East African Medical Journal Vol. 102. 9 September 2025
QUANTILE REGRESSION ANALYSIS OF DETERMINANTS OF STUNTING AMONG CHILDREN AGED 0-23 MONTHS IN TANZANIA: EVIDENCE FROM THE TANZANIA DEMOGRAPHIC HEALTH SURVEY REPORT, 2022

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ABSTRACT

Background: **Stunting affects 30% of Tanzanian children under five, posing significant health and developmental challenges, driven by complex factors including nutrition, maternal health, and socioeconomic conditions.**
Objective: **This study aims to identify determinants of stunting (Height-for-Age Z-score) HAZ) among children aged 0-23 months in Tanzania, examining heterogeneous effects across the HAZ distribution using quantile regression.**
Methods: **Using data from the 2022 Tanzania Demographic and Health Survey (TDHS), we applied quantile regression, guided by the UNICEF Conceptual Framework, to analyze child, maternal, household, and environmental factors at the 0.25, 0.5, and 0.75 HAZ quantiles.**
Results: **Breastfeeding significantly increased HAZ at the 0.25 quantile (coefficient = 1.01, $p < 0.001$), protecting severely stunted children. Middle birth order (2-4) was protective at the 0.25 quantile (coefficient = 0.82, $p = 0.002$), while maternal age (25-29 years) reduced HAZ at the 0.25 and 0.5 quantiles (coefficients = -0.61, -0.62, $p < 0.05$). Unexpectedly, normal (2501-4000g) and large (>4000g) birth weights lowered HAZ at the 0.5 and 0.75 quantiles, possibly due to interventions for low-birth-weight infants and postnatal food insecurity. Household head age positively influenced HAZ at the 0.75 quantile (coefficient = 0.018, $p = 0.049$). Wealth, education, and sanitation were non-significant, likely due to contextual homogeneity.**
Conclusion and Recommendation: **Findings emphasise the need for enhanced breastfeeding promotion, targeted support for mothers aged 25-29, and postnatal nutrition for all infants. The Ministry of Health should prioritise exclusive breastfeeding through community and hospital programs. At the same time, the Tanzania Food and Nutrition Centre should support firstborns**

with maternal and nutritional interventions to address their stunting vulnerability.
Keywords: **Quantile Regression, Stunting, Breastfeeding, Maternal Age, Tanzania**

INTRODUCTION

Stunting remains a critical global health issue, especially in low- and middle-income countries, where it impairs children's ability to achieve optimal growth and development relative to their genetic potential.[1,2] Defined as being too short for age due to chronic or recurrent malnutrition, stunting is a key indicator for the World Health Assembly nutrition targets and Sustainable Development Goal (SDG) 2, which aims to reduce stunting prevalence to 13.5% among children under five by 2030.[3,4] In 2024, 150.2 million children under five were stunted globally (23.2%), with 51% in Asia and 43% in Africa.[5] This condition is linked to long-term cognitive deficits, economic disadvantages, and psychological challenges.[6] Prevalence and age-related increases in stunting vary by region, socioeconomic status, and sex, with developing countries showing higher rates and steeper rises before age two.[7] In Tanzania, stunting is driven by inadequate dietary intake, recurrent infections (e.g., diarrhoea, fever), limited healthcare access, low maternal education, and poor water, sanitation, and hygiene (WASH) infrastructure, particularly in rural areas.[8,9] National efforts, including the Scaling up Growth: Addressing Stunting in Tanzania Early (ASTUTE) program (2015–2020) in the Lake Zone, the Njombe Stunting Reduction Plan (2024–2030), Micronutrient and Health System Strengthening, and the National Multi-sector Action Plan, reflect governmental commitment.[10,11] Despite these initiatives, stunting prevalence remains high, posing a significant public health burden. While numerous studies have identified risk factors for stunting—such as male sex, low parental education, poor sanitation, inadequate complementary feeding, breastfeeding duration, micronutrient supplementation, immunization status, and household wealth—most rely on mean-based regression models that assume uniform effects across the height-for-age Z-score (HAZ) distribution.[12,13] This approach overlooks heterogeneity in risk factors across severity levels, particularly among children aged 0–23 months, a critical window for growth faltering. For example, children aged 24 months or older, male gender, extreme birth weights, maternal BMI extremes, rural residence, multiple births, and low-income settings were found to elevate risk.[14] Studies in specific contexts further reveal nuanced predictors: low animal-source food intake, income disparities, low birth weight, socioeconomic status, unimproved toilets, short birth length, and short maternal stature.[15,16,17]

