, which impairs the functions of the immune system. It exposes the child to infectious disease and an increased risk of death, which is also a result of insufficient food consumption or a high frequency of irresistible illnesses, particularly diarrhea (WHO, 2010). Underweight (low weight for age) – is a composite indicator of stunting and wasting, which is considered both acute and chronic malnutrition (Mishra, Pandey, Chaubey, *et al*, 2015). Literature has demonstrated that the mortality risk of underweight children increased (WHO, 2010)

According to the literature, child undernutrition was strongly associated with socioeconomic status such as mother's household status, education, and nutritional status, and demographic variables such as child age, birth duration, and child size at birth (Messelu and Trueha, 2016; Corsi, Mejía-Guevara and Subramanian, 2015; Talukder, 2017; Boah, Azupogo, Amporfro, *et al*., 2019; Kang and Kim, 2019; Alom, Amirul and Quddus, 2009; Dessie, Fentie, Abebe, *et al*., 2019; Mishra, Pandey, Chaubey, *et al*., 2015; Kumar, Kumari and Singh., 2015).

The present study aims to investigate the socio-economic, demographic, and health determinants associated with undernutrition among the under-five age of children from NFHS-4 data in India.

Therefore, the national level recent data (NFHS-4) of India are useful in understanding its causes, and to identify the determinants of undernutrition among the under-five age of children. We hope that these findings will be helpful for policymakers, researchers, and other stakeholders to formulate appropriate strategies for removing regional imbalance in terms of undernutrition in the nation and its differential attributes among Indian states.

2. Data and Methods

Data are used from a 4th round of the NFHS-4, conducted by 2015-2016 (IIPS, 2017). The survey was conducted and obtained information about population, nutrition, and health information from each of the 29 states, for each of the seven union territories, of the total 640 districts in the country in India. The NFHS-4 was conducted by interviewing randomly selected women aged 15-49 and men aged 15-54. Stratified 2-stage sampling was used as the sampling design for the NFHS-4 study. In the first stage, the primary sampling units were selected, and in the second stage, the households for the study were selected. Primary sampling units with at least 300 households were divided into segments of approximately 100-150 households. Two of the segments were selected using systematic sampling with probability proportional to size. From each selected rural and urban cluster, 22 households were selected using systematic sampling. A total of 628,900 households were selected for the sample, of which 616,346 were occupied. Of the occupied households, 601,509 were successfully interviewed, for a response rate of 9%. In the interviewed households, 723,875 eligible women age 15-49 were identified for individual women's interviews. Interviews were completed with 699,686 women, for a response rate of 97%. NFHS-4 first provided district-level estimates for several significant markers. For this study, we considered

anthropometric indicators of unit-level data of 209,377 (after excluding missing and flagged cases) children aged 0-59 months.

2.1. Dependent Variable

Three markers of height-for-age, weight-for-age, and weight-for-height z-scores provide a complete picture of children's severe undernourishment; subsequently, we utilized anthropometric information on these three-pointers to study the child undernutrition. To estimate all three markers, we embraced another reference population of the WHO 2006 (Multicenter Growth Reference Study Group, 2006). As indicated by the WHO rules, if height-for-age Z-score of a child is <2 standard deviations (SDs), weight-for-age Z-score of a child <2 SDs, and weight-for-height Z-score of a child <2 SDs then the child is classified as stunted, underweight, and wasted, respectively. Thus, these three nutritional indices are treated as dependent variables and dichotomized. While those that were malnourished (Z- score below −2 SD) were coded as one and nourished children (Z- score above −2 SD) were coded as 0.

2.2. Independent Variable

Three classes of elements were evaluated as independent factors; First, socio-economic and demographic variables such as wealth index (poorest, poorer, middle, richer, and richest), and religion (Scheduled Caste, Scheduled Tribe, Other Backward Class, and Other caste) are taken into consideration. Second, child characteristics such as child age in months (0-6, 7-12, 13-24, and 25-59), birth order (1, 2, 3, 4, and above), and size at birth (average, small, and large) are taken. Third, maternal characteristics considered (Maternal age 15-49 years), maternal nutritional status (underweight: Body mass index [BMI] <18.5, normal/healthy weight: 18.5 <BMI <25, and overweight/obese BMI >25.0), and mother's education (No education, <5 years education, 5-7 years, 8-9 years, 10-11 years, 12 years or more) are considered. For the independent variable child age, 0-6 months were taken as the reference category for stunting and underweight (Khan, Zaheer and Safdar, 2019). For wasting, the reference category was chosen as 25-59 months since children aged 0-6, 7-12, and 13-24 months age group are the most affected by wasting and severe wasting (Akombi, Agho, Merom, *et al*., 2017).

2.3. Statistical Analysis

2.3.1. Logistic regression

The binary logistic regression analysis was carried out to identify the factors associated with child malnutrition. Odds ratio with 95% confidence interval was used to study the effect of independent variables (namely, child age in months, mother's educational status, mother's nutritional status, type of caste, wealth index, birth order, and size of a child at birth) on dependent variables being the three indicators of nutritional status (stunting, wasting, and underweight) (Bewick, Cheek and Ball, 2005). This analysis was performed utilizing the Statistical Package for the Social Sciences (SPSS), version 19.0 software.

2.3.2. CI

It quantifies socio-economic inequality and CI for nutritional status. It can be described utilizing the concentration curve, (Y-axis) which determines the cumulative percentage of undernourished children, whereas (X-axis) determines the total percentage of children ranked by household wealth status, and it begins with the poorest wealth quintile to the richest wealth quintile. When "y" takes on higher quality for poorer people, the concentration curve lies above the equality line. If the "y" takes lower confidence, the reverse is true, the health concentration curve lies below the equality line. The CI is termed as positive when the concentration curve lies below the diagonal and negative when it lies above the diagonal. Thus, the minimum and maximum value that CI assumes is −1 and +1 (Wagstaff, Paci and van Doorslaer, 1991; Giashuddin, Rahman, Rahman, *et al*., 2009; Kumar, Kumari and Singh *et al*., 2015). We calculated the corresponding indices and their CI, by the following formula for the grouped data case.

$$C = (p_1 L_2 - p_2 L_1) + (p_2 L_3 - p_3 L_2) + \ldots + (p_{T\text{-}1} L_T - p_T L_{T\text{-}1})$$

Where p is the cumulative percent of the sample ranked by economic status, L(p) is the corresponding concentration curve ordinate, and T is the number of socio-economic groups (O'Donnell, van Doorslaer, Wagstaff, *et al*., 2008; Zere, Tumusiime, Walker, *et al*., 2010).

3. Results

3.1. Descriptive Statistics

The descriptive results are presented in Table 1. In all the data about (248,174), children in the age group of 0-59 months were analyzed. Among them, 20% of children were stunted in the age group 0-6 months and steadily increased to 42% in the age group of 25-59 months. This indicates that the rate of stunting is found to be higher as the age increases, similar patterns in underweight. About half of the stunted children had mothers with no education, 45% of the children had mothers with <5 years of education. Furthermore, a similar pattern was observed among the underweight and wasted children.

