

Poor maternal anthropometric characteristics and newborns' birth weight and length: a cross-sectional study in Benin

Sètondji G. R. Padonou^{a,*}, Badirou Aguemon^a, Gilles M. A. Bognon^b, Nicole E. Houessou^c, Georgia Damien^a, Paul Ayelo^d and Elisette Djossou^a

^aDépartement de Santé Publique, Faculté des Sciences de la Santé, Université d'Abomey-Calavi, 01 BP 188 Cotonou, République du Bénin; ^bService de pédiatrie. Centre hospitalier universitaire départemental Ouémé-Plateau, Faculté des Sciences de la Santé, Université d'Abomey-Calavi, 01 BP 188 Cotonou, République du Bénin; ^cService de pédiatrie, Centre hospitalier universitaire Mère et Enfant Lagune, Faculté des Sciences de la Santé, Université d'Abomey-Calavi, 01 BP 188 Cotonou, République du Bénin; ^dUnité de recherche et d'enseignement en santé au travail et environnement, Faculté des Sciences de la Santé, Université d'Abomey-Calavi, 01 BP 188 Cotonou, République du Bénin

*Corresponding author: Tél: +00229 66 64 75 75; E-mail: geraudpad@yahoo.fr

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Background: Maternal undernutrition is known to negatively impact newborns' birth weight and length, but this finding is poorly documented in the Beninese population. This study aimed to assess the effect of maternal anthropometry on mean birth weight and length in a Beninese cohort of newborns.

Methods: A cross-sectional study was carried out in Tori Bossito, Republic of Benin. Pregnant women attending maternity wards between June 2007 and July 2008 were recruited. At delivery the women's characteristics, including weight and height, were gathered and newborns' birth weights and lengths were measured. Statistical analysis was performed using multiple linear regression.

Results: A total of 526 mother–infant pairs were enrolled; 29.8% of women had low weight status and 26.2% had short stature (<155 cm). The mean birth weight was 2985 g (standard deviation [SD] 384) the mean birth length was 48.7 cm (SD 2.2). Maternal low weight status (coefficient=−151.81, $p<0.001$) and short stature (coefficient=−135.49, $p<0.001$) reduced the mean birth weight. Similar results were found for mean birth length, which was decreased by maternal low weight status (coefficient=−0.42, $p=0.04$) and short stature (coefficient=−0.51, $p=0.01$).

Conclusion: Maternal undernutrition expressed by low anthropometry remains problematic in the Beninese population and induces transmission of malnutrition. Nutritional interventions are required to break this vicious cycle.

Keywords: birth length, birth weight, maternal low weight status, maternal short stature, transmission of malnutrition

Introduction

A newborn's birth weight and length indicate the evolution of fetal growth and intrauterine development. As such, they are major indicators of newborn health. Maternal anthropometric characteristics are a reflection of the mother's general health status. More particularly, these are indicators of nutritional status. In pregnant women, anthropometry is directly correlated with the outcomes of pregnancy for both mother and infant.^{1,2} It contributes to maternal mortality and morbidity and increased perinatal and neonatal risks in newborns. The nutritional status

of pregnant women, whether chronic or undergoing acute changes, has repercussions on the course of the pregnancy and fetal growth. Maternal nutritional deficiency is associated with disruption of fetoplacental exchange, including micronutrient intake of the fetus.³ Furthermore, anthropometric measures of the newborn, including birth weight and length, head circumference, brachial perimeter, abdominal perimeter and skinfold thickness, are also negatively impacted by maternal nutritional deficits.^{4,5} This nutritional deficiency in pregnant women can be expressed in different ways, including small size, which, apart from genetic factors reveals chronic nutritional deficiency. It can

also manifest as a low prepregnancy body mass index, low gestational weight gain or a combination of these, that translates to inadequate gestational nutritional intake.^{6,7}

Other factors such as the infant's gender, prenatal care visits and follow-up, and maternal obstetric data such as parity, anemia and infections during pregnancy are also described as possibly affecting the anthropometric measures of the newborn. Among infections, gestational malaria—specifically placental malaria—has been widely described as a risk factor for low birth weight.⁸ Children born with low birth weight or who are small for their gestational age have an increased risk of mortality and morbidity both in the neonatal period and later in life. As these children become adults they have associated growth disorders, impaired neurocognitive development, metabolic disorders and cardiovascular diseases.⁹ These risks are observed with greater intensity in low- and middle-income countries (LMICs).¹⁰

Given these considerations and the important risks that exist in health outcomes, it is necessary to regularly examine how changing the links and interactions between the anthropometric characteristics of the mother and newborn's birth weight and length can improve the indicators of maternal and child health.