However, few studies apply quantile regression to examine how determinants vary across the HAZ distribution (e.g., 0.25, 0.5, 0.75 quantiles), limiting the ability to design targeted interventions for severely stunted children versus those at moderate risk. This study addresses the gap by employing quantile regression analysis to investigate the determinants of stunting among children aged 0–23 months in Tanzania, using data from the 2022 Tanzania Demographic and Health Survey (TDHS).

The objective of the study is to determine the context-specific risk factors and their differential impacts across the HAZ distribution, enabling prioritization of interventions for severely stunted children (lower quantiles) versus those with milder growth deficits. By aligning with the World Health Organization's Global Nutrition Target of a 40% reduction in stunting by 2025,[18] the study aims to generate evidence-based insights to strengthen Tanzania's multisectoral strategies and inform policy in similar low-resource settings. This quantile-based approach marks a methodological advancement, offering nuanced, actionable recommendations to accelerate progress toward national and global nutrition goals.

Theoretical Framework and Conceptual Framework

This study is grounded in the UNICEF Conceptual Framework on the Determinants of Maternal and Child Nutrition.[19] This framework posits that child nutritional status, including stunting, is determined by a hierarchy of immediate, underlying, and basic causes. Immediate causes include inadequate dietary intake and disease (e.g., fever, diarrhoea), which directly affect nutritional status.[20] Underlying causes include household food security, caregiving practices (e.g., breastfeeding), access to healthcare services, and a healthy environment (e.g., access to clean water and sanitation). Maternal education and wealth influence feeding practices and healthcare access[21,22] Basic causes involve structural factors, such as socioeconomic conditions, cultural norms, and policies. In Tanzania, poverty, rural residence, and gender roles are basic drivers of stunting.[11] The UNICEF framework is widely used in nutritional research and is relevant here because it provides a multilevel perspective, aligning with the study's inclusion of child, maternal, household, and environmental factors.[22] The conceptual framework, adapted from the UNICEF framework, illustrates the hypothesized relationships between predictors and stunting (HAZ score) in the Tanzanian context, into four levels with pathways leading to stunting.