The prevalence of stunted, underweight, and wasting children is declining with the rise in mother's education. Over 50% of children in the poorest households were stunted, and it was 23% among the higher economic group. The frequency of stunted children in the scheduled caste is 44%, and it is decreased to 31% in general caste or other castes. Furthermore, the same was observed in underweight and wasting. About 49%, 43%, and 22% of the children were stunted, underweight, and wasting of forth or more birth order was decreased in the birth order one. Nearly 44% of the children belonging to the scheduled cast were stunted; the prevalence of stunted children in the other caste groups was around 31%. Underweight and wasted children were more among scheduled castes, and the prevalence was quite low among the other caste groups: 47%, 48%, and 27% of the children whose mother's nutritional status was BMI <18.50 were stunted, underweight, and wasted. The nutritional status of children was less common among the children's mothers' BMI >25.0. The prevalence of stunting, underweight, and wasting decreases as the mother's nutritional status increases. The Chi-square test performed on all selected categorical variables were found significantly related to the nutritional health status of the children

3.2. Multiple Logistic Regression Analysis

3.2.1. Risk factors for stunting

As shown in Table 2, it is noted that the odds of being stunted increased after the first 6 months of life. Children in the age group of 25-59 were 3 times more likely to be stunted when compared to the children in the age group of 0-6 months. Children in the age group of 13-24 months, 7-12 months age were 3 and 1.4 times more likely to be stunted, respectively. Children with small size (lower weight) at birth were 1.5 times more likely to be stunted than children with large size (heavier weight) at birth. Children with a higher birth order were more likely to be stunted than those having lower birth order. Children with birth order four and above had 1.3 times more chances of being a shorter height for their age.

The odds ratios reduced with the increase in mother's education. Illiterate mothers were twice as more likely to be stunted as compared to children of literate mothers whose education is of 12 years or more and similar to the mother's nutritional status. Children, whose mothers' BMI was below normal, were 1.2 times more likely to be suffering from chronic malnutrition as compared to those children whose BMI was normal. Children belonging to the poorest families are facing twice the risk of being stunted as compared to those belonging to richest families. Scheduled caste/tribes and other backward class families were more likely to have stunted children than other castes.

3.2.2. Risk factors for underweight

From Table 2, it was found that the factor approaching as the most reliable determinant was households' wealth index. Specifically, there exists an inverse relationship between the wealth quintile and the child's nutritional status. The household with the poorest wealth status was twice more likely to have underweight children as compared to the households which belong to the richest wealth quintile. Furthermore, it was in the mother's nutritional and educational status. Children with mother's nutrition (BMI <18.50) had 1.6 times the risk of being underweight than those whose mothers who were well-nourished and the same as the risk of having malnourished children than whose mothers had an education of 12 years or more.

The present study showed that the possibility of being underweight increased with an increase in the child's age. Among the children, age group of 25-59-months, the odds ratio for underweight was 2 times than children in the 0-6 month's age group. Children with a smaller size at birth were 1.7 times more likely to be thinner for their age than children with a larger size at birth. Taking caste into consideration, children belonging to the scheduled caste and those belonging to other backward classes were 1.3 times more likely to be underweight. Children having birth order four and above were more prone to be underweight as compared to children having birth order 1.

Table 1. Sample distribution and prevalence of stunting, underweight, and wasting children between the ages of 0 and 59 month's children (2, 48, and 174) by factors at different levels, based on NFHS-4 of samples.

Variables	n	%	Stunting	Underweight	Wasting
Age in months			(6124.75)*	(1490.77)*	(1985.74)*
0-6	23,768	9.6	20.3	26.2	29.4
7-12	23,528	9.5	25.5	28.9	25.9
13-24	46,488	18.7	43.7	34.7	20.9
25-59	139,271	56.1	42.3	37.4	18.1
Missing	15,119	6.1			
Size at birth			(833.19)*	(1402.74)*	(279.33)*
Large	42,073	17.0	35	31.2	19.6
Average size	169,966	68.5	38.1	34	20.2
Small size	29,960	12.1	46	44.7	24.5
Missing	6175	2.5			
Birth order			(2542.13)*	(1686.56)*	(47.90)*
1	92,026	37.1	34	31	20
2	76,094	30.7	37.2	33.8	20.2
3	39,766	16.0	42.2	38	21.3
4 and above	40,288	16.2	48.7	42.6	21.5
Mother's nutritional status			(3161.16)*	(7274.44)*	(2411.05)*
BMI <18.45	58,165	23.4	46.6	48.2	26.9
BMI 18.5<BMI <25.0	151,571	61.1	38.7	33.1	19.9
BMI >25.0	34,451	13.9	27.3	20.4	13.1
Missing	3987	1.6			
Wealth index			(9006.39)*	(9445.96)*	(1123.86)*
Poorest	65,229	26.3	51	48.2	24.9
Poorer	58,870	23.7	43.1	38.2	21
Middle	49,648	20.0	36.1	31.2	19.2
Richer	41,207	16.6	29.4	26.1	18.2
Richest	33,220	13.4	22.6	19.8	16.8
Mothers education			(8419.24)*	(7836.10)*	(560.43)*
No education	77,603	31.3	49.7	45.6	23.2
<5 years education	15,841	6.4	45	39.7	20.9
5-7 years education	40,097	16.2	40.5	36.6	21
8-9 years education	44,222	17.8	35.3	31.3	19.6
10-11 years education	27,223	11.0	30	27.1	19
12 years or more	43,188	17.4	24.1	21.2	17.6
Caste/tribe			(1538.89)*	(1624.13)*	(240.69)*
SC	46,845	18.9	43.6	39.9	21.9
ST	49,544	20.0	39.9	35.1	21.8
OBC	97,529	39.3	39.7	36.6	21
Other caste	43,191	17.4	30.8	27.1	18
Missing	11,065	4.5			

Figures in parenthesis are the Chi-square statistics; χ^2 test applied for each factor. Level of significance: $*p < 0.01$.

Table 2. Effects of explanatory variables on child nutritional status (95% CI; binary logistic regression models, estimators for the selected attributes) among children (209,377) aged 0-59 months NFHS-4.

Variables	Stunting		Underweight		Wasting	
	OR	95% C.I.	OR	95%C.I.	OR	95% C.I
Age in months						
0-6	1.00		1.00		1.89	1.83-1.96
7-12	1.35	1.28-1.41	1.11	1.06-1.16	1.55	1.50-1.60
13-24	3.17	3.05-3.30	1.48	1.42-1.54	1.17	1.13-1.20
25-59	2.94	2.84-3.05	1.70	1.65-1.76	1.00	
Size at birth						
Large	1.00		1.00		1.00	
Average Size	1.09	1.07-1.24	1.09	1.06-1.12	1.02	0.99-1.05
Small size	1.47	1.42-1.52	1.65	1.59-1.71	1.26	1.21-1.31
Birth order						
1	1.00		1.00		1.00	
2	1.08	1.06-1.11	1.08	1.06-1.10	1.03	1.00-1.05
3	1.15	1.11-1.18	1.12	1.09-1.15	1.02	0.98-1.05
4 and above	1.27	1.23-1.30	1.15	1.12-1.18	0.97	0.94-1.01
Mother's nutritional status						
BMI <18.5	1.24	1.21-1.26	1.67	1.63-1.70	1.43	1.39-1.46
BMI 18.5<BMI <25.0	1.00		1.00		1.00	
BMI >25.0	0.77	0.75-0.80	0.66	0.641-0.68	0.68	0.66-0.71
Mothers education						
No education	1.71	1.65-1.78	1.67	1.61-1.72	1.15	1.10-1.19
<5 years education	1.54	1.47-1.61	1.47	1.40-1.54	1.04	0.99-1.10
5-7 years education	1.44	1.39-1.49	1.41	1.37-1.47	1.08	1.04-1.13
8-9 education	1.28	1.24-1.32	1.25	1.20-1.29	1.02	0.98-1.07
10-11 education	1.15	1.10-1.19	1.16	1.11-1.20	1.05	1.00-1.09
12 years or more	1.00		1.00		1.00	
Wealth index						
Poorest	2.14	2.05-2.22	2.11	2.02-2.19	1.25	1.19-1.30
Poorer	1.77	1.70-1.84	1.62	1.56-1.68	1.06	1.01-1.10
Middle	1.48	1.43-1.54	1.35	1.30-1.40	1.01	0.97-1.05
Richer	1.22	1.17-1.26	1.19	1.14-1.23	1.01	0.97-1.05
Richest	1.00		1.00		1.00	
Caste/tribe						
SC	1.29	1.25-1.33	1.29	1.25-1.33	1.11	1.07-1.15
ST	1.04	1.01-1.07	0.99	0.96-1.03	1.10	1.05-1.14
OBC	1.21	1.18-1.24	1.25	1.21-1.28	1.10	1.06-1.13
Other caste	1.00		1.00		1.00	
Constant	0.08		0.18		0.16	

