DOI: 10.12923/cipms-2025-0009 Curr. Issues Pharm. Med. Sci.,

Current Issues in Pharmacy and Medical Sciences
Formerly ANNALES UNIVERSITATIS MARIAE CURIE-SKLODOWSKA, SECTIO DDD, PHARMACIA

journal homepage: https://czasopisma.umlub.pl/curipms

A comprehensive analysis of stillbirths influencing factors: Insights from Eastern Algeria's Maternal Health Study

Adel Kalla*, Lotfi Loucif, Abdelali Boussif, Mouloud Yahia

Department of Microbiology and Biochemistry, University of Batna 2, Algeria

ARTICLE INFO

Received 23 January 2024
Accepted 20 November 2024

Keywords:
pregnancy,
stillbirth,
prevention,
predictive model,
maternal health,
risk factors.

ABSTRACT

As defined by the World Health Organization, stillbirth refers to the delivery of a baby without signs of life at or after 28 weeks of gestation. This study aims to predict stillbirth occurrences by identifying influencing factors. Interviews were conducted with 786 pregnant women from Eastern Algeria between 2011 and 2015, resulting in a 9.03% stillbirth rate. Utilizing statistical techniques, a predictive model with a 95% confidence interval was developed. Findings indicated a significantly higher likelihood of stillbirths among pregnant women aged over 34 (OR 8.77; 1.70-161.28, p=0.039) and those with a high BMI of (25-30) (OR 1.73; 0.83-3.78, p=0.153) and (30-35) (OR 4.16; 2.04-8.93, p<0.001). Additionally, associations were observed with stress (OR 2.19; 1.15-4.49, p=0.023) and diabetes (OR 2.68; 1.15-5.90, p=0.017). Moderate correlations were noted with meat consumption (OR 0.53; 0.21-1.19, p=0.144), high fish intake (OR 3.02; 1.04-8.62, p=0.039), dairy products (OR 1.81; 0.94-3.67, p=0.085), and sweets (OR 0.47; 0.24-0.88, p=0.021). This study underscores that identifying these risk factors aids in preventing stillbirths, thereby safeguarding the well-being of both mothers and infants. Future research should explore the broader implications of these findings and potential avenues for further investigation.

INTRODUCTION

Over the course of gestation, a pregnant woman's body undergoes significant transformations [1], exposing her to potential risks, including the occurrence of stillbirths. The primary causes of stillbirths encompass maternal infections (such as malaria, syphilis and HIV), complications during childbirth, pregnancies that extend beyond their expected term, fetal growth restrictions, maternal health conditions (notably hypertension, obesity and diabetes), and congenital abnormalities. Alarmingly, nearly half of all stillbirth cases manifest during the labor process [2].

Furthermore, the occurrence of stillbirths is influenced by specific economic and geographical factors that vary by region. In 2015, the global count of stillbirths reached 2.6 million, translating to over 7,178 instances daily. A disproportionate burden of these tragedies falls on developing nations, where 98% of stillbirths are reported, particularly in low and middle-income countries. Nearly half of all stillbirths transpire during the intrapartum phase, which carries the highest risk. Intriguingly, the percentage of intrapartum stillbirths ranges from 10% in developed regions, to a staggering 59% in South Asia, with three-fourths of global stillbirths concentrated in South Asia and sub-Saharan Africa, affecting 60% of rural families in these regions. This underscores a correlation between maternal mortality and the availability of skilled obstetric health professionals.

Comparatively, sub-Saharan Africa experiences a stillbirth rate approximately ten times higher than that of developed nations, with rates of 29 per 1,000 births and 3 per 1,000 births, respectively. Globally, there has been a 19.4% reduction in the number of stillbirths between 2000 and 2015, equivalent to an Annual Rate of Reduction (ARR) of 2%. However, this decline in stillbirths is less pronounced than the reductions observed in maternal mortality (ARR=3.0%) and under-five mortality rates (ARR=3.9%) during the same period [2].

While our exploration of stillbirths has its roots in the global landscape, it is crucial to zoom in on specific regions for a more nuanced understanding. Transitioning from the broader perspective to a focused examination, we delved into the unique context of Algeria. This shift allows us to unravel the intricacies of stillbirth occurrences within the Eastern Algerian pregnant population, shedding light on

* **Corresponding author**
e-mail: a.kalla@univ-batna2.dz

region-specific factors and their potential contributions to this prevalent concern.

In Algeria, as in many other resource-constrained countries, there exists a dearth of precise data concerning the prevalence and severity of stillbirths, as well as the contributing variables. Rural areas and remote regions of the country remain underserved, with limited research conducted and scant findings available on pregnancy-related matters. The existing state of stillbirth data in Algeria reveals both strengths and significant limitations. While official statistics are available, underreporting and inconsistencies in reporting practices across healthcare facilities and regions pose challenges to obtaining an accurate prevalence. Data quality and accuracy may vary, hindering the identification of specific risk factors. Incomplete demographic information, limited access to advanced analyses and regional disparities further complicates the understanding of stillbirths. Temporal gaps and a lack of qualitative insights underscore the need for concerted efforts to enhance data collection practices, standardization and investment in both quantitative and qualitative research methodologies to provide a more comprehensive understanding of stillbirths.

Throughout this research, our primary objective was to uncover insights, engage in discussions regarding this connection and make predictions about the occurrence of stillbirths. Consequently, this study aims to achieve several objectives: (1) assess the prevalence of stillbirths through a retrospective survey involving population groups in Eastern Algeria, (2) identify the risk factors associated with stillbirths among pregnant women, and (3) develop a predictive model encompassing the risk factors identified. The overarching goal is to unearth solutions, explore the interplay between all identified factors and forecast the occurrence of stillbirths throughout the course of this research endeavor. Having established the critical context surrounding stillbirths and their multifaceted determinants, we now turn our attention to the methodological framework employed in this study. Through a rigorous examination of the Algerian pregnant population, we aimed to unravel the intricate interplay of various risk factors contributing to stillbirths. The following section delineates our comprehensive methodology, encompassing data collection, analysis techniques and the development of a predictive model, shedding light on the nuanced aspects of our investigation.

MATERIALS

Study design

A prospective research investigation spanning five years, from 2011 to 2015, was undertaken to examine the pregnancy period within a cohort of expectant mothers hailing from the Batna region in Eastern Algeria. This study involved the random selection of pregnant women from various geographical areas. Data collection took place during routine medical check-ups and was meticulously documented using multiple questionnaires. The research was conducted in various departments, including obstetrics and gynecology, neonatology and pediatric surgery, neurosurgery, and the biochemistry laboratory, all situated within the Mother-Child Unit across different hospitals within the Batna Department. Diverse analytical techniques were employed to ascertain which potential risk factors during pregnancy independently correlated with the occurrence of stillbirths. Importantly, written informed consent was diligently obtained from all participating individuals.

Data Collection

Between 2011 and 2015, interviews were conducted with pregnant women aged between 17 and 53 years in Eastern Algeria. Before the commencement of our research, ethical considerations were paramount. We obtained written informed consent from all participants, emphasizing the voluntary nature of their participation and the confidentiality of their information. Our study adheres to the ethical guidelines outlined by our institutions, ensuring the protection of participants' rights throughout the research process. Approval for our study was granted to guarantee that our research met the ethical standards required for human subjects research. This comprehensive ethical framework underscores our commitment to conducting the study responsibly and respecting the rights and well-being of our participants.