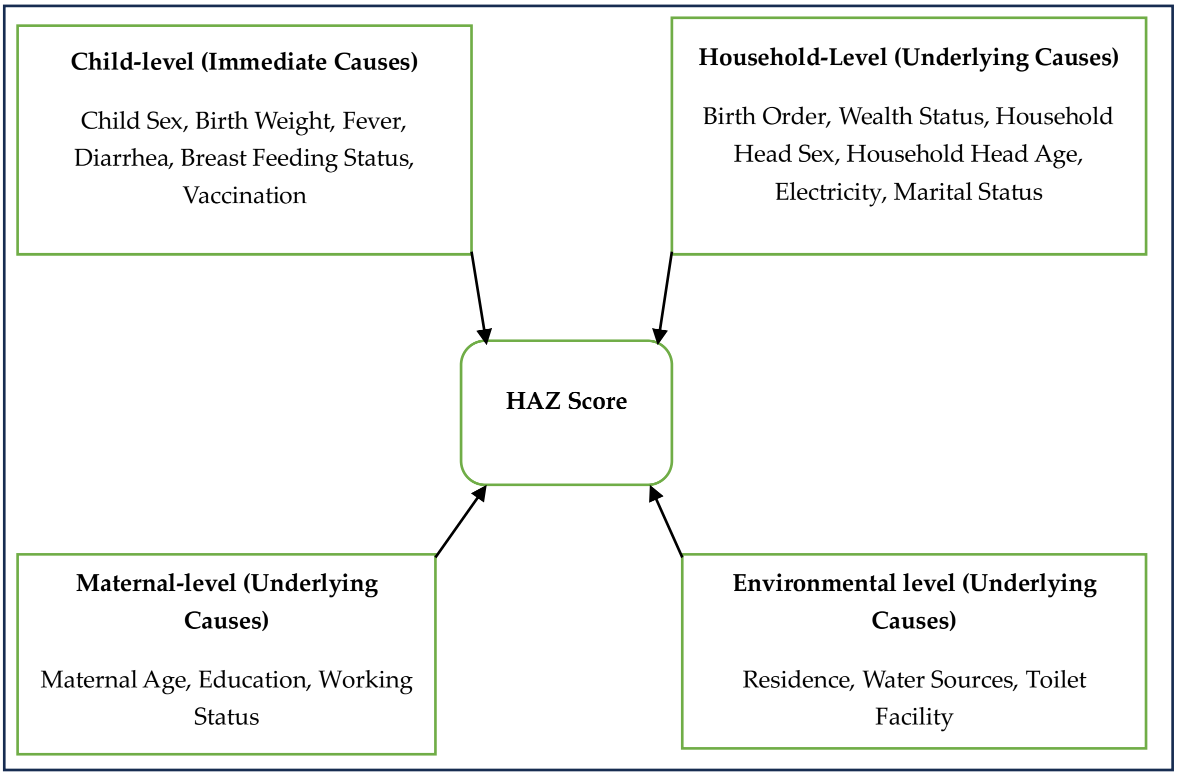

Figure 1: Conceptual Framework

Methods

Study Design and Population

The study uses data from the TDHS 2022, a nationally representative household survey conducted by the Ministry of Health, Community Development, Gender, Elderly and Children (MoHCDGEC) and the National Bureau of Statistics (NBS) in Tanzania. The TDHS 2022 employs a two-stage cluster sampling design, collecting health, nutrition, and socioeconomic indicators data. The analysis focuses on children aged 0-23 months with valid HAZ scores, comprising approximately 2,158 children.[9]

Data Analysis

The study conducted two analyses: summary statistics using frequency and percentage, and quantile regression to estimate the determinants of HAZ scores at the 0.25 (lower tail, more stunted), 0.5 (median), and 0.75 (upper tail, less stunted) quantiles. This method models the conditional quantiles of the HAZ distribution, capturing heterogeneity in predictor effects.[23] The analysis used Stata Version 16, with standard errors and p-values reported to assess significance ($p < 0.05$ threshold). Missing data were handled via listwise deletion, consistent with TDHS analysis practices.[24]

Model Specification

The quantile regression model is specified as:

$$Q_{\bar{\tau}}(HAz \setminus x) = xB_{\tau}$$

Where:

$Q_{\bar{\tau}}(HAz \setminus x)$ is the τ^{th} quantile of the HAZ score conditional on the predictors **(x)**.

(x) is a vector of child, maternal, household, and environmental predictors.

$B_{\tau}$is the vector of coefficients for the τ^{th} quantile (τ=0.25, 0.5, 0.75).

The model includes predictors aligned with the UNICEF framework and Tanzania's stunting context:

i). Child-level: Sex, birth weight, fever, diarrhoea, breastfeeding status, vaccination.

ii). Maternal-level: Age, education, working status.

iii). Household-level: Birth order, wealth status, household head sex and age, electricity, marital status.

iv). Environmental-level: Residence, water source, toilet facility.

Variable Measurement

Variables are defined based on TDHS 2022 conventions and summarized in Table 1.

Table 1: Variable Measurement for Quantile Regression Analysis

Variable	Description	Measurement
HAZ Score	Height-for-age z-score, standardized per WHO growth standards	Continuous
Child Sex	Child's gender	Binary: 1 = female, 0 = male
Birth Weight	Weight at birth, based on maternal recall or health records	Categorical: <2500g (ref), 2501-4000g (normal), >4000g (large)
Fever	Fever episode in the past two weeks, based on maternal report	Binary: 1 = yes, 0 = no
Diarrhea	Diarrhea episode in the past two weeks, based on maternal report	Binary: 1 = yes, 0 = no
Breastfeeding Status	Current breastfeeding status	Categorical: never breastfed (ref), still breastfed
Vaccination	Receipt of age-appropriate vaccines (e.g., BCG, DPT)	Binary: 1 = yes, 0 = no
Birth Order	Child's birth order in the family	Categorical: 1st born (ref), 2-4 order, 5+ order