For the factor child's age in months, for stunting and underweight, reference was taken as 0-6 months and for wasting, reference was taken as 25-59 months. CI: Confidence interval and OR: Odds ratio.

3.2.3. Risk factors for wasting

As shown in Table 2, the strongest determinant of acute malnutrition is identified as the mother's nutritional status. The children whose mother's BMI is below normal (BMI <18.5) were at higher risk of being wasted than those of children

whose mother's BMI is normal. Later it was observed that there was an inverse relationship between children's age and wasting, thus the odds ratio for wasting decreased with an increase in the child age. Among the children in the age group of 25-59 months were twice likely to be wasted than those of the age group between 0 and 6 months. Wasting has an inverse relationship with the mother's educational status and household wealth index. Children of mothers whose educational level is <5 years were 1.2 times more likely to have wasted than children of mothers whose level of education is 12 years or more. The odds of having acute malnutrition were 1.3 times more among the children belonging to the poorest family as compared to their reference. In comparison to the child belonging to other castes, SC, ST, and OBC were prone to be wasted. Babies born with smaller size were 1.3 times more possible to be wasted than that of babies born with the larger size

3.3. CI

The CI for stunting was −0.14 (standard error SE = 0.04), and a negative value indicates that the higher probability of being stunted is seen in poor children than their better-off peers. Similarly, the CI for underweight and wasting was observed as −0.16 (SE = 0.04) and −0.08 (SE = 0.02). These negative values imply that poor children had a higher probability than their better-off peers in underweight and wasting.

Similarly, the concentration curve for stunting, underweight, and wasting in India for the year of 2015-2016, respectively is, represented in Figure 1. The plot shows that the concentration curve for all three nutritional indices lie above the line of equality, which suggests that the burden of malnutrition was higher among the under-five aged children who have poorer wealth index. The negative sign of the CI (Table 3) also confirms this graphical exploration of inequality in child undernutrition.

4. Discussion

This study identified that the risk factors associated with child malnutrition are in terms of stunting, underweight, and wasting among 0-59 month's age children in India using the NFHS-4 data. Our study revealed that the factors (Child's age

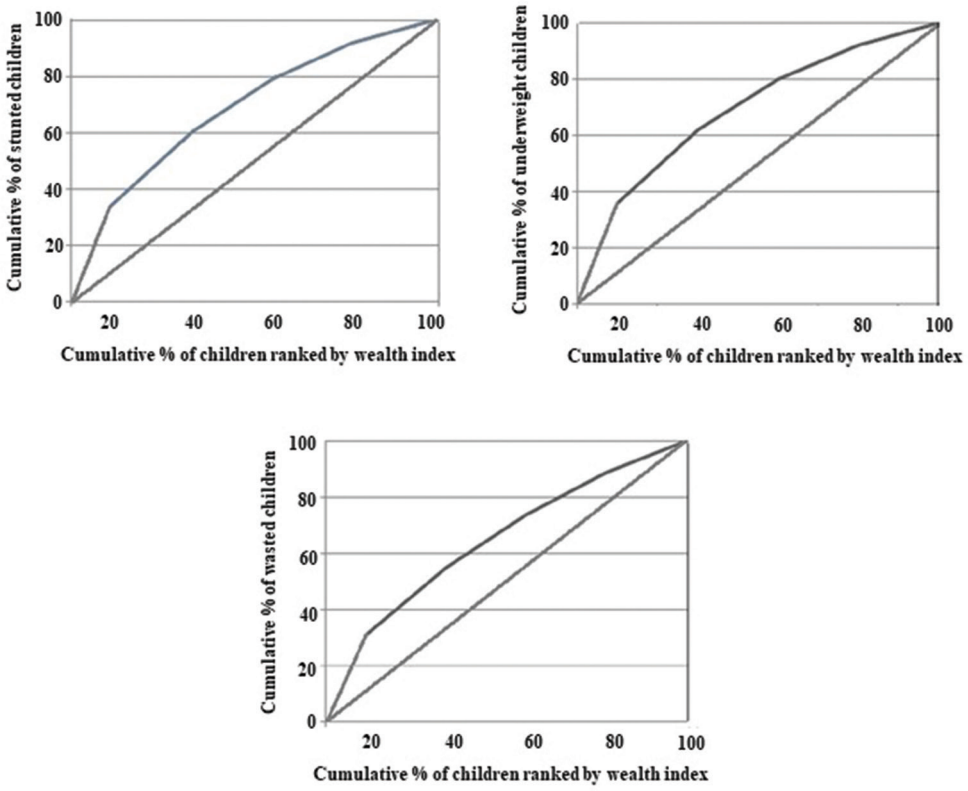

Figure 1. Concentration curves for the child malnutrition (Stunting, underweight, and wasting), India 2015-2016.

Table 3. Child stunting, underweight and wasting prevalence and socio-economic quintile stunting, underweight, and wasting prevalence, %, per quintile) among children (248,174) aged 0-59 months.

	Poorest	Poorer	Middle	Richer	Richest	Concentration index	SE(CI)
Stunting	51.0	43.0	36.0	29.0	23.0	−0.14	0.038
Underweight	48.0	38.0	31.0	26.0	20.0	−0.16	0.038
Wasting	25.0	21.0	19.0	18.0	17.0	−0.08	0.016

SE: Standard error.

in months, mother's education, size of a child at birth, wealth index, type of caste, and mother's nutritional status) have a significant association with child nutritional status. Child's age in months emerged as one of the strongest determinants of the nutritional status of children. In the first 6 months of life, stunting and underweight children were least and, it increased with the increase in age. Similar findings, along with other child health-related indicators, were reported from India (Singh, Srivastava and Upadhyay, 2019; Mishra, Pandey, Chaubey, *et al*. 2015; Vir, 2013). In malnourishment, the size of a newborn baby at birth plays a significant role. This study reveals that children have the least risk of being malnourished if they were born healthy and large size at birth when compared to children who were born weak (Rahman and Sultana, 2019; Prado and Dewey, 2014). A child with higher birth orders is at a greater risk of being severely undernourished. It may occur due to lack of food supplementation to the children (Rahman, 2016).