The dataset includes 17 parameters, with a focus on the presence (1) or absence (0) of stillbirths (SB) as a studied risk factor. Various factors were considered to assess their association with stillbirths. Age categories were defined as follows: (17-22), (22-34) and (34-53). Body Mass Index (BMI) ranges were categorized as (15-25), (25-30), (30-35) and (35-45). The dataset also included indicators for the presence (1) or absence (0) of various pathologies, including diabetes, hypertension (HT), kidney failure (KF), anemia, infections, and stress. Pathologies such as stress and diabetes were integral components, given their recognized associations with adverse pregnancy outcomes. Stress, in the context of our study, refers to chronic stress impacting maternal well-being during pregnancy. Diabetes, a critical pathology, encompasses both gestational diabetes (GD) and type 2 diabetes, with a focus on their potential contribution to stillbirth. Nutrient consumption categories from low to high (1, 2 or 3), including meat, fish, dairy products (DP), fruits-vegetables (FV), eggs, sweets, cereals, fish and soft drinks, were evaluated to understand the role of dietary habits. For instance, a moderate diet of meat and fish, as well as lower consumption of sweets, emerged as factors associated with stillbirth reduction. These parameters collectively contribute to a comprehensive analysis, allowing us to explore the intricate web of factors influencing stillbirth occurrences.

METHODS

To explore the complex interplay of factors associated with stillbirths, diverse analytical techniques were employed for a rigorous analytical approach. The research methodology in this study involved the utilization of statistical analysis techniques carried out using R (v3.6.3) within the RStudio environment (v1.3.959). To explore the associations between each predictor factor and the risk of stillbirths, univariate logistic regression initially was conducted. Predictor variables were assessed, focusing on selecting those displaying a p-value of less than 0.2 (3). Subsequently, variables showing significant associations in the univariate analyses

were considered for inclusion in the multivariate logistic regression model. The stepwise approach ensured a thorough examination of the potential predictors. Adjusted odds ratio with a 95% confidence interval, were used to assess the associations between various risk factors and stillbirth occurrences. Furthermore, we applied advanced statistical techniques, such as Hierarchical Cluster Analysis, to identify patterns within the dataset. The ANOVA test was chosen to validate our predictive model, offering insights into the significance of the identified risk factors. These analytical methods allowed us to comprehensively examine the multifaceted nature of stillbirth occurrences in our study population. To ensure the validity of logistic regression results, we assessed the assumptions of linearity, independence of errors and multicollinearity. Linearity was examined through visual inspection of partial regression plots and formal tests. The independence of errors was also evaluated. Multicollinearity was determined. In cases where assumptions were violated, appropriate measures such as transformations, inclusion of quadratic terms or addressing multicollinearity through variable selection were applied.

RESULTS

Studied population

In this forward-looking research endeavor, a total of 904 pregnant women were enrolled and underwent surveys throughout their pregnancy journey. Following a thorough screening process, 118 pregnant women were excluded due to incomplete questionnaires or missing data (Figure 1.A). Nevertheless, the study retained and successfully collected data from 786 women, out of which 71 individuals were identified as having experienced stillbirths, representing 9.03% of the cohort, while the remaining 715 women did not encounter stillbirths, comprising 90.97% of the study participants (Figure 1.B).

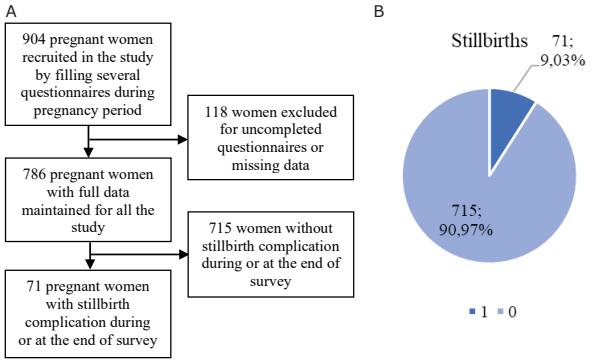

Figure 1. (A) Flow chart of the study population included stillbirths. (B) Prevalence of stillbirths in the included population (1: presence, 0: absence of stillbirths)

Various parameters have been investigated as potential risk factors possibly linked to stillbirths, encompassing factors like Age, BMI, medical conditions and dietary habits. Table 1 provides a comprehensive overview of the data about stillbirth cases categorized by these factors.

Regarding the age factor, a notable prevalence of stillbirths was observed among women falling within the age bracket of (34-53), accounting for 15.20% of women in this age group and 3.31% of the overall study population. Likewise, within the BMI range of (30-35), there was a higher prevalence of stillbirths, affecting 17.06% of women in this BMI category and 3.69% of the pregnant population. Additionally, substantial stillbirth prevalence was evident in the adjacent BMI ranges (25-30) and (35-40), collectively amounting to 36% (Table 1). Concerning medical conditions, pregnant women with diabetes and stress exhibited a notably high incidence of stillbirths, with 26.19% and 10.71% prevalence within these categories, respectively (corresponding to 1.40% and 7.51% of the entire population). However, stillbirths appeared to be more evenly distributed among other pathologies such as kidney failure, anemia, infections and hypertension.

In the context of dietary factors, our findings revealed a heightened occurrence of stillbirths among women with moderate consumption levels of fish (15.25%), fruits and vegetables (10.22%), eggs (11.92%), and a high intake of dairy products and soft drinks. The prevalence of stillbirths within these groups was 12.22% and 12.78%, respectively. Conversely, a group of pregnant women with a diet rich in meat exhibited a lower incidence of stillbirths, with a prevalence of only 2.68% within this group, constituting 0.38% of the entire study population. In contrast, stillbirth incidence displayed a more even distribution among various nutrient consumption levels, such as sweets and cereals (Table 1).

Association between stillbirth and risk factors

Based on the initial findings presented in Table 1, it became apparent that certain factors under examination were potential risk factors for the occurrence of stillbirths. To confirm these findings and explore the association between stillbirths and these risk factors, univariate analysis of odds ratios was conducted, maintaining a 95% confidence interval. However, it's important to note that this odds ratio analysis, while informative, was limited in its ability to account for the combined influence of multiple factors on stillbirths. As a result, a multivariate analysis of the odds ratio was undertaken to provide a more comprehensive investigation into the influential factors contributing to stillbirths in pregnant women. The detailed outcomes of this multivariate analysis are documented in Table 2.

Effectively, based on Table 2 results, the odds ratios' calculation in univariate analysis indicates a strong association between stillbirths and age in the (34-53) group, with an OR of 13.09 (95% IC: 2.70-235.95, p=0.012). Similarly, a huge association between stillbirths and BMI in (30-35) is remarkably evident for an OR estimated to be 5.28 (95% CI: 2.68-11.03, p<0.001). The same observation was noted for BMI for the (25-30) age range, where ORs have been estimated to be 2.16 (95% IC: 1.06-4.60, p=0.039), while less effect is noted for BMI in (35-45) (OR 14.44; 95% IC: 5.23-39.47, p<0.001).

