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"Survival Model to Analyze Unmet Needs of Demographic and Health Survey Data of Maharashtra State, India Using Cox-Regression and Aalen's Additive Model"

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KEYWORDS

"Survival Analysis" ; "Cox-Regression" ; "Hazard Ratio" ; "Aalen's Additive Model" ; "unmet need" ;

ABSTRACT

Several studies shown that many statistical tests are useful and adapted to evaluate the influence of other variables on unmet need. Every researcher has applied statistical test by considering has its own features and limitation. For this study the data from District Level Household Survey (DHS) data of Maharashtra state, India. In this study is used to see the influence of time related variables Respondent Current Age (V012) and Age at First time Sex (V525) influence on Unmet Need of Contraception associated with other statistically significant variable through the tools of survival analysis.

The hazard ratio using cox regression analysis were found for Had your uterus removed (S253) 5.92 (95% CI 1.52, 23.0, p = 0.010), Daughters at home (V203) 3.86 (95% CI 2.05, 7.28, p = <0.001), Daughters who have died (V207) 4.25 (95% CI 1.38, 13.1, p = 0.012), Age of respondent at 1st birth (V212) 0.83 (95% CI 0.69, 1.00, p =0.049), Contraceptive use and intention (V364) 3.16 (95% CI 1.04, 9.54, p = 0.042), Currently amenorrheic (V405) 5.83 (95% CI 1.31, 25.9, p =0.020), Currently abstaining (V406) 2.60 (95% CI 1.15, 5.89, p = 0.022), Covered by health insurance (V481) 5.70 (95% CI 2.42, 13.4, p = <0.001), Respondent's current age (V012) 0.79 (95% CI 0.68, 0.92, 0.002), and Ideal number of children (V613) 0.65 (95% CI 0.45, 0.96, p = 0.030) were observed as shown in Table 2 statistically significant while rest were non-significant p-value for hazard ratio.

INTRODUCTION:

Unmet need for contraception was key family planning indicator for showing the demand for birth control since late of 1970 conceptualized by population scientists(Colman, 1975), the conditions by which a woman classified as having unmet need would be contraceptive beneficiary in future(Charles F. Westoff, n.d.).Unmet need is also classified as behavioral indicator, conceptually framed around a woman's fertility preferences on the assumption that being a non-user with a desire to delay or limit childbearing signals a need for contraception but not a medical classification or characterization. The measure does not rely on a woman's directly expressed requirement or wish to use a contraceptive method, her perception of risk to pregnancy, or her intention or interest to use in the future(Staveteig, 2017).According to United Nations Unmet need level is defined as the percent of women of reproductive age (all or married) who want to delay or limit childbearing but are not using contraception(Dasgupt, A & Kantorova, V., 2018).to estimate Unmet need indicator population surveys are used mostly in middle and low-income countries. As these surveys are mostly cross-sectional, and limited information of predictive utility of the unmet need indicator(Charles F. Westoff, n.d.).

Journal of Chemical Health Risks
www.jchr.org
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Many research studies were conducted in across the world with help of Demographic and Health survey data with the individual research objectives with popular statistical methods, the study conducted on Ugandan women by Sarnakand Others used descriptive statistics, survival models and multi-variate hazard regression equations to evaluate the associations between a woman's unmet need status(Sarnak, Tsui, Makumbi, Kibira, & Ahmed, 2020). In another study on Nigerian Women by Adedini and other, studies the effect of unmet need for family planning on less than five year old mortality in Nigeria using Cox regression model(Adedini, Odimegwu, Imasiku, & Ononokpono, 2015). In another study on rural women in Ethiopia by Alem and other, A two-level multivariable logistic regression model wasused to predict individual and community-level featuresrelated with unmet need for family planning(Alem & Agegnehu, 2021). In another study in seven sub-Saharan African countries by Senderowicz and others, evaluates the supply-side unmet need, demand side-unmet need, and unidentified cause for unmet need in seven countries(Senderowicz & Maloney, 2022).In another study on Tanzanian women by Rwabilimbo and others, to evaluate the trends in the unmet need for Family Planning over the study period. Multivariable multinomial logistic regression were applied to explore the association between community-level, predisposing, enabling, and need factors with the unmet need for Family Planning in Tanzania(Rwabilimbo et al., 2023). In another study by Dwivedi,used survival genie performs overall survival (OS) and event-free survival (EFS)(Dwivedi, Mumme, Satpathy, Bhasin, & Bhasin, 2022)statistical models as employed in the 'survival' R package(Therneau, 2023). In another study on Chinese breast cancer survivors conducted by Xiaofan Bu and others, The association were analyzed using t-test, ANOVA, multiple regression and Pearson correlations.