Household's economic status also affects child malnutrition. In this study, we observed that odds of being stunted, underweight, and wasted were significantly higher among children with the lowest socio-economic background. Since these lower-income families are having limited access to food, health services and unable to fulfill the basic needs of children, which effects in growth and development of children (Agrawal, Farrell, Wethington, *et al*., 2019; Singh, Srivastava and Upadhyay, 2019). A child's nutritional status is likely to be affected by a mother's educational and nutritional status. This study shows that children of mothers with no education were more likely to be severely malnourished (stunted, underweight, and wasted) as compared to children whose mothers are educated. Hence, an association was found between maternal education and child nutritional status, which is consistent with several previous studies (Mishra, Pandey, Chaubey, *et al.*, 2015; Khan, Zaheer and Safdar, 2019). Educated mothers are well aware of the nutritional requirements of infants, also make comparative choices of existing health services over traditional practices for improved health care of their children. Hence, they are capable of taking proper care as compared to illiterate mothers, who may contribute to the increase in malnourished children (Banerjee, Alok, Lakhtakia, *et al*., 2019; Hetherington and McNally, 2020). Hence, these maternal characteristics should be carefully examined for executing proper interventions to reduce the burden of child malnutrition status in India.

The present study also established a strong association between the child's and the mother's nutritional status. Healthy mothers (children whose mothers BMI is not below normal) were more likely to produce healthy and well-nourished children as compared to the unhealthy and weak undernourished mothers. Therefore, the risk of stunting, underweight, and wasting was higher in those children whose mothers' BMI was below normal. Social characteristics were also one of the significant determinants of child malnutrition other than demographic characteristics. Hence, mothers belonging to the scheduled castes or tribes were more likely to have malnourished children than those who are not from any of the sub-classes mentioned.

5. Conclusions

According to the findings, the poorest family children were associated with an increased risk of undernutrition when compared to the wealthiest of children. Child undernutrition causes the poorer family to bear an extra burden, resulting in more illnesses in additions to infectious and non-communicable diseases. There is an immediate need to establish services to low-income families to avoid child malnutrition. In the health sector, priority should be given to current programs for children suffering undernutrition, as well as for the most deprived group of families. The findings of this study illustrate the need to increase the level of education of parents, to improve the nutritional status of the mother and therefore achieve better nutritional status among under-five children in India.

Acknowledgments

The authors gratefully acknowledge the financial support and fellowship granted by the National Institute of Nutrition (NIN), Indian Council of Medical Research, Hyderabad, India, for carrying out the study. The authors wish to thank

Dr. R Hemalatha (Director, NIN) for her encouragement, Dr. Subbarao M Gavaravarapu, Mr. K. Venkaiah and Dr. N. Bala Krishna for their insightful inputs. The authors would also like to thank Dr. Ramesh Athe (Assistant Professor, IIT Dharwad), Prof V. V. Haragopal (retd), Mounika Kandukuri (DST-INSPIRE Fellow) from Department of Statistics, Osmania University and Ungarala Venkat Ramakrishna (Research Scholar) from NIN.

Authors' Contributions

Thirupathi Reddy M contributed in the data collection, analysis, and manuscript preparation. Vishnu Vardhana Rao M developed the study protocol, secured funds, supervised the study, and guided in manuscript preparation.

Conflicts of Interest

There are no conflicts of interest associated with this work.

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International Journal of Population Studies

RESEARCH ARTICLE

Maternal characteristics and the risk of neonatal mortality in Brazil between 2006 and 2016

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ARTICLE INFO

Received: May 13, 2019
Accepted: June 29, 2019
Published: July 6, 2019

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CITATION

Costa PH, Alves LC, Beluzo CE, Arruda NM, Bresan RC, Carvalho T. (2019). Maternal characteristics and the risk of neonatal mortality in Brazil between 2006 and 2016. *International Journal of Population Studies*, 5(2):24-33. doi: 10.18063/ijps.v5i2.1130

Abstract: Neonatal deaths account for more than 60% of infant deaths and are a major concern in Brazil. The reduction of the occurrence of these events appears to be more challenging than post-neonatal deaths, as such a reduction depends more on factors related to the pregnancy and childbirth than sanitary and health conditions. The aim of the present study was to evaluate the influence of maternal factors (schooling, marital status, and age) on the risk of neonatal mortality in Brazil between 2006 and 2016. Data were collected from the Brazilian Institute of Geography and Statistics as well as two information systems of the public health-care system: Mortality Information System and Live Birth Information System. The total valid sample size was 28,362,359 children. Visualization and classification methods were performed. The results revealed a considerably higher risk of neonatal deaths when the mothers were unmarried, had a low level of schooling, and were outside the 20-34-year-old age group. Different demographic profiles in Brazil exert an influence on neonatal health. The identification of the risk factors of neonatal mortality can assist in ensuring pregnancy, delivery, and a neonatal period of greater quality.

Keywords: Infant mortality; Neonatal mortality; Maternal age; Risk factors; Brazil

1. Introduction

The infant mortality rate (IMR) is considered one of the best indicators of a population's standard of living and social well-being. The decline in this rate constitutes a remarkable success of governments, civil society, and academia and health professionals in the past two centuries. Global mortality has declined 5 times in the past 65 years, reaching 4.5% in 2015. Particularly in Brazil, the reduction was greater than 10 times in the same period (World Bank, 2019). Nonetheless, disparities between developed and developing countries demonstrate that there is much work left to do. The fact that mortality rates in developing countries can be 10 times higher than those in developed countries is proof that we are dealing with a high percentage of avoidable deaths.

A reduction in child mortality rates is listed as one of United Nations (UN) Sustainable Development Goals for 2030 (UN Resolution, 2015) and was also listed as one of UN's Millennium Development Goals for 2015, which aimed to reduce Child Mortality Rates by two-thirds between 1990 and 2015, a goal that Brazil achieved in 2011. The global IMR declined from 65 deaths per 1000 live births in 1990 to less than 30 by 2018, which is a considerable improvement, but still far from the rate considered acceptable by the World Health Organization (WHO), which is 12 neonatal deaths per 1000 live births by 2030.

This will be significant, as almost half of these under-five deaths are newborns whose deaths can be prevented through higher coverage of quality prenatal care, skilled care at birth, postnatal care for both the mother and infant and the care of small, sick newborns (UN IGME, 2019), that is, conditions that could be prevented or treated with access to simple, low-cost interventions. These avoidable deaths are one of the focuses of the UN goals for 2030 (WHO, 2020; ODS, 2020; Golding *et al.,* 2017).

Monitoring infant mortality and associated risk factors are essential to evaluating public policy and development. This measure is a strong indicator of socioeconomic conditions, such as poverty, access to education and health services (Gaiva, Fujimori and Sato, 2015; Carvalho *et al.,* 2020). A study on the determinants of infant mortality can be of considerable help to the better targeting of public policy funding, which is increasingly possible through online platforms that make data available, such as DATASUS, which is a Department of Brazilian Health Ministry responsible for collecting, processing, and disseminating public health data.