Concerning pathologies, the association between stillbirths and stress and diabetes is confirmed, calculated Ors, respectively, were 2.23 (95% IC: 1.22-4.43, p=0.014), 4.05 (95% IC: 1.86-8.24, p<0.001). Expectedly, the study revealed that there is a significant association between hypertension and stillbirths with an OR of 1.80 (95% IC: 1.06-2.99, p=0.026). However, anemia is not revealed as a potentially associated factor (OR 1.31; 95% IC: 0.76-2.18,

p=0.319). Whereas a diet rich in meat is revealed again to be negatively associated with stillbirth incidence, the OR was estimated to be 0.24 (95% IC: 0.06-0.67, p=0.018).

Table 1. Stillbirth prevalence according to different risk factors

Risk factors		No		Yes		Prevalence in range %$
		n	%*	n	%*	
Age	17-22	73	9.29	1	0.13	1.35
	22-34	497	63.23	44	5.60	8.13
	34-53	145	18.45	26	3.31	15.20
BMI	15-25	308	39.19	12	1.53	3.75
	25-30	250	31.81	21	2.67	7.75
	30-35	141	17.94	29	3.69	17.06
	35-40	16	2.04	9	1.15	36.00
Diabetes	0	684	87.02	60	7.63	8.06
	1	31	3.94	11	1.40	26.19
Hypertension	0	549	69.85	46	5.85	7.73
	1	166	21.12	25	3.18	13.09
Kidney Failure	0	675	85.88	65	8.27	8.78
	1	40	5.09	6	0.76	13.04
Anemia	0	523	66.54	48	6.11	8.41
	1	192	24.43	23	2.93	10.70
Infections	0	475	60.43	48	6.11	9.18
	1	240	30.53	23	2.93	8.75
Stress	0	223	28.37	12	1.53	5.11
	1	492	62.60	59	7.51	10.71
Meat	1	480	61.07	55	7.00	10.28
	2	126	16.03	13	1.65	9.35
	3	109	13.87	3	0.38	2.68
Fish	1	480	61.07	48	6.11	9.09
	2	50	6.36	9	1.15	15.25
	3	185	23.54	14	1.78	7.04
Eggs	1	457	58.14	47	5.98	9.33
	2	133	16.92	18	2.29	11.92
	3	125	15.90	6	0.76	4.58
Dairy products	1	195	24.81	14	1.78	6.70
	2	441	56.11	46	5.85	9.45
	3	79	10.05	11	1.40	12.22
Fruits-Vegetables	1	275	34.99	22	2.80	7.41
	2	413	52.54	47	5.98	10.22
	3	27	3.44	2	0.25	6.90
Cereals	1	410	52.16	44	5.60	9.69
	2	147	18.70	14	1.78	8.70
	3	158	20.10	13	1.65	7.60
Sweets	1	368	46.82	45	5.73	10.90
	2	233	29.64	17	2.16	6.80
	3	114	14.50	9	1.15	7.32
Soft Drinks	1	331	42.11	32	4.07	8.82
	2	268	34.10	22	2.80	7.59
	3	116	14.76	17	2.16	12.78

Notes. For pathologies: (0) indicates the absence and (1) the presence of pathology. For nutrients: (1), (2), and (3) indicate levels of consumption, from low to high. (*) Percent of all pregnant population. ($) Percent of stillbirth in the same range or category

Table 2. Odds Ratios (OR, 95% CI) of different risk factors potentially associated with stillbirth

Risk Factors	Univariate analysis			Multivariate analysis		
	OR	95% IC	p-value	AOR	95% IC	p-value
Age 22-34	6.46	(1.38-115.39)	0.067	4.28	(0.85-78.39)	0.164
Age 34-53	13.09	(2.70-235.95)	0.012*	8.69	(1.63-162.26)	0.042*
BMI 25-30	2.16	(1.06-4.60)	0.039*	1.78	(0.84-3.94)	0.139
BMI 30-35	5.28	(2.68-11.03)	<0.001***	4.53	(2.17-9.99)	<0.001***
BMI 35-45	14.44	(5.23-39.47)	<0.001***	12.85	(4.11-40.16)	<0.001***
Stress	2.23	(1.22-4.43)	0.014*	2.20	(1.11-4.67)	0.030*
Diabetes	4.05	(1.86-8.24)	<0.001***	2.46	(1.03-5.60)	0.035*
HT	1.80	(1.06-2.99)	0.026*	1.03	(0.56-1.84)	0.921
KF	1.56	(0.58-3.56)	0.332	1.21	(0.41-3.12)	0.710
Anemia	1.31	(0.76-2.18)	0.319	1.49	(0.81-2.68)	0.187
Infections	0.95	(0.55-1.58)	0.842	0.71	(0.39-1.28)	0.265
Meat2	0.90	(0.46-1.65)	0.746	0.53	(0.20-1.23)	0.163
Meat3	0.24	(0.06-0.67)	0.018*	0.32	(0.07-1.11)	0.102
Fish2	1.80	(0.79-3.73)	0.134	2.49	(0.79-7.71)	0.113
Fish3	0.76	(0.39-1.37)	0.378	1.02	(0.46-2.11)	0.958
Eggs2	1.32	(0.72-2.30)	0.351	1.35	(0.61-2.84)	0.443
Eggs3	0.47	(0.18-1.04)	0.087*	0.73	(0.23-2.03)	0.569
DP2	1.45	(0.80-2.80)	0.239	1.54	(0.77-3.22)	0.237
DP3	1.94	(0.83-4.45)	0.119	2.57	(0.99-6.57)	0.049*
FV2	1.42	(0.85-2.45)	0.191	1.92	(1.04-3.64)	0.040*
FV3	0.93	(0.14-3.38)	0.920	1.20	(0.15-5.80)	0.841
Cereals2	0.89	(0.46-1.63)	0.710	0.77	(0.37-1.53)	0.468
Cereals3	0.77	(0.39-1.42)	0.420	0.81	(0.38-1.62)	0.559
Sweets2	0.60	(0.33-1.05)	0.082*	0.43	(0.21-0.83)	0.015*
Sweets3	0.65	(0.29-1.30)	0.250	0.39	(0.15-0.90)	0.037*
Soft Drinks2	0.85	(0.48-1.49)	0.571	0.95	(0.49-1.79)	0.864
Soft Drinks3	1.52	(0.80-2.80)	0.192	1.61	(0.78-3.24)	0.200

Notes. OR: Odds Ratio; 95%IC: Interval of Confidence at 95%; *: OR significant at α=0.1; **: OR significant at α=0.05; ***: OR significant at α=0.01

Contrarily, OR calculation showed a potential positive association (significant at α=0.1) between medium rates of fish and sweets diets, with OR estimated to be 1.80 (95% IC: 0.79-3.73, p=0.134), 0.60 (95% IC: 0.33-1.05, p=0.082), respectively, and high rates of eggs and dairy products with OR estimated to be 0.47 (95% IC: 0.18-1.04, p=0.087) and 1.94 (95% IC: 0.83-4.45, p=0.119), respectively. Based on the results of the multivariate analysis, as detailed in Table 2, the adjusted odds ratios and corresponding p-values substantiate several of the associations previously identified in the univariate analysis. Specifically, advanced maternal age (>35), a high BMI in the (30-35) age group, and moderate consumption of fish and meat are strongly linked to the occurrence of stillbirths during pregnancies. Notably, women with a BMI in the (30,35) age range experience a more than threefold increase in the risk of stillbirths, while a diet characterized by moderate fish consumption elevates the risk by nearly threefold.