Although this topic is widely described in the literature, in Benin few data exist on the undernutrition of pregnant women, and no study has highlighted the associations with the anthropometric measures of Beninese newborns. In addition, during prenatal consultations, identification of women with nutritional deficiency is not done. Moreover, in Benin, there is no public health strategy to prevent maternal undernutrition. Sometimes supplementation with iron and vitamin B₁₂ is proposed in cases of anemia during pregnancy, which is mainly due to gestational malaria, as Benin is located in a malaria-endemic area. But anemia can also be due to poor diet and fits into a global context of nutritional deficiency in pregnant women. This lack of information results in a lack of early care and a lack of preventive strategies.

The purpose of this study is to identify mothers with nutritional deficits, using short stature and low weight status, in a cohort of mothers and their newborns in southern Benin, and to measure the effect of these maternal anthropometric characteristics on mean birth weight and birth length independent of confounders such as the infant's gender, prenatal follow-up and other maternal factors (parity, anemia).

Materials and methods

Study area, population and settings

This study took place in Tori Bossito, a town located 40 km northeast of Cotonou, in the south of the Republic of Benin. Nine villages and three health centers with a maternity ward were selected (Avame, Cada and Gare). All women living in the study area and who delivered between June 2007 and July 2008 in one of the maternity hospitals were recruited. A total of 656 children were born. Multiple pregnancies (25 twins and 1 triplets) were excluded. Eighteen extreme premature infants (gestational age <28 weeks) who were evacuated to a larger hospital equipped with a neonatal intensive unit were excluded.

Subjects with missing or unreadable data on birth weight, birth length, gestational age or gender were excluded. Thus a total of 526 mother–child pairs were selected.

Mothers' data collection

When coming to a health center for delivery, the mother's weight and height were measured. Weight was measured to the nearest 100 g using a mechanical scale (seca 761; Seca, Hamburg, Germany). Height was recorded to the nearest 1 mm using a measuring tape (seca 206; Seca). Placental malaria infection was defined by the presence of the asexual form of *Plasmodium falciparum* on a placental smear read by two different technicians. Maternal hemoglobin was measured at delivery and anemia was defined as <110 g/L.¹¹ At delivery, sociodemographic and gynecologic–obstetric information was collected. The household wealth score, as described by Bangirana et al.,¹² was computed and ranged from 1 to 11, based on the possession of items such as a lamp, radio, bike, electricity and motor-bike, and on several characteristics of the house, such as the materials used for the walls and roof.

Newborns' data collection

Anthropometric measurements such as weight and length were performed according to WHO recommendations and methods.¹³ Weight was measured to the nearest 10 g using a mechanical baby scale (seca 745; Seca). Length was recorded to the nearest 1 mm with a locally made wooden board equipped with two metal measuring tapes. Newborn measurements were taken by two different trained midwives and, in the case of discordance, a third measurement was performed. Gestational age was estimated by experienced and trained midwives using the Ballard method and prematurity was defined as gestational age <37 weeks.¹⁴ Small for gestational age (SGA) was defined as a birth weight below the 10th percentile of Williams et al.'s reference curve of birth weight for gestational age,¹⁵ which is sex specific, as recommended by the WHO.¹³

Definition of maternal undernutrition

We used two variables to characterize maternal undernutrition: short stature and low weight status. Mothers were classified as short stature if their height was <155 cm and they were classified as low weight status when they had a low prepregnancy weight or a low gestational weight gain calculated according to the method recommended by the WHO's Nutrition Subcommittee¹⁶ and validated elsewhere.¹⁷ This calculation takes into account two parameters, a minimal recommended prepregnancy body mass index (BMI) of 20 kg/m² and a theoretical minimal gestational weight gain of 1 kg per month from month 4 until delivery. A calculation example for a woman of 59 kg at delivery and 1.67 m tall follows: using the minimal recommended prepregnancy BMI of 20 kg/m², the minimal weight before pregnancy is 55.78 kg. If this woman delivered after 9 months of gestation, her gestational weight gain should be 6 kg and her calculated minimum weight at delivery is therefore 61.78 kg. As her actual

measured weight at delivery (59 kg) is less than the calculated minimum weight at delivery (61.78 kg), this woman is classified in the low weight status category.