In Brazil, the IMR has undergone a continual decrease in the recent decades, mainly due to the reduction in post-neonatal deaths (those occurring between 28 days and 1 year) and improvements in sanitary conditions. The share of post-neonatal deaths among total infant deaths declined from 51% in 1990 to 38% in 2015 (IGME, 2020). Neonatal mortality (deaths occuring less than 28 days), which is the main component of the IMR in Brazil, has also been following a declining trend, mainly due to favorable changes in factors related to pregnancy and childbirth, despite the increase of its shared proportion. Neonatal mortality is harder to address and extends to the perinatal period (Duarte, 2007; Carvalho *et al.*, 2020). Indeed, neonatal mortality has become the biggest challenge in fighting infant mortality, as it currently corresponds to the majority of such deaths and involves various biological, socioeconomic, and health-care factors. Neonatal mortality rates (NMR) have decreased but have also become the focus of public policies on infant mortality due to its proportion of the global IMR. The greater availability and the quality of health data in Brazil have enabled more precise analyses of this issue on a nationwide scale. This availability of data and the increasing importance of neonatal deaths on infant mortality have led to a significant number of studies covering different factors, regions, and methods concerning neonatal deaths.

The aim of the present study is to investigate the maternal factors associated with neonatal mortality by employing the framework proposed by Mosley and Chen (2003), using a hierarchical model based on the hypothesis that socioeconomic factors determine behaviors that exert an impact on biological factors. In their influential paper, Mosley and Chen argue that mortality studies usually have a bias toward the social or biological approach, isolating the external determinants according to the field of study. Therefore, even if biological factors are directly responsible for deaths, this information may be insufficient regarding the establishment of adequate recommendations and effective public policies. Maternal characteristics also have the advantage of being available earlier compared to childbirth or pregnancy-related factors. Moreover, some studies have shown the predictive power of these factors in affecting the IMR (Fonseca, Flores, Camargo Jr. *et al*., 2017; Bertoldi *et al*., 2019).

This study offers an analysis and discussion of neonatal mortality in Brazil considering a broader perspective available through a nationwide sample, using data visualization techniques and classifications to summarize the results. The aim is to help predict the risk of neonatal mortality in Brazil by evaluating important characteristics related to the mother and considering the period between 2006 and 2016.

2. Materials and Methods

An observational, retrospective, and cohort study was conducted with secondary data on births and deaths of infants in Brazil between 2006 and 2016. Data were obtained from two sources: *Sistema de Informação sobre Mortalidade* (SIM [Mortality Information System]) and *Sistema de Informação sobre Nascidos Vivos* (SINASC [Live Birth Information System]), both of which are available through DATASUS (Health Informatics Department of the Brazilian Ministry of Health) and the *Instituto Brasileiro de Geografia e Estatística* (IBGE [Brazilian Institute of Geography and Statistics]). Figure 1 illustrates the linkage process between the two datasets (SIM and SINASC) concerning the characteristics selected for this study as well as the data selection process. The main problem is the availability of a standard variable between the two datasets to enable successful merging. The standard variable Declaration of Live Birth Number (NUMERODN) was only available in 36.5% of the cases (197,971 out of 543,437 deaths), despite the fact that filling in this information is mandatory. From this percentage, it was possible to link 95% of the cases, resulting in a large dataset. Some entries were also excluded due to inaccurate data (such as extreme outliers of age – above 90 years). The final sample was 28,362,359 children, representing 151,473 neonatal deaths records. Moreover, the datasets are unbalanced, i.e., the percentage of death class samples outnumbers the percentage of living class samples.

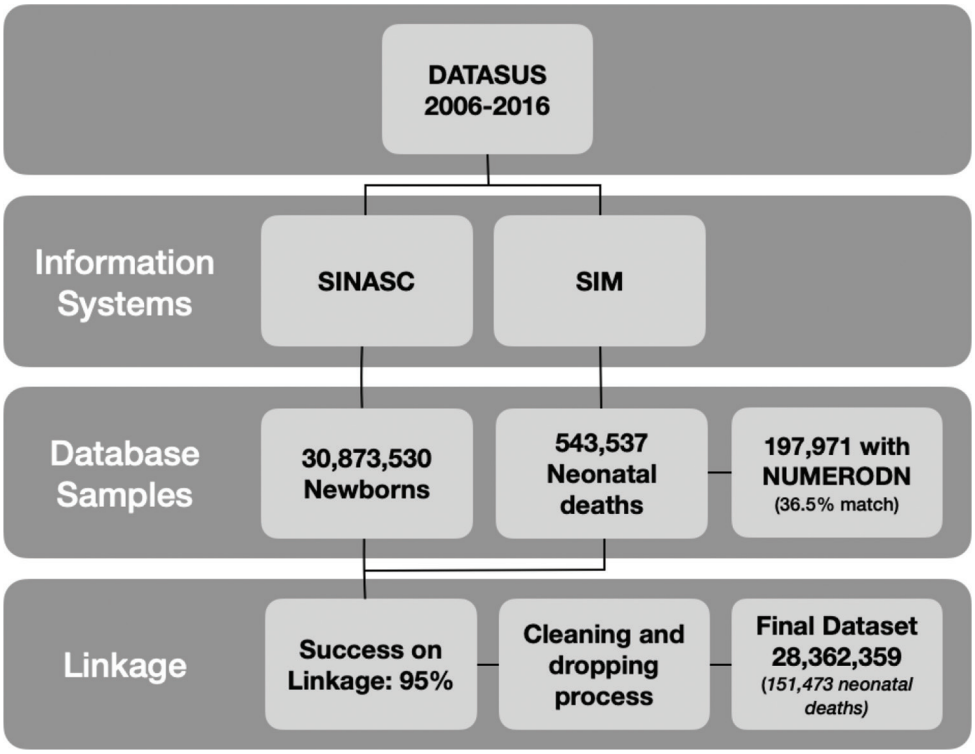

Figure 1. Flowchart of linkage process with data from SIM and SINASC, Brazil.

For the present investigation, we considered the following maternal characteristics: age (10-14, 15-19, 20-24, 25-29, 30-34, 35-39, 40-44, 45-49, 50, or more years), schooling (0, 1-3, 4-7, 8-11, 12, or more years of study), marital status (single, married/stable relationship, widowed, and separated/divorced), and race/skin color (white, black/brown, and yellow/indigenous). About 50% of newborns had missing data on race/skin color and were therefore excluded from the analysis.

Descriptive statistics were performed for all variables analyzed in the study. The NMR was estimated by dividing the number of deaths of infants less than 28 days of age by the number of live births per 1,000. Decision trees constitute a method for identifying homogenous subgroups of the population. As only three categorical variables were used in the present study, we created three decision trees through a descriptive analysis between the NMR and the following combinations: marital status and years of schooling, age and marital status, and years of schooling and age. Each of the visualizations enables identifying the relationship between a variable and the NMR and the relationship between two variables combined and the NMR, resulting in a more specific classification. The other visualization methods used were line graphs, bar plots, and boxplots.

The methods used to treat the data and produce visualizations were the Python programming language (3.6) along with the Pandas, Matplotlib, and Seaborn modules. LibreOffice Calc and Google Drawings were used for the displays.

3. Results

Between 2006 and 2016, a considerable decrease in infant mortality occurred in Brazil. However, while the post-neonatal mortality dropped by 27%, neonatal mortality decreased by only 20% in the same period, reaching the nine deaths per every 1,000 births, as shown in Figure 2.

Figure 3 shows the descriptive characteristics of births in Brazil between 2006 and 2016 and the NMR according to mother's age, schooling, and marital status. Most mothers had 8-11 years of schooling (50.5%) and, despite the difference, mortality rates were similar for mothers with 1-11 years of schooling, whereas mortality rates decreased notably when mothers had 12 or more years of schooling, which corresponded to 16.2% of the sample. Although a small part of the population (1.3%), mothers with no education had a much higher risk of losing their infants in the first 28 days, with a rate at least 18% higher in comparison to the other groups.