A lesser effect has been recorded for a BMI in the (25-30) group (AOR 1.78; 95% IC: 0.84-3.94, p=0.139) compared to the BMI of (30-35), but it remained strongly associated

(AOR 4.53; 95% IC: 2.17-9.99, p<0.001) with stillbirths. Stress and diabetes are also confirmed as associated factors with stillbirths even if their effects are diminished in the multivariate analysis (AOR 2.20; 95% IC: 1.11-4.67, p=0.030), (AOR 2.46; 95% IC: 1.03-5.60, p=0.035), respectively. Having anemia and high consumption of eggs preserved the same effects since their odds ratios are not changed and their effects are lost in signification. Similarly, a diet rich in meat preserved its effects as protecting factors against stillbirths (AOR 0.33; 95% IC: 0.07-1.15; p=0.112), also a diet moderate in fish (AOR 2.49; 95% IC: 0.79-7.71), though its signification is seen reduced (p=0.113).

We observe that the consumption of dairy products, fruits and vegetables, and sweets have also an effect on stillbirths according to their odds ratio and p-values (AOR 2.57; 95% IC: 0.99-6.57, p=0.049), (AOR 1.92; 95% IC: 1.04-3.64, p=0.040), (AOR 0.43; 95% IC: 0.21-0.83, p=0.015), respectively; while the effect of the factors like soft drinks, cereals has disappeared, which means that these factors are not significant in its influence on stillbirths. In summary, these findings collectively indicate that a range of factors, encompassing BMI, stress, diabetes and dietary habits such as fish, meat, dairy products, fruits-vegetables and sweets consumption, emerge as the most influential and statistically significant contributors. Consequently, associations exist not only among these individual factors, but also between these factors and the occurrence of stillbirths, underscoring the complex interplay of these variables in influencing stillbirth outcomes.

Interaction between Factors and Predictive Model

The multitude of factors at play, along with their intricate relationships, as well as the aforementioned findings, pose challenges in validating associations and understanding their impact during the pregnancy period. Consequently, to mitigate potential statistical confounding biases, a comprehensive multivariate logistic regression analysis was conducted. This involved testing for possible interactions among independent factors by incorporating all variables into an exhaustive model. Notably, this methodology necessitates the execution of numerous logistic regression models. As outlined in the results presented in Table 3, the factor exerting the most pronounced influence is a BMI exceeding 30. Several factors emerged as statistically significant, including age exceeding 34, stress, diabetes, and dietary habits encompassing the consumption of dairy products, fruits and vegetables and sweets. Conversely, factors such as anemia and moderate consumption of fish or a diet rich in meat demonstrated comparatively less significance in their impact.

Other factors, such as kidney failure, infections, and the consumption of eggs, cereals and soft drinks, were found to have negligible influence and demonstrated limited association with stillbirths. The complexity arising from the multitude of factors made it challenging to discern their impact and interactions. Consequently, the adoption of a Top-down Stepwise Strategy became necessary. The outcomes of this strategy in refining the Stillbirth model, along with associated risk factors, revealed a selected model comprising influential factors that resulted in a reduced AIC value of 429.72. These influential factors encompass advanced maternal age within the (34-53) range, high BMI within the (25-35) range,

Table 3. Selected factors of the Stillbirth model

Selected factors	Df	Deviance	AIC	
Fish	2	401.86	429.86	
DP	2	402.90	430.90	
Meat	2	404.04	432.04	
Diabetes	1	402.89	432.89	
Stress	1	403.49	433.49	
Sweets	2	405.60	433.60	
Age	2	407.38	435.38	
BMI	3	425.05	451.05	
Risk factors	**Estimate Std.**	**Error**	**z value**	**Pr (>|z|)**
(Intercept)	-5.481	1.118	-4.899	<0.001***
Age 22-34	1.522	1.036	1.469	0.141
Age 34-53	2.171	1.050	2.069	0.038*
BMI 25-30	0.550	0.384	1.430	0.152
BMI 30-35	1.424	0.373	3.811	<0.001***
BMI 35-45	2.403	0.548	4.380	<0.001***
Fish2	1.106	0.535	2.068	0.038 *
Fish3	0.030	0.363	0.084	0.933
Stress1	0.783	0.345	2.270	0.023*
Diabetes1	0.984	0.413	2.381	0.017*
Meat2	-0.639	0.437	-1.459	0.144
Meat3	-1.261	0.659	-1.912	0.055.
DP2	0.593	0.344	1.723	0.085.
DP3	0.994	0.468	2.124	0.033*
Sweets2	-0.760	0.330	-2.299	0.021*
Sweets3	-0.851	0.430	-1.980	0.047*

Notes. Signification; *: p<0.1, **: p<0.05, ***: p<0.001. Null deviance: 476.79 on 785 degrees of freedom. Residual deviance: 397.72 on 770 degrees of freedom. AIC: 429.72. Number of Fisher Scoring iterations: 7

stress, diabetes, moderate consumption of fish and sweets, as well as high consumption of meat and dairy products. Notably, other risk factors, including hypertension, infections, kidney failure, anemia and the consumption of eggs, fruits-vegetables, cereals and soft drinks, were excluded from the final model. To identify the most effective predictor model encompassing the interactions among risk factors and their association with stillbirths, a multinomial regression analysis was applied to models comprising stillbirths and their associated factors. This iterative process culminated in a stable model after approximately 592,600 iterations, characterized by the interaction between high BMI, advanced age, stress, diabetes and the consumption of fish, meat, dairy products and sweets, as depicted in Figure 2.

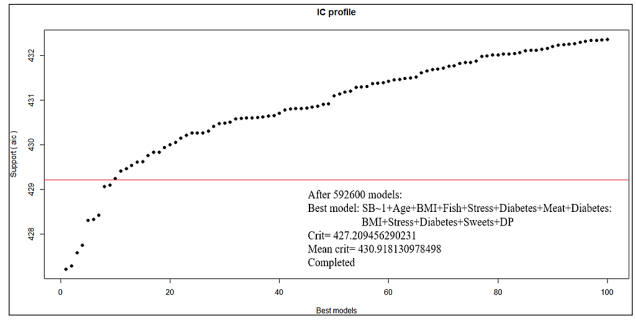

Figure 2. Regression curve of the best predictive model of stillbirths and its associated factors

To validate the effectiveness of the best predictor model, a comprehensive analysis was conducted using the ANOVA (Analysis of Variance) test to assess the robustness and predictive accuracy. This statistical test was employed to examine the influence of independent variables, which represent the various risk factors, on the dependent variable, which in this context is stillbirths. The primary objective was to determine whether there were statistically significant differences among the means associated with different risk factors. The Analysis of the Deviance, specifically employing Type II tests, was utilized for this purpose. Type II tests in ANOVA are designed to evaluate the significance of each independent variable while accounting for the presence of other variables in the model. In essence, it helps ascertain the individual contributions of these variables to the occurrence of stillbirths. The inclusion of ANOVA in our analysis strengthens the overall validation process, ensuring that our predictive model is not only statistically sound but also clinically relevant. The results of the ANOVA analysis, reported in Table 4, provide insights into the statistical significance of the risk factors included in the final selected model generated through the Stepwise strategy. These findings serve to confirm the associations and impacts of these factors on the occurrence of stillbirths, further validating the effectiveness of the predictor model.