Data analysis

We used means and percent for quantitative and qualitative variables, respectively, to describe the study population characteristics. Univariate and multivariate analyses were performed to search for factors having an effect on mean birth weight and birth length. Univariate analysis was done by Student's test and analysis of variance (ANOVA) when necessary. All variables linked with $p \leq 0.20$ in univariate analysis were introduced in a linear regression model for multivariate analysis. The significance level was set at $p < 0.05$. Only parity was retained in the final model when collinearity existed with maternal age. Even if not reaching significance, placental malaria infection was kept in the final model, because it is known to be related to newborn birth weight and length.

Ethics

The protocol was explained in detail in the local language to women and their husbands, and written informed consent was obtained. Each participant had the right to withdraw at any time during the study. The protocol of the study was validated by the ethics committee of the Faculté des Sciences de la Santé, Université d'Abomey-Calavi.

Results

Description of the study population

A total of 526 mothers and their newborns were enrolled in the study. Table 1 provides an overview of the characteristics of the mothers and their children.

The mothers' mean age was 27.5 (standard deviation [SD] 5.6), 13.5% were < 20 y old and 26.9% were > 30 y old. Slightly more than 26% showed short stature (height < 155 cm) and 29.8% had low weight status. The prevalence of maternal anemia at delivery was 38.5%, 10.9% of mothers presented with placental malaria infection and 14.8% were primiparous. During their pregnancy, 56.6% of women attended at least four prenatal care visits and almost 83% reported receiving at least one dose of intermittent preventive treatment for malaria. The majority of mothers (85.4%) were unschooled and living in a monogamous household (70.9%). The mean household wealth score was 5.5 (SD 1.8).

Regarding the newborns, the mean birth weight and birth length were 2985 g (SD 384) and 48.7 cm (SD 2.2), respectively. The mean birth weight of male infants was 3016.33 g (SD 384.30) and that of female infants was 2954.21 g (SD 382.04). The mean birth length for male infants was 49.01 cm (SD 2.23) and that of female infants was 48.48 cm (SD 2.14). The sex ratio (male:female) was 0.96. Prematurity accounted for 10.3% ($n=54$) of infants, with the majority born at 33 and 36 weeks gestational age. The mean birth weight and birth length for preterm newborns was 2899.92 g (SD 428.70) and 47.83 cm (SD 2.69),

Table 1. Baseline characteristics of the study population

	n (N=526)	Mean (SD)	%
Mothers			
Age (y)		27.5 (5.6)	
Maternal height (cm)		158.7 (6.3)	
Maternal short stature (height < 155 cm)	138		26.2
Maternal low weight status	157		29.8
Maternal anemia (hemoglobin ≤ 110 g/L)	200		38.5
Primiparity	78		14.8
Placental malaria infection	57		10.9
Number of prenatal care visits			
< 4	217		43.4
≥ 4	283		56.6
Use of intermittent preventive treatment of malaria for pregnant women	433		82.8
Unschooled mothers status	449		85.4
Marital status			
Polygamous	153		29.1
Monogamous	373		70.9
Household wealth score		5.5 (1.8)	
Newborns			
Birth weight (g)		2985 (384)	
Length at birth (cm)		48.7 (2.2)	
Sex ratio (male:female)		0.96	
Gestational age (weeks)		38.47 (1.7)	

respectively. There were 133 SGA newborns and 393 normal for gestational age (NGA) newborns in the sample, accounting for 25.3% and 74.7%, respectively. Among the SGA infants, the mean birth weight was 2606.85 kg (SD 208.22) and the mean birth length was 47.49 cm (SD 2.24). Distributions of birth weight and length in the sample are presented in Figures 1 and 2, respectively.

Analysis of factors associated with birth weight

In univariate analysis, factors that were related to birth weight were the infant's sex, maternal stature and weight status, maternal age, parity and the number of prenatal care visits. The univariate analyses data are summarized in Table 2.