Maternal Age	Mother's age at the time of the survey	Categorical: 15-25 years (ref), 25-29 years, 30-34 years, 35-49 years
Maternal Education	Mother's highest level of education	Categorical: no education (ref), primary, secondary, and above
Maternal Working Status	Mother's employment outside the home	Binary: 1 = yes, 0 = no
Residence	Household location	Binary: 1 = rural, 0 = urban
Wealth Status	Household wealth based on asset index	Categorical: poor (ref), middle, rich
Household Head Sex	Gender of the household head	Binary: 1 = female, 0 = male
Household Head Age	Age of the household head	Continuous (years)
Electricity	Household access to electricity	Binary: 1 = yes, 0 = no
Marital Status	Mother's marital status	Categorical: single (ref), married, widowed/divorced/separated
Water Source	Primary drinking water source, per WHO/UNICEF standards	Binary: 1 = unimproved, 0 = improved
Toilet Facility	Type of toilet facility, per WHO/UNICEF standards	Categorical: improved (ref), unimproved, open defecation

Results

Table 2 summarizes child, maternal, and household characteristics from the TDHS 2022. Of 2,158 children, 50.49% were male, and 26.37% were aged 0-5 months. Most (70.44%) had normal birth weight (2,501-4,000g), and 62.31% were average-sized at birth. Health-wise, 86.96% had no recent fever or diarrhoea, 78.13% were still breastfeeding, and 72.81% were vaccinated. Firstborns comprised 22.94%, while 51.07% were 2nd-4th born. Mothers mainly were under 25 years (34.94%), with primary education (50.63%), married (84.01%), and working (56.02%). Most (64.5%) attended ≥4 antenatal care visits. Households were predominantly male-headed (76.27%), with heads aged 25-49 (66.82%). Rural residence was common (73.4%), and 41.2% were poor. Improved toilet facilities were used by 47.05%, while 11.8% practiced open defecation. Improved water sources served 70.16% of households, but only 31.91% had electricity.

Table 2: Summary Statistics

Variable	**Frequency**	**Percentage**
Child's characteristics		
Sex		
Male	1090	50.51
Female	1068	49.49
Age		
0-5 months	569	26.37
6-11 months	528	24.47
12-17 months	525	24.33
18-23 months	536	24.84
Birth weight (in grams)		
<2501 Small	143	6.63
2501-4000 Normal	1520	70.44
>4000 Large	495	22.94
Size of the child at birth		
Small	147	7.22
Average	1268	62.31
Large	620	30.47
Had fever 2 weeks before the survey		
No	1899	88.04
Yes	258	11.96
Had diarrhea 2 weeks before the survey		
No	1874	86.96
Yes	281	13.04
Breastfeeding status		
Ever, not currently	407	18.86
Never Breastfeeding	65	3.01
Still Breastfeeding	1686	78.13
Ever received a vaccination?		
No	121	27.19
Yes	324	72.81
Birth order		
1st born	495	22.94
2-4 order	1102	51.07
5+ order	561	26
Mother's characteristics		
Age		
<25 years	754	34.94
25-29 years	525	24.33
30-34 years	399	18.49
35-49 years	480	22.24
Highest education level		
No education	450	20.85

Primary	1093	50.65
Secondary+	615	28.5
Marital status		
Single	170	7.88
Married	1813	84.01
Divorced/Separated/Widow	175	8.11
Working status		
No	949	43.98
Yes	1209	56.02
Number of Antenatal Care visits		
< 4 visits	766	35.5
>=4 visits	1392	64.5
Household characteristics		
Sex of the Household head		
Male	1646	76.27
Female	512	23.73
Age of the household Head		
below 25 years	123	5.7
25-49 years	1442	66.82
above 50 years	593	27.48
Place of residence		
Urban	574	26.6
Rural	1584	73.4
Wealth index		
Poor	889	41.2
Middle	447	20.71
Rich	822	38.09
Type of toilet facility		
Improved	973	47.05
Unimproved	851	41.15
Open defecation	244	11.8
Source of drinking water		
Improved	1451	70.16
Unimproved	617	29.84
Access to electricity		
No	1408	68.09
Yes	660	31.91

Source: Tanzania Demographic and Health Survey and Malaria Indicator Survey, 2022