Table 4. The ANOVA test of the selected model of Stillbirth

Risk factors	χ^2 Value	df	Pr (>Chisq)
Age	9.658	2	0.008 **
BMI	27.33	3	< 0.001 ***
Fish	4.14	2	0.126
Stress	5.770	1	0.017 *
Diabetes	5.173	1	0.023 *
Meat	6.325	2	0.042 *
DP	5.183	2	0.075 .
Sweets	7.881	2	0.020 *

Notes. Signification: * p<0.1, ** p<0.05, *** p<0.001; df: degree of freedom

The analysis is applied to the selected factors that appeared in the final model. The Chi-square (χ^2) test application revealed that the most influential factors are Age (p=0.008), BMI (p<0.001), stress (p=0.017), diabetes (p=0.023) and moderate consumption of fish (p=0.126), meat (p=0.042) and dairy products (p=0.075). Low consumption of sweets appeared as a significant factor (p=0.020), while other factors were not significant and have been ruled out. Once the best model was identified, we proceeded to recalculate the adjusted odds ratios of this final predictor model, expressing them as percentages (OR%). This percentage representation provided a clear understanding of the magnitude of the effect of each risk factor. Consequently, both the odds ratios and p-values transformed.

In this context, it became evident that certain risk factors exerted particularly strong effects. Notably, advanced maternal age within the (34-53) range exhibited a threefold percent effect, while BMI within the (25-30) range demonstrated a substantial effect of 63.76%. A higher BMI in the (30-35) range displayed an even more pronounced effect of 152.85%. Additionally, low consumption of fish was associated with an effect of 111.17%, followed by diabetes with 98.42% and stress with 80.54%. Dairy product consumption showed an effect of 66.58%. Conversely, low-meat diets had a relatively modest effect at 19.41%, and sweets exhibited a minor effect at 17.20%.

In contrast, several other factors, including infections, anemia and dairy product consumption, were not found to be significantly influential. To offer a comprehensive overview of the factors influencing stillbirths within the retained model, the odds ratios were further presented with 95% confidence intervals, depicted in a forest plot as illustrated in Figure 3. Notably, the p-values associated with the adjusted odds ratios of the selected factors were lower compared to the p-values of the previous odds ratios, reaffirming their significance in the context of stillbirths.

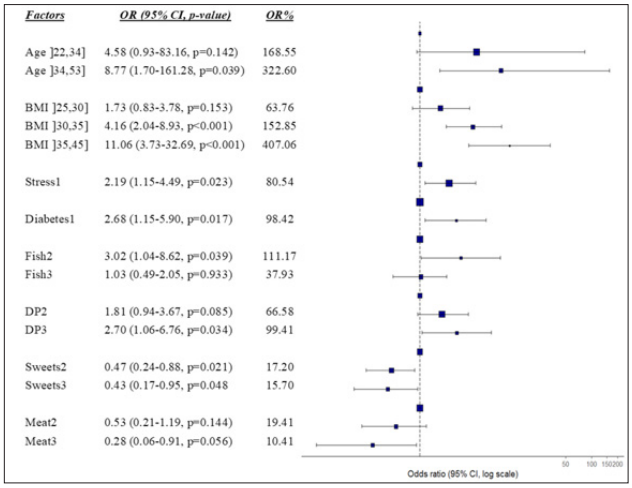

Figure 3. Forest model of associated risk factors and their influence on stillbirths (OR are new adjusted estimates)

The findings reveal reduced odds ratios for certain influential factors in the retained model, which could potentially heighten the risk of stillbirths, in comparison to the outcomes of univariate and multivariate analyses. Notably, factors such as advanced maternal age (>34), a BMI exceeding 25, stress, diabetes and moderate consumption of fish and dairy products, all positioned themselves to the right of the vertical line within the forest plot of the model. This positioning signifies a positive association with stillbirths and reaffirms their role as contributing risk factors in the general population. Conversely, the consumption of meat and sweets occupied the left side of the forest plot model, indicating that these factors wield comparatively less influence or exhibit a negative association with stillbirths.

The final stage involves predictive analysis, designed to anticipate the likelihood of stillbirth and elucidate the connections and associations between factors and their respective impacts. This predictive analysis is visually depicted in Figure 4, which presents a graphical representation of how various factors relate to the prediction of stillbirths. It delineates the percentage of stillbirth occurrences across different levels of each factor. In essence, these factors collectively form a predictive model for stillbirths, offering valuable insights that can aid in the prevention of pregnancy complications and the safeguarding of pregnant women's well-being.

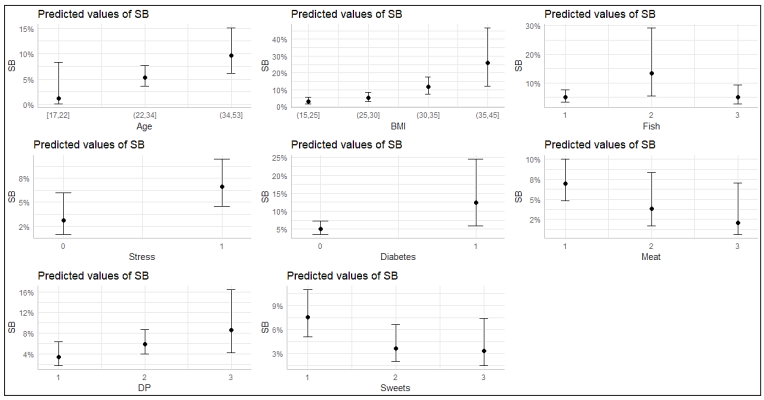

Figure 4. Predicted values of stillbirths based on the factor level

When delving into the quest for factors linked to a specific phenomenon, it is a common temptation to include a multitude of potential explanatory variables within a model. This approach may seem comprehensive, but it is essential to recognize that a larger, more complex model is not necessarily the most efficient or informative one. In reality, some of these included factors may have negligible or statistically insignificant effects on the risk being studied. Consequently, there arises a critical need to explore alternative methodologies that can aid in identifying the truly influential factors and elucidating their interrelationships.

One such valuable approach is hierarchical clustering analysis. This technique operates on the premise that it is essential to group and organize the factors into meaningful clusters based on their similarities or patterns of association. By doing so, it becomes possible to uncover underlying structures and discern which factors are more closely related or impactful concerning the phenomenon under investigation.

Hierarchical clustering analysis facilitates the identification of distinct groups or categories of factors, shedding light on how they interact with each other and contribute to the observed outcomes. This method offers a more nuanced and refined understanding of the factors at play, allowing for more effective decision-making and model refinement. In essence, it helps researchers navigate the complex web of variables, ensuring that the resulting models are not only comprehensive but also insightful and pragmatic.

Hierarchical Cluster Analysis of Stillbirth

To explore and identify patterns of similarity within our study population, we employed a Hierarchical Clustering Analysis, a method that allows us to uncover cohesive groups of subjects or variables that exhibit higher degrees of correlation. This analysis involves a two-step process. The first step entails organizing individuals into clusters based on a predefined similarity criterion. This criterion serves as a measure of how closely related individuals are in terms of their characteristics or behaviors. By grouping individuals with similar attributes or traits, we can gain insights into the underlying structure of our study population.

In the context of the Stillbirth model, this clustering approach revealed the presence of three distinct clusters. These clusters represent subgroups of individuals or variables that share common characteristics or exhibit similar patterns concerning stillbirths. The visual representation of these clusters can be observed in Figure 5, offering a clearer understanding of the relationships and associations among different factors and their influence on stillbirth outcomes. The hierarchical clustering analysis provides a valuable tool for unraveling complex patterns and relationships within our data, ultimately enhancing our ability to make informed conclusions and decisions.