In the dataset, the percentage of missing data on marital status was less than 2%. Unmarried women surpassed married women and those in a stable relationship, accounting for 61.2% of the total. The risk of neonatal mortality was lower when the mothers were married or in a stable relationship.

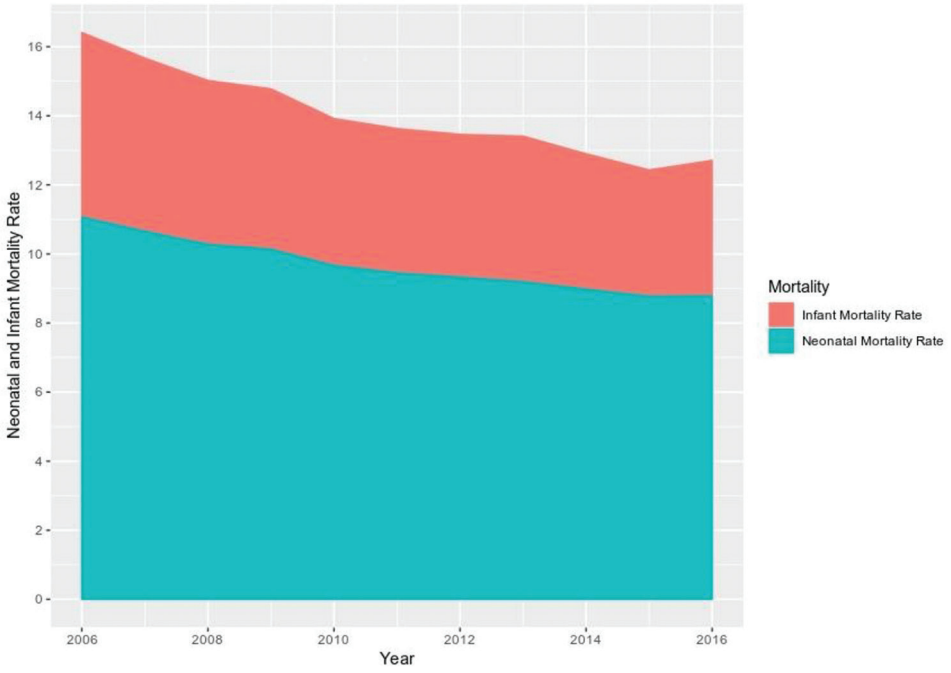

Figure 2. Neonatal mortality rate and infant mortality rate, Brazil, 2006-2016. Source: IBGE (2006-2016).

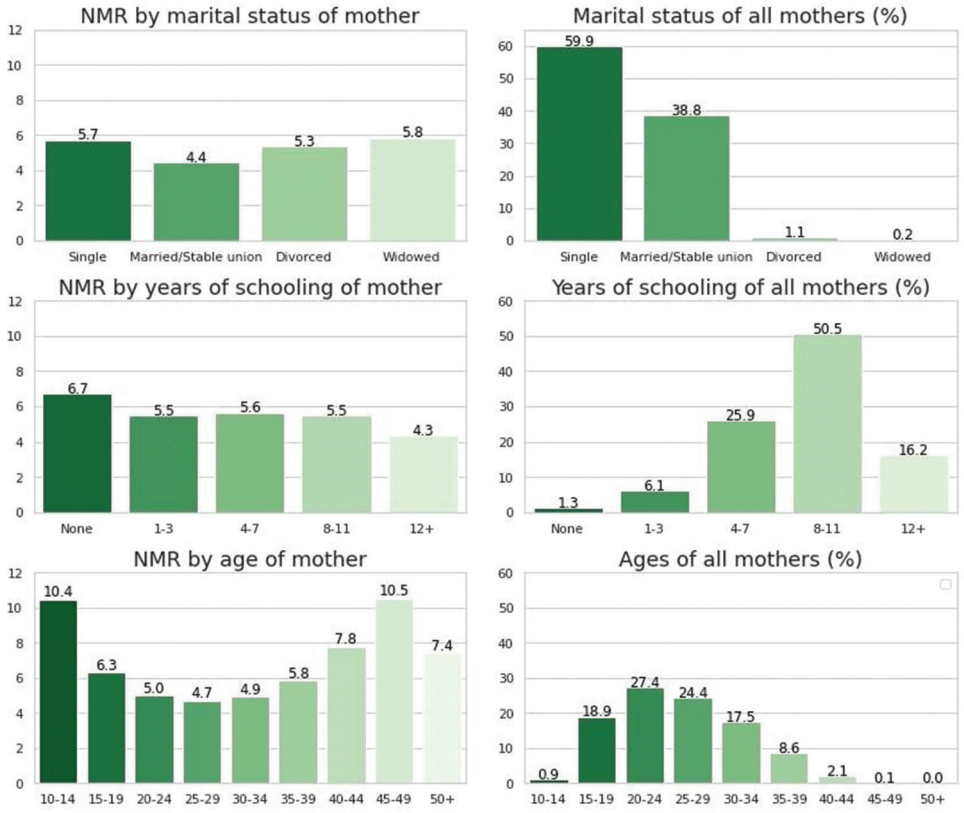

Figure 3. Neonatal mortality rate and descriptive characteristics of births according to mother's age, schooling, and marital status, Brazil, 2006-2016. Source: SIM, SINASC, 2006-2016. NMR: per 1,000.

Most births (69.3%) were concentrated in the 20-34 years old age and the risk of neonatal death was lower in this group. The lowest NMR was found in the group of mothers between 25 and 29 years of age. The choice of having children later in life due to cultural and career changes in the lives of women has pushed the average age of childbirth higher. Mothers less than 15 years of age and those older than 40 years had the highest risks of neonatal mortality.

The boxplot on Figure 4 shows how the standard deviation is increased in the neonatal death group, even though the large amount of women 20-34 years of age strongly pushes the average to a center and the deviation to a smaller range. As 69.3% of the mothers were between 20 and 34 years old, the standard deviation shift is high. No differences were found in median age and mean age between the neonatal death group and the all mothers group.

The last visualizations (Figures 5) are three decision trees (James, Witten, Hastie *et al.*, 2003). The middle boxes contain the NMR and the percentage of the group within the sample. The node boxes on the right contain only the NMR for each combined feature. The results reveal higher NMRs among older mothers, unmarried mothers, and those with no schooling compared to mothers younger than 35 years of age, married mothers, and those with 12 or more years of schooling. The NMR was 17% higher among unmarried mothers compared to married mothers. In the analysis of combined features, the NMRs were higher among older mothers even when they had a higher level of schooling. These higher rates among older mothers were similar to those found among younger mothers with no schooling, suggesting an important influence of extremes of age on neonatal mortality in Brazil. In the analysis of marital status and mother's age, higher NMRs were found among older (35 years or more) unmarried mothers. The NMR was also high in youngest group (10-19 years of age) and this result was more unfavorable among unmarried mothers. Indeed, the NMR was higher among unmarried mothers in all age groups. In the analysis of schooling and marital status, higher NMRs were found among married and unmarried mothers without schooling, with higher rates found among the married mothers. The lowest NMR (4.16) was found among married mothers with 12 or more years of schooling. The majority of mothers (82.1%) had between 1 and 11 years of schooling. In this group, the NMR was lower among the married mothers (5.31) compared to unmarried mothers (6.0). This decision tree also showed that the mothers with no schooling only accounted for 1.3% of the sample. Although this proportion is small, it represents nearly 2,600 neonatal deaths.