Quantile regression results (Table 3) identify height-for-age Z-scores (HAZ) determinants at the 0.25, 0.5, and 0.75 quantiles, aligned with the UNICEF framework. At the 0.25 quantile (severely stunted), breastfeeding significantly increased HAZ by 1.01 units ($p < 0.001$), highlighting its protective role. Middle birth order (2-4) raised HAZ by 0.82 units ($p = 0.002$), suggesting benefits from maternal experience or resource sharing. Maternal age 25-29 years reduced HAZ by 0.61 units ($p = 0.022$), indicating socioeconomic or health-related risks. The constant was -3.11 (p < 0.001), reflecting severe stunting. At the 0.5 quantile (median), normal birth weight (2,501-4,000g) unexpectedly lowered HAZ by 1.27 units (p = 0.005), and considerable birth weight (>4,000g) by 1.03 units (p = 0.027), suggesting confounding or postnatal challenges. Breastfeeding increased HAZ by 0.54 units (p = 0.017), though less impactful than at 0.25. Maternal age 25-29 years reduced HAZ by 0.62 units (p = 0.025). The constant was -1.47 (p = 0.054), indicating a poor nutritional baseline. At the 0.75 quantile (less stunted), normal and large birth weights reduced HAZ by 1.64 (p = 0.011) and 1.60 units (p = 0.018), respectively. Household head age increased HAZ by 0.018 units per year (p = 0.049). The constant was near zero (-0.0048, p = 0.996). Child sex, fever, diarrhea, vaccination, maternal education, working status, residence, wealth, household head sex, electricity, marital status, water source, and toilet facility were non-significant (p > 0.05) across all quantiles.

Table 3: Quantile Regression Coefficients and P-values for Determinants of HAZ Scores

Variable	**0.25 Coef.**	**0.25 P>t**	**0.5 Coef.**	**0.5 P>t**	**0.75 Coef.**	**0.75 P>t**
Child Sex (female)	0.229	0.184	0.156	0.384	0.006	0.981
Birth Weight (2501-4000g, normal)	-0.344	0.421	-1.267	0.005	-1.645	0.011
Birth Weight (>4000g, large)	-0.314	0.484	-1.034	0.027	-1.601	0.018
Fever (yes)	-0.265	0.455	-0.376	0.309	-0.265	0.619
Diarrhea (yes)	-0.155	0.648	-0.387	0.275	-0.547	0.286
Breastfeeding (never breastfed)	0.548	0.339	0.551	0.354	-0.581	0.498
Breastfeeding (still breastfeeding)	1.012	P<0.001	0.535	0.017	0.176	0.584
Vaccination (yes)	-0.052	0.797	-0.172	0.410	-0.345	0.251
Birth Order (2-4 order)	0.817	0.002	0.413	0.131	0.3333242	0.398
Birth Order (5+ order)	0.425	0.252	-0.296	0.442	-0.5123278	0.356
Maternal Age (25-29 years)	-0.611	0.022	-0.621	0.025	-0.3018789	0.448
Maternal Age (30-34 years)	-0.369	0.219	0.135	0.664	-0.0426288	0.924
Maternal Age (35-49 years)	-0.376	0.256	-0.291	0.397	-0.0877004	0.860
Maternal Education (primary)	-0.234	0.288	-0.243	0.287	-0.4025235	0.222
Maternal Education (secondary and above)	0.213	0.476	0.256	0.412	-0.0929309	0.836

Maternal Working Status (yes)	0.151	0.389	0.0711	0.696	0.0342623	0.896
Residence (rural)	-0.002	0.994	0.229	0.381	0.4614552	0.222
Wealth Status (middle)	-0.334	0.221	0.014	0.960	-0.0965859	0.813
Wealth Status (rich)	0.541	0.156	0.568	0.152	0.5702455	0.319
Household Head Sex (female)	0.181	0.395	0.217	0.325	0.2207329	0.489
Household Head Age	0.001	0.907	0.011	0.077	0.0183121	0.049
Electricity (yes)	-0.194	0.549	-0.308	0.361	-0.3502966	0.471
Marital Status (married)	0.276	0.420	0.580	0.104	0.6731303	0.191
Marital Status (widowed/divorced/separated)	0.253	0.564	0.564	0.216	0.6735971	0.306
Water Source (unimproved)	-0.118	0.561	0.005	0.980	-0.1558725	0.610
Toilet Facility (unimproved)	-0.125	0.620	-0.077	0.768	0.091857	0.808
Toilet Facility (open defecation)	-0.067	0.837	-0.349	0.298	-0.1669015	0.730
Constant	-3.11	0.000	-1.47	0.054	-0.0048491	0.996