Cluster 1 predominantly comprised cases with advanced maternal age and exhibit a high frequency of stillbirths when their diet is characterized by poor consumption of meat, eggs, fish, soft drinks, cereals and sweets. Conversely, within this cluster, women who consume high amounts of eggs, meat, fish and cereals tend to experience a lower frequency of stillbirths.

Cluster 2 exhibited a higher prevalence of obesity and diabetes, it consists of individuals with a high stillbirth frequency if they maintain a diet moderately rich in nutrients, except for cereals. However, when their BMI falls and they are within the (15-25) age range and they experience low stress levels, coupled with low consumption of meat, eggs, fish, dairy products, sweets, and fruits-vegetables, their stillbirth frequency is notably lower.

Cluster 3 showed a unique profile characterized by stress and dietary factors. We find women who exhibit a high stillbirth frequency when their diet primarily consists of rich sources of meat, eggs, fish and cereals, and they experience stress without infections. Conversely, women within this cluster who maintain a diet poor or moderate in fish, meat, eggs, cereals and dairy products, have no stress, and are devoid of infections, tend to experience a lower stillbirth frequency.

These clusters provide a nuanced understanding of the diverse risk factor combinations contributing to stillbirth occurrences. The identification of these patterns is crucial for tailoring targeted interventions, as each cluster may benefit from distinct preventive strategies.

The second stage of clustering reveals homogeneous groups of subjects or variables that have a stronger

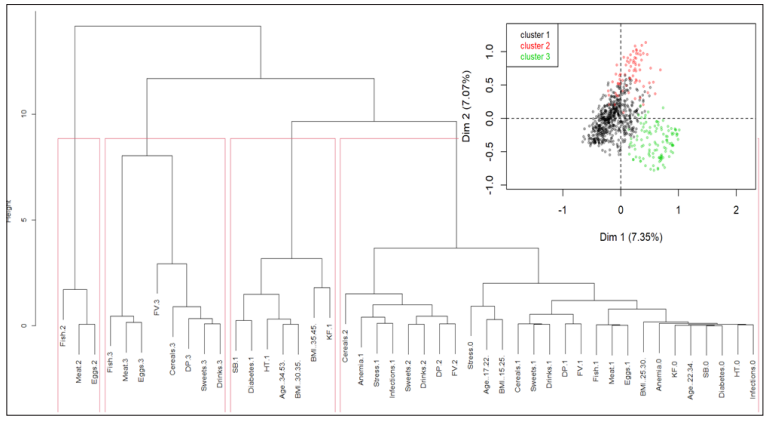

Figure 5. HCA Stillbirths' clusters partition and dendrogram of associated risk factors

correlation with stillbirths when compared to others. These groupings are visually represented in a dendrogram, illustrating the distinct cluster partitions and subgroups. Within this population, several factors emerge as strongly significant contributors to stillbirths, with BMI exceeding 30 and age surpassing 34 ranking as the most influential. These are followed by hypertension, diabetes and kidney failure as significant factors. Additionally, anemia, stress, infections and moderate consumption of sweets, soft drinks, dairy products, fruits-vegetables and cereals also play significant roles in influencing stillbirths. Conversely, factors such as low consumption of eggs, meat, fish, dairy products, soft drinks, cereals and fruits and vegetables are interconnected and exhibit significance. Lastly, other factors are deemed non-significant and have minimal impact on pregnancy outcomes.

DISCUSSION

In our research, we focused on investigating the occurrence of stillbirth complications and their correlation with risk factors within the pregnant population of Eastern Algeria. Our findings reveal a notable prevalence of stillbirths, which are linked to factors such as inadequate or insufficient dietary habits, older maternal age, excessive body weight or obesity, and the presence of certain health conditions (specifically, stress, diabetes, hypertension, anemia, kidney failure and infections). Among these, advanced maternal age, elevated BMI, stress and diabetes emerged as prominent contributors. Notably, specific dietary factors, such as inadequate meat consumption and elevated intake of fish and sweets, also exhibited significant associations.

These factors may constitute a predictive model for a stillbirth occurrence. However, based on the selected model and the association analysis (adjusted odds ratio, 95% CI), we revealed here, that among all factors, stillbirths are strongly associated with Age in the (34-53) range (8.77; 95% CI: 1.70-161.28, p=0.039), BMI in the (25-30) group (1.73; 95% CI: 0.83-3.78, p=0.153), BMI in the (30-35) category (4.16; 95% CI: 2.04-8.93, p<0.001), and over all ranges, stress (2.19; 95% CI: 1.15-4.49, p=0.023), diabetes (2.68; 95% CI: 1.15-5.90, p=0.017), moderate diet in meat (0.53; 95% CI: 0.21-1.19, p=0.144), fish (3.02; 95% CI: 1.04-8.62, p=0.039), dairy products (1.81; 95% CI: 0.94-3.67, p=0.085) and sweets (0.47; 95% CI: 0.24-0.88, p=0.021).

The findings regarding age and BMI align with research conducted not only in Algeria, but also on a global scale according to [4,5]. Previous studies in Algeria have demonstrated a significant rise in the occurrence of spontaneous abortion as maternal age increases. For instance, the incidence increases from 7.2% among patients aged between (24-29) years to 11% among those aged between (35-39) years and further rises to 16% in the (40-45) years age category. These findings align with the trends identified in our study, reinforcing the influence of age on the outcomes of pregnancy [6], Alternatively, this could also be attributed to genetic factors [7]. Researchers worldwide have dedicated significant efforts to explore risk factors and their impact on pregnancy. According to [8,9], Maternal age exerts a significant influence [10].

Moreover, additional studies have demonstrated an elevated risk of pregnancy complications among obese mothers [11], which can be attributed to the effects of dietary supplementation during pregnancy on maternal weight gain, as well as the absence of physical exercise among pregnant women [12]. Being overweight or obese during early pregnancy raises the risk of infant mortality [13,14], premature mortality among adult offspring due to cardiovascular events [15], risk of preterm birth and low birth weight [16]. What is more, weight gain during pregnancy is associated with gestational diabetes and hypertension, leading to adverse outcomes [17].

To elaborate further, stress is considered an influential factor in the occurrence of stillbirths based on our study's findings. This association can be attributed to the physiological response to stress, which involves the activation and release of stress hormones such as cortisol and adrenaline. These hormones, when consistently elevated due to chronic stress, can disrupt the delicate balance of biochemical pathways involved in maintaining a healthy pregnancy. For instance, prolonged stress can lead to increased inflammation in the body, which may negatively impact placental and fetal development. Additionally, stress can affect blood flow and oxygen delivery to the fetus, potentially leading to complications that increase the risk of stillbirth.

Overall, the link between stress and stillbirths underscores the importance of addressing maternal mental well-being during pregnancy as part of comprehensive prenatal care. Stress management strategies and psychological support may play a crucial role in reducing the risk of stillbirth and promoting healthier pregnancy outcomes [18,19]. Nevertheless, certain research studies have concluded that there is insufficient evidence to support the notion that stress directly causes stillbirth, as per their findings [20]. The influence of stress is a topic that has received substantial attention and discussion in a wide array of scientific articles. Indeed, researchers and experts are investigating the complexities of stress during pregnancy, exploring its potential impact on maternal and fetal health. These discussions often encompass various aspects of stress, including its physiological effects on the body, its potential to trigger hormonal changes, and its role in affecting both the mother and the developing fetus. Researchers are also scrutinizing the association between stress and pregnancy complications, including stillbirths, preterm birth and low birth weight. While some studies suggest a significant link between maternal stress and adverse pregnancy outcomes, it is worth noting that the exact mechanisms and causal relationships remain a subject of ongoing investigation and debate in the scientific community. Nonetheless, the extensive body of literature on this topic underscores its importance and the need for continued research to better understand the complexities of stress during pregnancy [21,22].