Several studies shown that many statistical tests are useful and adapted to evaluate the influence of other variables on unmet need. Every researcher has applied statistical test by considering has its own features and limitation. For this study the data from District Level Household Survey (DHS) data of Maharashtra state, India. In this study is used to see the influence of time related variables Respondent Current Age (V012) and Age at First time Sex (V525) influence on Unmet Need of Contraception associated with other statistically significant variable through the tools of survival analysis. So primarily focused on application of survival model to analyze the variable influenced on unmet need on complete response variables.

Material and Methodology:

Data Collection:

the study used District Level Household Survey (DHS) data for state Maharashtra, India. Birth Records in Maharashtra State, India 2019-21. containing cohort data micro-level data from interviews conducted with individual women aged in between 16 – 49 years have used. Among 57071 respondents of Demographic and health Survey information of women respondent were chosen based on completeness of variable V130 (Religion), S253 (Had your uterus removed?), V624 (Unmet need), V525 (Age at first sex) and V613 (Ideal number of children).

Statistical Method:

Survival Analysis:

Survival analysis is one of branchin statistics which analyze the expected duration of time until one event occurs, such as death in biological organisms and failure in mechanical systems. The terms defined Klein and others(Klein & Moeschberger, 2003).

The Survival Function:

Let X be the time until some specified event. This event may be death, the appearance of a tumor, the development of some disease, recurrence of a disease, equipment breakdown, cessation of breast feeding, and so forth. X is a nonnegative random variable from a homogeneous population.

Four functions characterize the distribution of X, namely, the $survival\ function$, which is the probability of an individual surviving to $time\ x$; the $hazard\ rate\ (function)$, sometimes termed risk function, which is the chance an individual of age x experiences the event in the next instant in time; the $probability\ density\ (or\ probability\ mass)$ function, which is the unconditional probability of the event's occurring at time x; and the $mean\ residual\ life\ at\ time\ x$, which is the mean time to the event of interest, given the event has not occurred at x.

Journal of Chemical Health Risks
www.jchr.org
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The basic quantity used to describe time-to-event phenomena is the **survival function**, the probability of an individual surviving beyond time x (experiencing the event after time x). It is defined as

$S(x) = \Pr(X > x)$ (1.1)

In the context of equipment or manufactured item failures, S (x) is referred to as the reliability function. If X is a continuous random variable, then, S (x) is a continuous, strictly decreasing function.

When X is a continuous random variable, the survival function is the complement of the cumulative distribution function, that is, $S(x) = 1 - F(x)$, where $F(x) = \Pr(X \leq x)$. Also, the survival function is the integral of the probability density function, $f\ (x)$, that is,

$S(x) = \Pr(X > x) = \int_t^\infty f(t)dt$ (1.2)

Thus,

$$f(x) = -\frac{dS(x)}{dx}$$

Note that $f\ (x)\, dx$ may be thought of as the "approximate" probability that the event will occur at $time\ x$ and that $f\ (x)$ is a nonnegative function with the area under $f\ (x)$ being equal to one

When X is a discrete, random variable, different techniques are required. Discrete, random variables in survival analyses arise due to rounding off measurements, grouping of failure times into intervals, or when lifetimes refer to an integral number of units. Suppose that X can take on values $x_j j = 1,2, \dots \dots,$ with probability mass function (p.m.f.) $p(x_j) = \Pr(\ X = \ x_j),\ j = 1, 2, \dots.$ where $x_1 < x_2 < \dots.$