Multivariate analyses, presented in Table 4, showed that maternal short stature (coefficient= -135.49), maternal low weight status (coefficient= -151.81) and primiparity (coefficient= -192.34) are factors that were statistically significantly

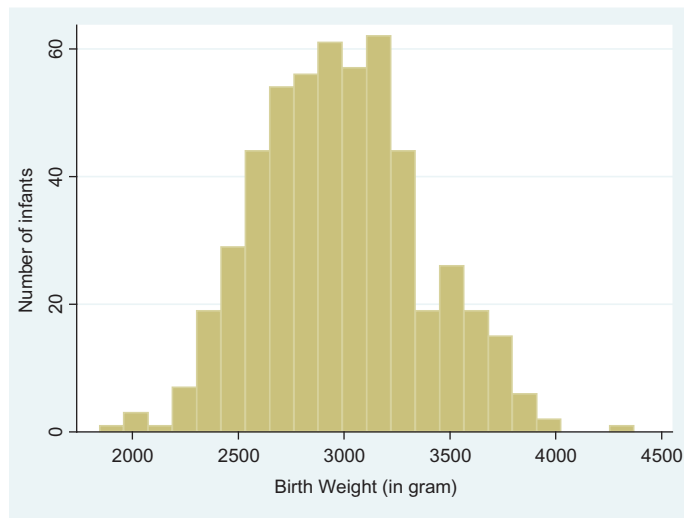


Figure 1. Distribution of birth weight in the newborn population.

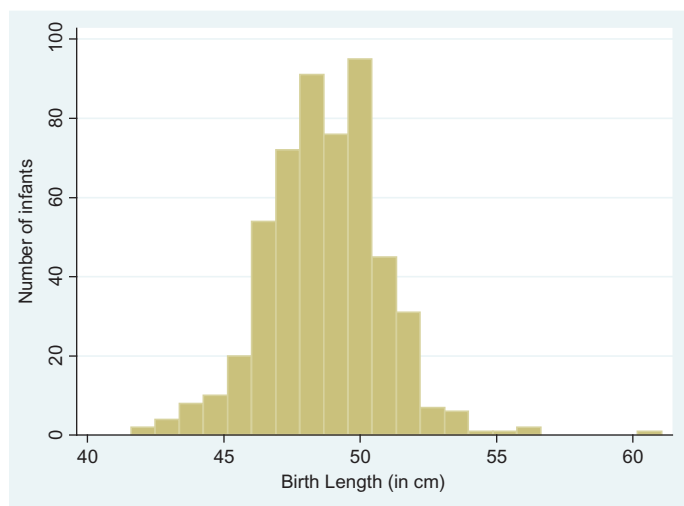


Figure 2. Distribution of birth length in the newborn population.

related to birth weight. However, having more than four prenatal care visits significantly improved the birth weight of the newborns (coefficient= 119.87). Male newborns weighted more than females.

Analysis of factors associated with birth length

Factors similar to those in the birth weight analysis, except parity, were associated with birth length in the univariate analysis (Table 3).

During the multivariate analysis, our results showed that birth length was mainly reduced by the two maternal anthropometric characteristics, short stature (coefficient= -0.51) and low weight status (coefficient= -0.42). Male newborns were larger in size than females. In addition, attending more than four prenatal care visits had a significant beneficial effect on birth length.

No association of placental malaria infection was found either with birth weight or with birth length.

The results are presented in Table 4.

Discussion

This cross-sectional study conducted in Tori Bossito, southern Benin, among 526 mothers and their newborns highlights the negative effect of poor maternal anthropometric characteristics (undernutrition, i.e. short stature and low weight status) on newborns' anthropometry (birth weight and birth length). We also showed the beneficial impact of prenatal care visits on newborns' weight and length.