Discussion

Continued breastfeeding offers a robust protective effect against childhood stunting. Studies in Eastern Indonesia show exclusive breastfeeding for the first six months can reduce stunting risk by up to 50% in resource-limited settings.[25,26] This aligns with Tanzania's efforts to promote breastfeeding through initiatives like the Baby-Friendly Hospital Initiative and community health worker programs, reinforcing dietary intake as a critical factor in global nutrition frameworks.[11,14] Additionally, children of second to fourth birth order exhibit a 0.82-unit increase in height-for-age Z-scores (HAZ) ($p = 0.002$), consistent with quantile regression analyses where higher birth order correlates with modest HAZ improvements at lower quantiles.[27] Maternal age in the mid-twenties (25–29 years) presents context-specific risks, potentially due to socioeconomic pressures, heavy workloads, or inadequate reproductive spacing, as observed in studies from Ghana and Sub-Saharan Africa.[28] To address these factors, nutrition strategies should prioritise early support for firstborn children, who lack the growth advantage seen in later-born siblings. Additionally, extending maternal health and family-planning services beyond adolescence is essential, particularly for mothers aged 25–29, to mitigate context-specific risks. Interventions must be multifaceted, combining immediate actions (e.g., breastfeeding education), underlying support (e.g., maternal socioeconomic empowerment), and targeted measures (e.g., assistance for firstborns and age-specific maternal support) to reduce stunting, especially among the most disadvantaged children effectively. A surprising result emerges in the middle of the HAZ distribution, where normal birth weight is associated with lower growth scores compared to low birth weight, challenging conventional understanding.[28,29] This counterintuitive pattern may reflect the "low birth weight paradox," where surviving low-birth-weight infants represent a resilient subgroup, while some normal-birth-weight infants face unmeasured adverse conditions that impair long-term growth.[30] Postnatal factors like feeding practices, infections, and caregiving outweigh birth weight on HAZ variability. The age of the household head also plays a role, with older heads linked to slightly higher child HAZ.[1] This may stem from greater economic resources, maturity, childcare experience, or stronger caregiving networks. These insights highlight the value of engaging both young parents and older caregivers in nutritional counselling to enhance child health outcomes. Notably, factors such as child sex, fever, diarrhea, vaccination status, maternal education, employment, residence, wealth, household head sex, electricity, marital status, water source, and toilet facilities showed no consistent direct impact on child growth in this quantile regression model. While these factors are often significant in other contexts, their influence varies across the HAZ distribution. This variability suggests that uniform policies targeting these factors may not effectively reach children with the lowest growth outcomes. Instead, strategies should focus on subgroup-specific interventions informed by quantile analysis, emphasizing upstream determinants like maternal health during pregnancy, household resilience, and community sanitation.

Limitations of the study

The cross-sectional design of the TDHS 2022 limits causal inference, as temporal relationships between predictors and stunting cannot be established. Moreover, self-reported data on breastfeeding, infections, and vaccination may recall bias. Finally, the focus on children aged 0-23 months restricts generalizability to older age groups.

Conclusion

This study highlights that child stunting in Tanzania is influenced by various factors across the HAZ distribution, demonstrating the value of a quantile regression approach. Protective factors like higher birth order (2nd–4th) and continued breastfeeding are linked to better growth outcomes in the most stunted children. Maternal age (25–29 years) emerged as a consistent risk factor, likely reflecting socioeconomic stresses. Interestingly, normal and high birth weights correlated negatively with HAZ, suggesting the need to re-evaluate conventional assumptions. The positive association between household head age and HAZ indicates that caregiver maturity contributes to child growth. Notably, conventional variables such as household wealth and maternal education showed no significance, underscoring the necessity for tailored strategies. Therefore, the Ministry of Health should promote breastfeeding through community health workers and support firstborn children with maternal assistance and early nutritional counselling. Additionally, expanding maternal health services for women aged 25–29 is essential to address their unique reproductive challenges.

Authorship

RPN conceived the idea and drafted the manuscript. NM operationalized the models and participated in data analysis, and EZ critically revised and edited the manuscript. All authors reviewed the first draft of the manuscript and approved the final draft.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable

Competing interests

The author(s) have no competing interests to declare

Funding

No, any fund was given to the authors to complete the study and the manuscript.

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