Diabetes is another significant factor that can have a profound impact on pregnancy. Women affected by diabetes experience elevated levels of blood sugar, which their bodies struggle to regulate due to inadequate insulin production or insulin resistance. This condition can lead to a range of complications during pregnancy and can affect both the mother and the developing fetus. In pregnant

women with diabetes, careful monitoring and management of blood sugar levels are essential to mitigate potential risks. Uncontrolled diabetes during pregnancy can increase the chances of complications such as gestational diabetes, preeclampsia, preterm birth and larger birth weight babies (macrosomia). Additionally, it can heighten the risk of birth defects and stillbirth. Managing diabetes during pregnancy typically involves dietary adjustments, exercise, and, in some cases, insulin therapy. Close medical supervision and collaboration with healthcare providers are crucial to ensure a healthy pregnancy outcome for women with diabetes [23]. Among our study participants, pregnant women with diabetes faced a risk that was four times higher than those without diabetes. In Algeria, a significant proportion of pregnant women, approximately 15 to 20%, are at risk of developing gestational diabetes (GD) or type 2 diabetes during their pregnancy. It is noteworthy that the incidence of gestational diabetes has been on the rise in recent years, highlighting the importance of proactive screening and management for diabetes in pregnant women to ensure healthier pregnancy outcomes [24].

It is well-established that maternal age exceeding 35 years, as well as being overweight or obese, are recognized risk factors that increase the likelihood of developing gestational diabetes (GD) or type 2 diabetes during pregnancy. These factors contribute to the overall risk profile for diabetes in pregnant women, emphasizing the importance of proactive screening and tailored care for individuals with these risk factors to manage and reduce the impact of diabetes during pregnancy according to [17,25]. Other research studies have demonstrated that diabetes in the mother can heighten the susceptibility of their offspring to cardiovascular disease (CVD). This highlights the potential long-term health implications of maternal diabetes on the health and well-being of the child, emphasizing the importance of effective management and preventive measures during pregnancy to reduce the risk of such health issues in the future [26].

Among the various factors that were examined in our study, there are several that do not directly cause stillbirths. These factors include hypertension, anemia, kidney failure, infections and various dietary components such as fruits and vegetables, soft drinks and cereals. However, it is important to note that the risk factors we have discussed in detail above are significantly associated with stillbirths in our specific population. These factors exert a strong influence on a woman's pregnancy and substantially elevate the risk of stillbirth occurrence. As a result, these factors hold the potential to collectively form a predictive model for stillbirths. Such a model could play a crucial role in preventing this pregnancy complication and safeguarding the well-being of pregnant women by identifying those at higher risk and enabling timely interventions.

Our findings hold crucial implications for prenatal care and call for targeted interventions to mitigate the risk of stillbirths. Healthcare providers can leverage this information to enhance the precision of prenatal care by implementing risk assessment protocols. For instance, regular monitoring of maternal age, BMI and stress levels during prenatal visits can aid in the early identification of high-risk pregnancies. Additionally, personalized dietary counseling focusing on factors such as balanced meat and fish intake can be integrated into routine prenatal care to address specific nutritional contributors to stillbirth risk. Timely diabetes screening and management, especially in older pregnant women, is paramount to reduce the associated risk.

Implementing educational programs for expectant mothers on the importance of maintaining a healthy diet, managing stress and controlling diabetes can be instrumental in preventing stillbirths. Our findings, furthermore, underscore the need for comprehensive screening programs, particularly for gestational diabetes, targeting pregnant women aged 35 and older. Such initiatives can contribute to the development of evidence-based public health policies that address the specific risk factors prevalent in the population, ultimately working towards the reduction of stillbirth rates. These measures collectively contribute to a proactive and personalized approach to prenatal care, aligning with the broader goal of reducing the incidence of stillbirths.

CONCLUSION

Stillbirths represent a prevalent and distressing risk that pregnant women may encounter, stemming from a complex interplay of behavioral and pathological factors. Our study makes a significant contribution to the understanding of stillbirths, especially in regions with limited data, such as Eastern Algeria. By exploring over fifteen distinct factors, encompassing both pathologies and dietary considerations, our research extends beyond existing knowledge. The comprehensive nature of our investigation allows for a more nuanced understanding of the complex interplay of factors associated with stillbirths.

The investigation draws upon data collected from a sample of 786 pregnant women residing in Eastern Algeria to shed light on the multitude of factors associated with this risk. Among the prominent risk factors identified in our study are maternal age, maternal body mass index (BMI), pregnancy-related pathologies and nutritional deficiencies, all of which contribute to the tragic outcome of stillbirths. Nutrition holds a pivotal role, not only in safeguarding the health of expectant mothers but also in ensuring the well-being of the unborn child, underscoring the potential harm that nutrient or vitamin deficiencies can pose to both. The identification of these risk factors is instrumental in the development of predictive models and strategies aimed at averting the heart-wrenching consequences of stillbirths and preserving maternal health.

It is worth underlining that in Algeria, much like many other developing nations, there exists a significant dearth of dependable data concerning the occurrence and severity of pregnancy complications and their associated determinants. The rural and countryside regions of the country remain largely uncharted territory, where pregnancy-related issues continue to be shrouded in taboo, resulting in a dearth of comprehensive research efforts and limited access to findings.

While global research endeavors have predominantly focused on a select subset of factors, our study extends the scope considerably by examining over fifteen distinct factors, encompassing both pathologies and dietary considerations.

By doing so, our research contributes a significant dimension to the body of knowledge on pregnancy complications, suggesting that certain instances of stillbirths may indeed be preventable and can potentially be forecasted based on their underlying risk factors. We advocate for increased attention and resources to address this data gap, particularly in rural areas, to facilitate comprehensive research and improve access to crucial findings.

Our study serves as a comprehensive endeavor, encompassing the estimation of stillbirth prevalence and frequency. It delves into the meticulous documentation of potential risk factors intertwined within the study population. It also culminates in the development of a predictive model, rooted in several advanced statistical analysis techniques, offering insights into the occurrence of stillbirths driven by their associated risk factors. This predictive model holds the promise of being a valuable tool for healthcare providers, policymakers and researchers, enabling a more targeted and effective approach to preventive measures. By identifying high-risk individuals based on a combination of factors, interventions can be implemented timely, potentially reducing the incidence of stillbirths and improving overall maternal and fetal health outcomes.

Future research in the field of stillbirths and associated risk factors should focus on multidimensional approaches to gain a comprehensive understanding of this complex issue. Longitudinal studies, genetic investigations and intervention strategies are essential to refine our knowledge. Examining regional and cultural variations, the impact of healthcare access, and employing advanced data analytics will provide insights into how diverse factors interact. Education and awareness programs for expectant mothers, along with evidence-based public health policies, can play pivotal roles in reducing stillbirth rates. Collaborative research efforts and community engagement should be emphasized to create a holistic approach to tackling stillbirths and ensuring the health and well-being of both mothers and their unborn children.