In our sample, male newborns had significantly higher birth weight and birth length. Other researchers have had similar findings.^{1,18,19} The exact process that leads to this observation is not well understood. Various hypotheses have been advanced to explain this, without any real confirmation. However, it is very likely that genetic factors responsible for the physiological mechanisms underlying the better fetal development of males are involved. This opinion, although shared by some authors, remains the subject to discussion.²⁰

Children born to primiparous mothers had significantly lower birth weights. This result is consistent with the literature.^{1,21,22} Primiparous mothers are often very young, and indeed there is a strong correlation between parity and age. One hypothesis to explain our findings is that the bodies of primiparous mothers have not yet reached full physiological maturity, being barely out of puberty. The uterus and related organs are not yet ready and adapted to support pregnancy, a very sensitive period during which the physiological needs of the mother are increased to meet those of the fetus. Under these conditions there is a placental insufficiency that deprives the fetus of adequate intake of the micronutrients and oxygen necessary for good fetal growth, leading to low weight and length at delivery. It is therefore relevant that public health actions, such as nutritional interventions, that aim to reduce the incidence of low birth weight must target primiparous women.

In the present study, placental malaria infection was detected on placental smears at delivery. Even if not significant in our analysis, we cannot totally rule out the negative effect of

Table 2. Factors associated with birth weight: univariate analysis

Covariates	Birth weight		
	Coefficient	95% CI	p-Value
Male gender	62.12	−3.59 to 127.83	0.06
Maternal anemia (hemoglobin \leq 110 g/L)	10.45	−57.63 to 78.54	NS
Placental malaria infection	−78.42	−184.40 to 27.56	NS
Maternal short stature (height <155 cm)	−158.07	−231.61 to −84.53	<0.001
Maternal low weight status	−169.32	−239.73 to −98.81	<0.001
Maternal age (y)	13.83	8.04 to 19.61	<0.001
Household wealth score	0.36	−18.37 to 19.10	NS
Unschooling mother status	−73.56	−166.41 to 19.29	NS
Polygamous marital status	24.04	−48.37 to 95.45	NS
Primiparous	−213.33	−304.07 to −122.59	<0.001
Number of prenatal care visits \geq 4	93.55	26.81 to 160.28	0.006
Use of intermittent preventive treatment of malaria for pregnant women	19.44	−67.84 to 106.72	NS

NS: not significant.

Table 3. Factors associated with birth length: univariate analysis

Covariates	Birth length		
	Coefficient	95% CI	p-Value
Male gender	0.53	0.16 to 0.90	0.006
Maternal anemia (hemoglobin \leq 110 g/L)	0.23	−0.16 to 0.62	NS
Placental malaria infection	−0.20	−0.80 to 0.40	NS
Maternal short stature (height <155 cm)	−0.55	−0.98 to −0.12	0.01
Maternal low weight status	−0.43	−0.84 to −0.02	0.04
Maternal age (y)	0.04	0.01 to 0.07	0.02
Household wealth score	−0.001	−0.11 to 0.10	NS
Unschooling mother status	−0.20	−0.73 to 0.33	NS
Polygamous marital status	0.02	−0.39 to 0.43	NS
Primiparous	−0.35	−0.88 to 0.18	NS
Number of prenatal care visits \geq 4	0.72	0.33 to 1.10	<0.001
Use of intermittent preventive treatment of malaria for pregnant women	0.006	−0.49 to 0.51	NS

NS: not significant.

placental malaria infection. Indeed, malaria earlier in pregnancy may impair fetal growth but may not be detected on placental smears at delivery.

We observed in our population that children born to women who had good medical follow-up of their pregnancy had significantly higher birth weight and birth length than other children. Indeed, 56.6% of the pregnant women in our study attended at least four prenatal care visits as recommended by the WHO.²³ However, this recommendation is not always followed in the LMICs. In fact, the United Nations Children's Fund found that during the period 2007–2012, only 38% of pregnant women

living in LMICs had attended at least four prenatal consultations.²³ The 56% recorded in our study undoubtedly represent better gynecologic–obstetric follow-up, and this contributes to greatly reducing the complications that can occur during pregnancy. During prenatal consultations, the pregnant woman undergoes a medical examination to check the progress of the pregnancy and to detect early complications. Fetal vitality and growth are verified. During this interview, pregnant women also receive advice to prevent pregnancy-related pathologies. Our results are consistent with those of other authors. Good pregnancy monitoring has a positive effect on pregnancy outcomes

Table 4. Factors associated with birth weight and birth length: multivariate analysis by linear regression^a