The survival function for a discrete random variable X is given by

$S(x) = \Pr(X > x) = \sum_{x_j > x} p(x_j)$ (1.3)

The Hazard Function:

A basic quantity, fundamental in survival analysis, is the hazard function. This function is also known as the conditional failure rate in reliability, the force of mortality in demography, the intensity function in stochastic processes, the age-specific failure rate in epidemiology, the inverse of the Mill's ratio in economics, or simply as the hazard rate. The hazard rate is defined by

$b(x) = \lim_{\Delta x \to 0} \frac{P[x \leq X < \Delta x \mid X \geq x]}{\Delta x}$

(2.1)

If X is a continuous random variable, then,

$b(x) = f(x)/S(x) = -d \ln[S(x)]/dx.$

(2.2)

A related quantity is the cumulative hazard function $H(x)$, defined by

$H(x) = \int_0^x b(u)du = -\ln[S(x)].$

(2.3)

Thus, for continuous lifetimes,

$S(x) = \exp[-H(x)] = exp\left[-\int_0^x b(u)du\right].$

(2.4)

When X is a discrete random variable, the hazard function is given by

$b(x_j) = \Pr(X = x_j \mid X \geq x_j) = \frac{p(x_j)}{S(x_{j-1})},\quad j = 1, 2, \dots$

(2.5)

The Mean Residual Life Function and Median Life:

Another basic parameter of interest in survival analyses is the M$ean\ residual\ life\ at\ time\ x$. For individuals of age x, this parameter measures their expected remaining lifetime. It is defined as $mrl(x) = E(X - x|X > x)$. the mean life, $\mu = mrl(0)$, is the total area under the survival curve. For a continuous random variable,

$mrl(x) = \frac{\int_x^\infty (t-x)f(t)dt}{S(x)} = \frac{\int_x^\infty S(t)dt}{S(x)}$

(3.1)

And

$\mu = E(x) = \int_0^\infty t\, f(t)\, dt = \int_0^\infty S(t)dt.$

(3.2)

Also, the variance of X is related to the survival function by

$Var(x) = 2\int_0^\infty tS(t)dt - \left[\int_0^\infty S(t)dt\right]^2$ (3.3)

The p^{th} quantile (also referred to as the 100 p^{th} percentile) of the distribution of X is the smallest x_p so that

$S(x_p) \leq 1 - p,\ i.e\ x_p = \inf\{t : S(t) \leq 1 - p\}.$

(3.4)

Result:

Among 57071 total respondent women from Maharashtra State, India, 5862 (10.27%) respondents were chosen for statistical modeling based on

Journal of Chemical Health Risks
www.jchr.org
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completeness of responses given by responded participant women. The study used two different models to explore insights of data influencing Unmet need. The cox regression model as shown in Table 1shows the effect of Age of the Respondent (V012).

The Cox proportional hazards analysis was used to observe the effect of respondent's current age (V012) onUnmet Need. A Likelihood Ratio Test were performed to confirmed the proportionality assumption, Likelihood Ratio Test = 446, on 26 df, p=< 2.2e-16, n = 5860, number of events= 54. The hazard ratio were for Religion (V130) 1.41 (95% CI 1.03, 1.93, p = 0.034), Sons at home (V202) 0.08 (95% CI 0.04, 0.18, p = <0.001), Daughters elsewhere (V205) 0.13 (95% CI 0.05, 0.39, p = <0.001), Daughters who have died (V207) 0.15 (95% CI 0.04, 0.50, p = 0.002), Births in last five years (V208) 13.1 (95% CI 6.05, 28.3, p = <0.001), Births in past year (V209) 0.19 (95% CI 0.04, 0.95, p = 0.044), Age of respondent at 1st birth (V212) 0.75 (95% CI 0.66, 0.85, p = <0.001), Pattern of use (V361) 4.31 (95% CI 1.99, 11.6, p = <0.001), Currently amenorrheic (V405) 9.96 (95% CI 2.03, 48.8, p = 0.005), Currently abstaining (V406) 4.23 (95% CI 1.46, 12.2, p = 0.008) and Covered by health insurance (V481) 6.67 (95% CI 2.86, 15.5, p = <0.001) were observed as shown in Table 1 statistically significant while rest were non-significant p-value for hazard ratio.