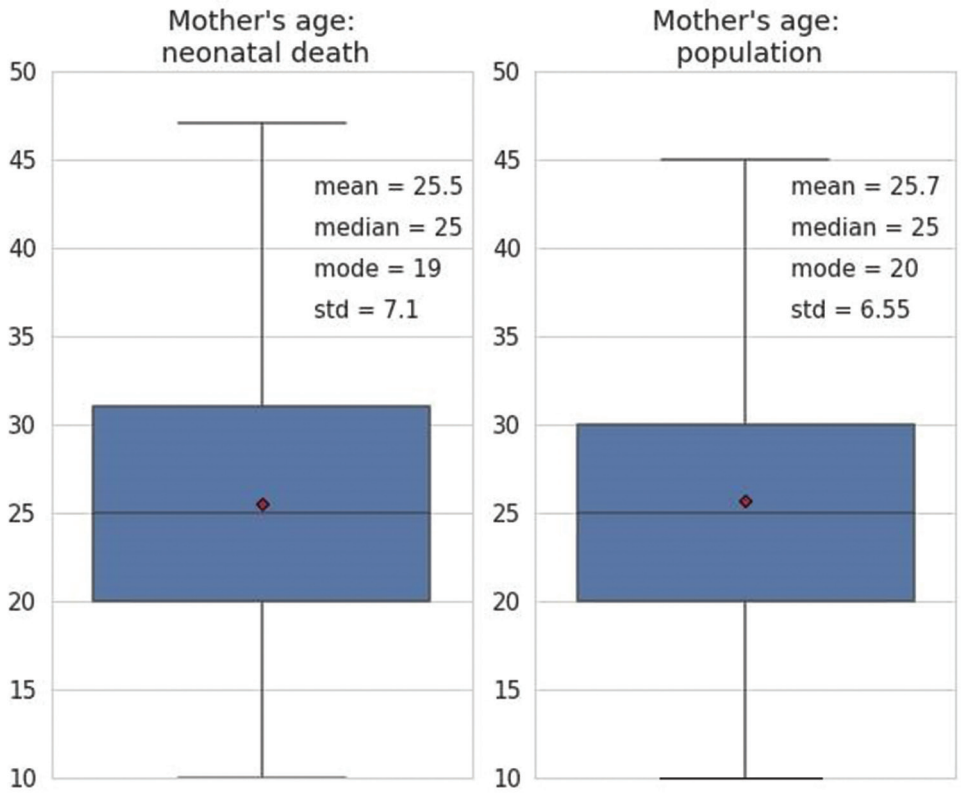

Figure 4. Boxplots of the mother's age at childbirth, Brazil, 2006-2016. Source: SIM, SINASC, 2006-2016.

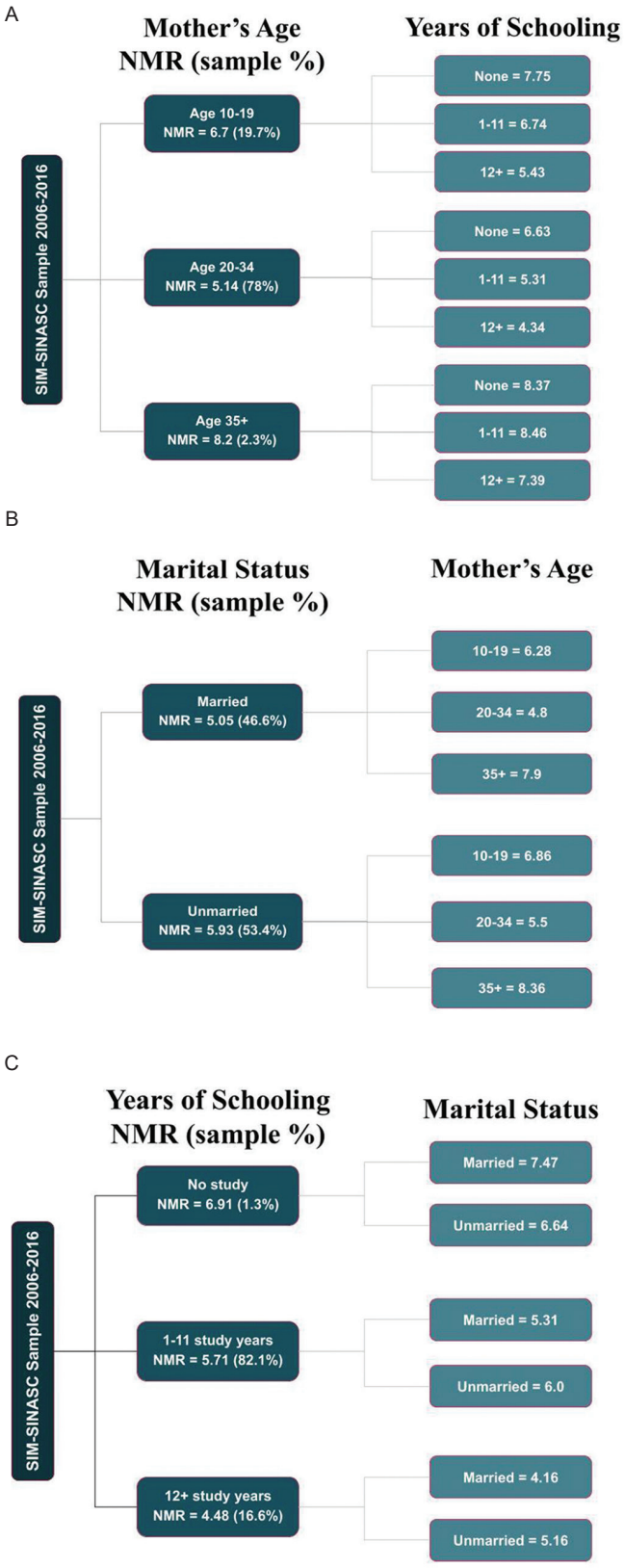

Figure 5. (A-C) Decision trees combining neonatal mortality risk for years of schooling, age, and marital status, Brazil, 2006-2016. Source: SIM, SINASC, 2006-2016.

4. Discussion

In this study, we examined the risk of neonatal mortality according to the maternal characteristics in Brazil between 2006 and 2016. Using the decision trees, we measured the effect of different characteristics on the NMR. Combining two different determinants makes disparities in NMR more evident. This classification enables us to offer specific solutions according to the characteristics of each group in addition to contributing to better monitoring of the effect of each determinant. The lowest NMR were found when mothers were 20-34 years of age and had 12 or more of schooling. In contrast, high rates were found when mothers had no education, were unmarried, and were older than 34 years of age. When combined, these factors compose the highest risk groups.

The previous studies have assessed the importance of maternal characteristics in the distribution of neonatal mortality using local samples. The present study is an effort to provide new information in this direction. According to Flenady (2015), most neonatal deaths in developing countries could be prevented with better care during pregnancy, since many are due to inadequate health care for the mother before birth, as shown by Gaiva, Fujimori and Sato (2015) in Brazil. The features selected in the present investigation are available at the onset of a pregnancy and can help detect such cases more quickly.