ABBREVIATIONS

AIC – Akaike Information Criterion
ANOVA – Analysis Of Variance
aOR – adjusted Odds Ratio
ARR – Annual Rate of Reduction
BMI – Body Mass Index
CI – Confidence Interval
DP – Dairy Products
FV – Fruits-Vegetables
GD – Gestational Diabetes
HCA – Hierarchical Clustering Analysis
KF – Kidney Failure
OR – Odds Ratio
WHO – World Health Organization

FUNDING

No funds, grants, or other support were received.

COMPETING INTERESTS

The authors have no conflicts of interest to declare.

ETHICAL APPROVAL

Consent to participate/for publication involvement statement Patients were not involved in the design, conduct, reporting, or dissemination plans of our research. However, informed written consent was obtained from all individual participants included in the study before conducting the interviews.

AVAILABILITY OF DATA AND MATERIAL/CODE AVAILABILITY

Not available.

ORCID iDs

Adel Kalla https://orcid.org/0000-0001-7683-8721
Lotfi Loucif https://orcid.org/0000-0001-5246-9132
Abdelali Boussif https://orcid.org/0000-0001-6595-6861

REFERENCES

1. Delabaere A, Huchon C, Deffieux X, Beucher G, Gallot V, Nedellec S, et al. Épidémiologie des pertes de grossesse. *J Gynecol Obstet Biol la Reprod*. 2014;43(10):764-75.
2. WHO. WHO: Stillbirths; 2016. [http://www.who.int/maternal_child_adolescent/epidemiology/stillbirth/en/] (acces: 1.08.2020).
3. El Sanharawi M, Naudet F. Understanding logistic regression. J Fr Ophtalmol. 2013;36(8):710-5.
4. World Health Organization. Improving maternal and newborn health and survival and reducing stillbirth – Progress report 2023. UNICEF; 2023. [https://www.who.int/publications/i/item/9789240073678]
5. Mukherjee A, Di Stefano L, Blencowe H, Mee P. Determinants of stillbirths in sub-Saharan Africa: A systematic review. BJOG An Int J Obstet Gynaecol. 2024;131(2):140-50.
6. Haoud K, Mellali S, Gouas L, Tchirkov A, Vago P, Moulessehoul S. Prevalence of aneuploidies in products of spontaneous abortion: Interest of FISH and MLPA. Morphologie. 2014;98(320):40-6.
7. Mellali S, Haoud K, Gouas L, Khaled MB, Vago P, Moulessehoul S. Prenatal BoBsTM in the cytogenetic analysis of products of spontaneous miscarriage. South African Med J. 2015;105(10):870-3.
8. Andersen AN, Wohlfahrt J, Christens P, Olsen J, Melbye M, Nybo A. General practice linkage study. BMJ. 2000;320:1708-12.
9. Fuchs F, Monet B, Ducruet T, Chaillet N, Audibert F. Effect of maternal age on the risk of preterm birth: A large cohort study. Obstet Gynecol Surv. 2018;13(1):1-10.
10. Salgado H de O, Andreucci CB, Gomes ACR, Souza JP. The perinatal bereavement project: development and evaluation of supportive guidelines for families experiencing stillbirth and neonatal death in Southeast Brazil – a quasi-experimental before-and-after study. Reprod Health. 2021;18(1):1-17.
11. Atkins B, Kindinger L, Mahindra MP, Moatti Z, Siassakos D. Stillbirth: prevention and supportive bereavement care. BMJ Med. 2023;2(1):e000262.
12. Tabrizi JS, Asghari A, Pourali F, Kousha H, Nikniaz L. Effects of food supplementation during pregnancy on maternal weight gain, hemoglobin levels and pregnancy outcomes in Iran. Matern Child Health J. 2019;23(2):258-64.
13. Johansson S, Villamor E, Altman M, Bonamy AKE, Granath F, Cnattingius S. Maternal overweight and obesity in early pregnancy and risk of infant mortality: A Population based cohort study in Sweden. BMJ. 2014;349:1-12.
14. Yusuf H, Stokes J, Wattar BHA, Petrie A, Whitten SM, Siassakos D. Chance of healthy versus adverse outcome in subsequent pregnancy after previous loss beyond 16 weeks: data from a specialized follow-up clinic. J Matern Neonatal Med. 2023;36(1).
15. Reynolds RM, Allan KM, Raja EA, Bhattacharya S, McNeill G, Hannaford PC, et al. Maternal obesity during pregnancy and premature mortality from cardiovascular event in adult offspring: Follow-up of 1 323 275 person years. BMJ. 2013;347(7921):1-10.
16. Ju AC, Heyman MB, Garber AK, Wojcicki JM. Maternal obesity and risk of preterm birth and low birthweight in Hawaii PRAMS, 2000–2011. Matern Child Health J. 2018;22(6):893–902. A

17. Heude B, Thiébaugeorges O, Goua V, Forhan A, Kaminski M, Foliguet B, et al. Pre-pregnancy body mass index and weight gain during pregnancy: Relations with gestational diabetes and hypertension, and birth outcomes. Matern Child Health J. 2012;16(2):355-63.
18. Golbasi Z, Kelleci M, Kisacik G, Cetin A. Prevalence and correlates of depression in pregnancy among Turkish women. Matern Child Health J. 2010;14(4):485-91.
19. Gardosi J, Madurasinghe V, Williams M, Malik A, Francis A. Maternal and fetal risk factors for stillbirth: Population based study. BMJ. 2013;346(7893):1-14.
20. Nelson DB, Grisso JA, Joffe MM, Brensinger C, Shaw L, Datner E. Does stress influence early pregnancy loss? Ann Epidemiol. 2003;13(4):223-9.
21. Lynch CD, Sundaram R, Buck Louis GM. Biomarkers of preconception stress and the incidence of pregnancy loss. Hum Reprod. 2018;33(4):728-35.
22. Hall KS, Dalton VK, Zochowski M, Johnson TRB, Harris LH. Stressful life events around the time of unplanned pregnancy and women's health: Exploratory findings from a national sample. Matern Child Health J. 2017;21(6):1336-48.
23. Figueroa Gray M, Hsu C, Kiel L, Dublin S. It's a Very big burden on me: Women's experiences using insulin for gestational diabetes. Matern Child Health J. 2017;21(8):1678-85.
24. Nadir–Azirou et al. National survey on the measurement of the weight of risk factors for Non-Communicable Diseases according to the WHO STEPwise approach Main results. Organisation mondiale de la Santé. Algérie: AFRO-OMS; 2017. [https://www.afro.who.int/fr/publications/enquete-nationale-sur-la-mesure-du-poids-des-facteurs-de-risque-des-maladies-non]
25. Davies HR, Visser J, Tomlinson M, Rotherham-Borus MJ, LeRoux I, Gissane C. An investigation into the influence of socioeconomic variables on gestational Body Mass Index in pregnant women living in a peri-urban settlement, South Africa. Matern Child Health J. 2012;16(8):1732-41.
26. Yu Y, Arah OA, Liew Z, Cnattingius S, Olsen J, Sørensen HT, et al. Maternal diabetes during pregnancy and early onset of cardiovascular disease in offspring: Population based cohort study with 40 years of follow-up. BMJ. 2019;367(Cvd):1-4.