The cox proportional hazards analysis was used to observe effect Age at first time sex on Unmet Need. A Likelihood Ratio Test were used to confirmed the proportionality assumption, Likelihood ratio test=383.1on 26 df, p=< 2.2e-16, n= 5862, number of events= 54. The hazard ratio were for Had your uterus removed (S253) 5.92 (95% CI 1.52, 23.0, p = 0.010), Daughters at home (V203) 3.86 (95% CI 2.05, 7.28, p = <0.001), Daughters who have died (V207) 4.25 (95% CI 1.38, 13.1, p = 0.012), Age of respondent at 1st birth (V212) 0.83 (95% CI 0.69, 1.00, p =0.049), Contraceptive use and intention (V364) 3.16 (95% CI 1.04, 9.54, p = 0.042), Currently amenorrheic (V405) 5.83 (95% CI 1.31, 25.9, p =0.020), Currently abstaining (V406) 2.60 (95% CI 1.15, 5.89, p = 0.022), Covered by health insurance (V481) 5.70 (95% CI 2.42, 13.4, p = <0.001), Respondent's current age (V012) 0.79 (95% CI 0.68, 0.92, 0.002), and Ideal number of children (V613) 0.65 (95% CI 0.45, 0.96, p = 0.030)were observed as shown in Table 2 statistically significant while rest were non-significant p-value for hazard ratio.

the Graph 1(a and b) and Graph 2(a and b) Shows the survival Curve for the Aalen’s Additive Regression Model for individual variable including coefficient of intercepts. The Graph 1(a and b) is made-up of 26 independent variable and 1 intercept similarly Graph 2 (a and b) as well. As the negative coefficient of estimate means the hazard decreases with increasing values of the variable.The Aalen’s Additive Model for Respondent Current Age (V012) shown in Graph 1 (a and b), the intercept survival curve varies from 0 to 0.07, Births in last five years (V208) varies 0 to 0.08, Currently amenorrheic (V405) varies 0 to 0.36, Currently abstaining (V406) varies 0 to 0.27, Covered by health insurance (V481) varies 0 to 0.18 as shown in Graph 1(a and b). while for the Aalen’s Additive Model for Age at the time of first sex shown in Graph 2 (a and b), the intercept survival curve varies Number of household members (listed) (V136) varies 0 to 0.006, Daughters at home (V203) varies 0 to 0.06, Births in last five years (V208) varies 0 to 0.09, Pattern of use (V361) varies 0 to 0.08 and currently abstaining (V406) varies 0 to 0.09.

Discussion:

In present research we studied the influence of variables effecting on Hazards estimates of cox regression models on Unmet Need withRespondent Current Age (V012) and Age at First time Sex (V525). Its observed that thehazards ratio were affected significantly because ofthe Daughters who have died (V207)?, Currently amenorrheic (V405)? and Currently abstaining (V406)? commonlyfor both cox regression models. The significant hazards ratio observed in Religion (V130) and Births in past year (V209) are in cox regression model of Respondent Current Age (V012) as shown in Table 1. The Cox Regression Model for Age at First Time Sex (V525) shows statisticallysignificant in Hazards associated by variables Had your uterus removed (S253)?, Age of respondent at 1st birth (V212)?, Contraceptive use and intention (V364), Respondent's current age (V012) and Ideal number of children (V613)? As shown in Table 2. While Aalen’s Additive Regression Model survival curves for these Current Age (V012) and Age at First time Sex (V525) represents Births in last five years (V208) and currently abstaining (V406) shows positive values on curve for both of the models. The survival curve for Currently amenorrheic (V405) and covered by health insurance (V481) of Aalen's Additive Model shows positive values on curve for Respondent Current Age (V012) while Number of household members (listed) (V136), Daughters at home (V203) and Pattern of use (V361) shows positive values on curve for Aalen's Additive Model Age at First time Sex (V525) as shown in Graph 1(a and b) and Graph 2 (a and b).