The results concerning mother's age confirm the findings of the previous investigations. Some studies report strong evidence for both socioeconomic and biological issues concerning the risk of infant death among adolescent mothers (Fonseca, Flores, Camargo Jr. *et al.,* 2017; Oliveira, Gonçalves, Costa *et al.,* 2016; Teixeira *et al.,* 2016). In Brazil, the pregnancy rate among adolescents has generally declined in recent decades, although levels remain high (UNFPA, 2018). Adolescent pregnancies are more likely to occur in marginalized communities, which are commonly characterized by poverty as well as lack of education and employment opportunities (UNICEF, 2013), leading to an increased risk of infant mortality (Oliveira, Gama and Silva, 2010). According to César, Ribeiro and Abreu (2000), the difference found in the mortality of children of adolescent mothers may reflect the poverty effect more than the age effect and is also an indicator of the precariousness or even lack of adequate prenatal care.

While the average age of mothers at childbirth has decreased in Latin America to around 20-24 years old in the past decade, the average age in developed countries had increased significantly to above 28 years. Mothers older than 35 years of age tend to have a better education, a planned pregnancy and better care in terms of both medical and emotional aspects. However, they face challenges due to their older age. Age is related to an increase in the incidence of diseases such as diabetes and hypertension, both of which are associated with higher infant mortality risk (Jahromi and Husseini, 2008; Dietl, Cupisti, Beckmann *et al.*, 2015; Oliveira, Gonçalves, Costa *et al.,* 2016; Vidal *et al.*, 2018).

Education provides several health advantages because it exerts a positive influence on psychosocial and behavioral factors. The results of the present investigation are in agreement with data described in the previous studies (Fonseca, Flores, Camargo Jr. *et al.,* 2017; Oliveira, Gonçalves, Costa *et al.,* 2016), which report that mothers with 10 or more years of schooling have half the risk of losing their babies in the 1st month than mothers with 1-4 years of schooling, whereas women with no schooling have a higher risk of NMR compared to women with schooling. Teixeira *el al.* (2016) found that more than 8 years of mother's schooling were a protective factor, exerting positive effect on the reduction in infant mortality. In the present investigation, the risk of neonatal mortality was significantly higher among mothers with no schooling. Fonseca, Flores, Camargo Jr. *et al.* (2017) found that children of mothers with less than 4 years of schooling had a greater chance of neonatal death compared to the children of mothers with at least 4 years of education. The authors report that the ability to acquire knowledge on health issues and the optimal use of health services are attributed to a higher educational level. The ability to assess the onset of symptoms properly is also correlated with education.

Many changes have occurred in recent decades. Access to information and the standardization of health-care protocols has diminished the impact of mother's schooling on the life outcome. However, this variable has an explanatory power that needs to be better distinguished from its correlation to wealth and the availability of health-care services. The present study confirms a trend found in recent research. Fonseca, Flores, Camargo Jr. *et al.* (2017) investigated data from the state of Rio de Janeiro between 2004 and 2010 and found that NMR was reduced at a lower rate among mothers with fewer years of schooling and that there was no reduction in the NMR among mothers with no schooling.

Marital status is the least studied factor in terms of infant mortality. Most studies often distinguish this variable into two major groups (married and unmarried). According to DeRose, Salazar-Arango, García *et al.* (2017), unmarried mothers in the Global South are younger, have less schooling and a lower socioeconomic status compared to the married mothers. A systematic review and meta-analysis of neonatal mortality risk factors in Brazil were

recently published (Veloso, Kassar, Oliveira, *et al*., 2019) and show that mother's age above 35 years and the absence of a partner are the most significant predictors of neonatal death. This confirms the results found in the present study, but the study by Veloso, Kassar, Oliveira *et al*. did not consider the role of education in reducing mortality rates.

The inadequate quality and availability of data persist as a significant barrier to a better understanding of neonatal mortality in Brazil, as the most vulnerable places are also those with the weakest data reporting (Maia, Souza and Mendes, 2015; Morais and Costa, 2017; Szwarcwald *et al.,* 2019). The inadequate quality of the data affects the accuracy of the results, such that this extensive database must be analyzed as a sample.

5. Conclusion

In the present study, we found that the risk of neonatal deaths was considerably higher among unmarried mothers with a low level of schooling as well as those outside the 20-34 years old age group, demonstrating that these features are relevant to the outcome. The investigation of maternal characteristics is crucial to accurate monitoring and ensuring continuity in the reduction of NMR in Brazil.

Throughout this work, we performed an exploratory analysis of data from the SIM and SINASC databases, resulting in graphical visualizations that enabled the evaluation of maternal characteristics from this quantitative perspective, along with the demographic, biological, and cultural elements developed in the discussion. However, this study has some limitations that should be considered. Although the dataset had nearly 30 million entries, problems related to the quality and consistency of the data impeded a perfect dataset linkage. Indeed, inadequate data quality and availability constitute a significant barrier. There were missing data on mother's race and the most vulnerable places have weak data coverage. Working with higher quality data and greater coverage is an open issue for further research that would enable more precision and the use of other technologies that require data on a specific condition or quantity, such as machine learning algorithms.

Infant and NMR are among the most important indices for gauging the overall level of public health as well as the social and economic development of a country or region (WHO, 1981). As Brazil has already achieved the Sustainable Development Goals (SDGs) for the reduction of infant and neonatal mortality established by the UN, new targets have been determined, such as an estimated NMR of 5.3 per 1,000 live births. The results of the present study confirm a trend in this direction and underscore the need to continue investing in actions aimed at combating preventable deaths through policies designed at reducing inequalities, expanding education, as well as the accessibility of effective health-care services to ensure a safe pregnancy for all ages and marital statuses. It is also important for Brazil to continue investing in public access platforms and the quality of information through a broadening of coverage for better guided decision-making.

Availability of Data and Materials Section

The dataset used in this paper is available at https://drive.google.com/drive/folders/19dFhQ8XEYzUBVYkqV9NKafxrKgWf5iOB?usp=sharing.

Authors' Contributions

PHC designed the study, performed the analysis, interpreted the data, and drafted the manuscript. LCA designed the study, interpreted the data, drafted, and revised the manuscript. CEB performed the analysis and revised the manuscript. NMA and RCB performed the analysis. TC designed the study, interpreted the data, and revised the manuscript. All authors read and approved the final manuscript.

Ethics

This paper uses publicly available data (SIM and SINASC) that has been de-identified and was deemed exempt from approval from a human research ethics committee.

Conflicts of Interest and Funding

All authors report no conflicts of interest. This research was supported by the Brazilian Ministry of Health through the National Council for Scientific and Technological Development (CNPq) (Process n: 443774/2018-8). It was also supported by NVIDIA, which donated a GPU XP Titan used by the research team.

Acknowledgments

We thank the Bill and Melinda Gates Foundation. We thank also the editor and anonymous reviewers for their insightful comments, which improved the content of the manuscript.

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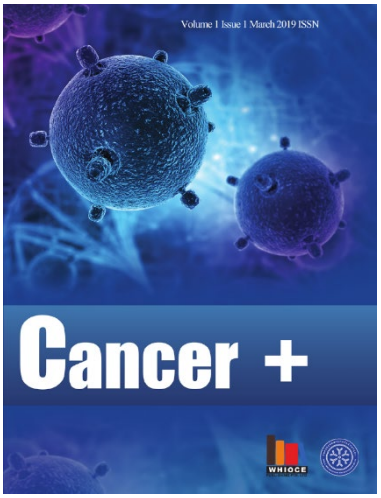

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