Covariates	Birth weight			Birth length		
	Coefficient	95% CI	p-Value	Coefficient	95% CI	p-Value
Constant	2994.70	2916.3 to 3073.1	<0.001	47.78	47.33 to 48.23	<0.001
Male gender	62.12	-1.72 to 125.96	0.05	0.58	0.21 to 0.95	0.002
Maternal short stature (<155 cm)	-135.49	-208.19 to -62.78	<0.001	-0.51	-0.93 to -0.08	0.01
Maternal low weight status	-151.81	-221.60 to -82.02	<0.001	-0.42	-0.83 to -0.02	0.04
Number of prenatal care visits \geq 4	119.87	54.82 to 184.91	<0.001	0.85	0.48 to 1.23	<0.001
Primiparous	-192.34	-281.62 to -103.05	<0.001	-0.32	-0.84 to 0.20	NS
Presence of placental malaria infection	-46.90	-149.63 to 55.82	NS	-0.28	-0.87 to 0.32	NS

^aAdjustment was made for the place of delivery.
NS: not significant.

and newborns' birth weight and length, as has been found in studies in Kenya²⁴ and Ethiopia.²⁵

Since women were included at the time of delivery, we did not have data concerning their prepregnancy weight. To overcome this difficulty, we have proposed a calculation method based on estimation from the WHO Nutrition Subcommittee.¹⁶ This process is not optimal since it does not distinguish between women with low weight status before pregnancy, those with low gestational weight gain and those that combine the two deficits. The prevalence of maternal undernutrition found in our population (29.8%) is consistent with data from the literature concerning developing countries and therefore it reinforces the validity of this method of calculation. Indeed, >20% of women of childbearing age are malnourished in sub-Saharan Africa,²⁶ 30% in Bangladesh and 27% in Ethiopia.²⁷

In our study we identified mothers as short stature if they were <155 cm tall. This threshold has been used by other authors, as Ozaltin et al.²⁸ pointed it out in a review of the literature concerning 54 LMICs between 1991 and 2008. From this work, several values (<145, 145–149.9, 150–154.9, 155–159.9 and <160 cm) were used in different populations living in different areas. The result obtained by using our threshold of 155 cm confirms the association between maternal height and newborns' birth weight and length: short maternal height has a negative effect on mean birth weight and mean birth length. It is also important to stress another point, i.e. the implication of genetic factors: constitutionally small mothers will give birth to small children.²⁹ Despite the physiological aspect of this phenomenon, these children remain at higher risk of mortality and morbidity.¹⁰

We found that maternal low weight status and short stature, both reflecting maternal undernutrition, are very deleterious for newborns' birth weight and length. Our results are consistent with the literature^{26,30} and are in accordance with a meta-analysis from many countries.⁷ Two main explanations support this result. First, there is insufficient fetoplacental exchange with vascular dysfunction, resulting in a chronic reduction in the supply of oxygen and micronutrients necessary for good growth and development of the fetus. Second, the mother's nutritional

and caloric intakes are poor and insufficient. During pregnancy the basic metabolism of a woman increases to meet the needs of both the mother and the fetus. In the case of undernutrition, the pregnant women is unable to meet these needs. In addition, insufficient nutritional intake is aggravated by placental insufficiency that does not allow optimal transfer of nutrients to the fetus. The combination of all these factors leads to restricted fetal growth and reduction of the newborn's birth weight and length. These points confirm that poor maternal anthropometric characteristics are strongly related to newborns' birth weight and length and illustrate what is called the intergenerational transmission of malnutrition.³¹

Conclusions

In this study we pointed out the negative role of maternal undernutrition, expressed by maternal low weight status and short stature, on newborns' birth weight and length. This is the key point of the intergenerational cycle of malnutrition. Enhancement of the nutritional status of young women must be considered a priority.³² Our results reinforce and justify continuing public health initiatives to break the cycle of malnutrition.

Authors' contributions: SP supervised data collection. SP, GB and NH analyzed data and drafted the manuscript. BA, GD, ED and PA critically revised the manuscript for intellectual content. All authors read and approved the final manuscript. SP, GB and NH are guarantors of the paper.

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Competing interests: None declared.

Ethical approval: The protocol was explained in detail in the local language to women and their husbands, and written informed consent was obtained. Each participant had the right to withdraw at any time during the study. The protocol of the study was validated by the ethics committee of the Faculté des Sciences de la Santé, Université d'Abomey-Calavi.

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