The survival model on unmet need using Cox Regression used for two different stages of Age gives significant hazards ratio'sfor the different variables which leads to conclusion the effect of duration of sexual time span of women. while Aalen's Additive Regression model were observed different nature for the same variables which leads to diversity in the conclusion.Major issues in implementation of survival methods were discussed by Klein JP(Klein & Moeschberger, 2003). An application paper Sarnak D used survival model in his study to explain the predictive utility of unmet need estimator for the family planning(Sarnak et al., 2020). To effect of less than five year old mortality on family planning a study by Adedini SA has also used the cox regression(Adedini et al., 2015). Similarly multivariable logistic regression used by Alem AZ(Alem &Agegnehu, 2021) and Rwabilimbo AG(Rwabilimbo et al., 2023).

Conclusion:

The Survival Analysis is an important statistical tool for medical research with having good enough wide angle to explore the features the data. Implementation of one survival tool is not enough to prove the strength of association of variables on predictors. the implementation of survival models in medical records required good enough assistance of health professionals. The present study used the Demographic and Health Survey Data which is having enough large dataset and while dealing for these datasets required good computational skill and better configured computer system to solve the complexity of data.

Limitation:

Even the availability of Demographic and Health Survey (DHS) data, the study was performed on limited variable of Birth record dataset 2019-21 of Maharashtra State, India.

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Tables:

Table 1: Hazzard Ratio of Respondent's Current Age on Unmet Need using Cox-Regression Model.

Characteristic	**HR**	**95% CI**	**p-value**
Had your uterus removed (S253)	1.76	0.41, 7.66	0.5
Usually go to a cinema hall or theatre to see a movie at least once a month (S113)	0.29	0.03, 2.59	0.3
Currently in union (S301)	0.10	0.00, 2.60	0.2
Type of place of residence (V025)	0.51	0.22, 1.15	0.10
Highest educational level (V106)	0.64	0.38, 1.05	0.079
Religion (V130)	1.41	1.03, 1.93	0.034
Number of household members (listed) (V136)	1.21	0.98, 1.50	0.083
Number of children 5 and under in household (de jure) (V137)	1.07	0.69, 1.65	0.8
Number of eligible women in household (de facto) (V138)	1.00	0.55, 1.83	>0.9
Sons at home (V202)	0.08	0.04, 0.18	<0.001
Daughters at home (V203)	0.73	0.46, 1.15	0.2
Daughters elsewhere (V205)	0.13	0.05, 0.39	<0.001
Sons who have died (V206)	0.12	0.01, 1.37	0.088
Daughters who have died (V207)	0.15	0.04, 0.50	0.002
Births in last five years (V208)	13.1	6.05, 28.3	<0.001
Births in past year (V209)	0.19	0.04, 0.95	0.044
Age of respondent at 1st birth (V212)	0.75	0.66, 0.85	<0.001
Ever had a terminated pregnancy (V228)	0.35	0.11, 1.11	0.075
Pattern of use (V361)	4.81	1.99, 11.6	<0.001
Contraceptive use and intention (V364)	1.12	0.38, 3.25	0.8
Currently breastfeeding (V404)	1.38	0.32, 5.95	0.7
Currently amenorrheic (V405)	9.96	2.03, 48.8	0.005
Currently abstaining (V406)	4.23	1.46, 12.2	0.008
Covered by health insurance (V481)	6.67	2.86, 15.5	<0.001
Age at first sex (V525)	0.97	0.84, 1.13	0.7
Ideal number of children (V613)	0.89	0.60, 1.32	0.6

Journal of Chemical Health Risks

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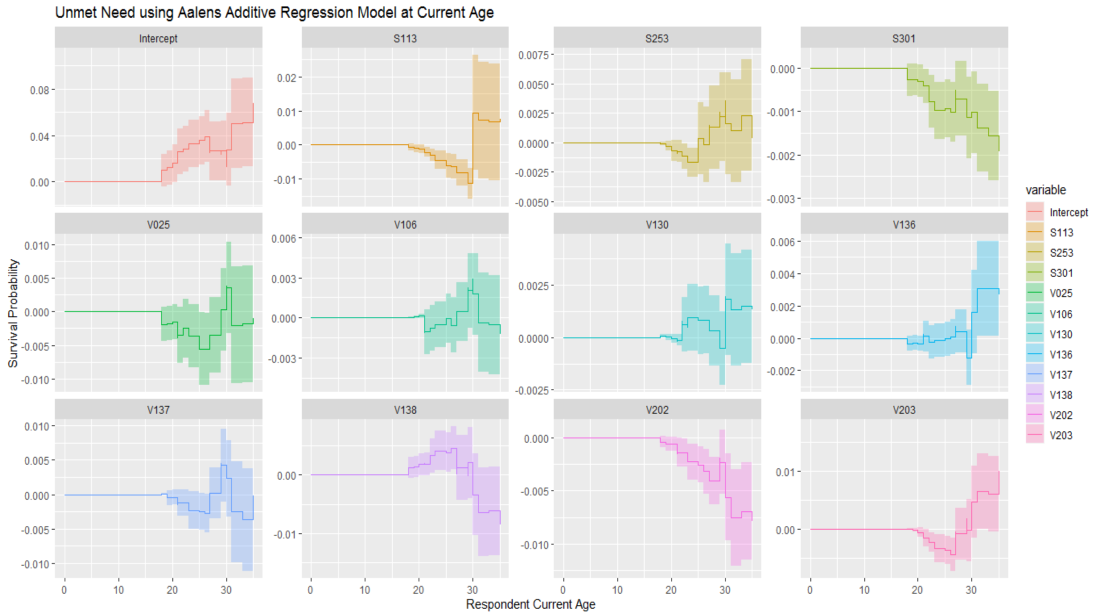
Table 2: Hazzard Ratio of Age at First Sex on Unmet Need using Cox-Regression Model.

Characteristic	HR	95% CI	p-value
Had your uterus removed (S253)	5.92	1.52, 23.0	0.010
Usually go to a cinema hall or theatre to see a movie at least once a month (S113)	0.15	0.02, 1.19	0.072
Currently in union (S301)	0.51	0.04, 6.42	0.6
Type of place of residence (V025)	0.50	0.22, 1.13	0.10
Highest educational level (V106)	0.42	0.26, 0.67	<0.001
Religion (V130)	1.18	0.89, 1.58	0.3
Number of household members (listed) (V136)	1.00	0.78, 1.27	>0.9
Number of children 5 and under in household (de jure) (V137)	1.47	0.84, 2.57	0.2
Number of eligible women in household (de facto) (V138)	0.93	0.52, 1.66	0.8
Sons at home (V202)	0.90	0.41, 1.99	0.8
Daughters at home (V203)	3.86	2.05, 7.28	<0.001
Daughters elsewhere (V205)	1.85	0.65, 5.30	0.3
Sons who have died (V206)	1.01	0.13, 7.67	>0.9
Daughters who have died (V207)	4.25	1.38, 13.1	0.012
Births in last five years (V208)	0.80	0.38, 1.69	0.6
Births in past year (V209)	0.44	0.13, 1.49	0.2
Age of respondent at 1st birth (V212)	0.83	0.69, 1.00	0.049
Ever had a terminated pregnancy (V228)	1.62	0.54, 4.92	0.4
Pattern of use (V361)	1.80	0.83, 3.88	0.13
Contraceptive use and intention (V364)	3.16	1.04, 9.54	0.042
Currently breastfeeding (V404)	0.62	0.15, 2.54	0.5
Currently amenorrheic (V405)	5.83	1.31, 25.9	0.020
Currently abstaining (V406)	2.60	1.15, 5.89	0.022
Covered by health insurance (V481)	5.70	2.42, 13.4	<0.001
Respondent's current age (V012)	0.79	0.68, 0.92	0.002
Ideal number of children (V613)	0.65	0.45, 0.96	0.030

Graphs:

Graph 1: Survival Curve of Respondent's Current Age on Unmet Need using Aalen Additive Regression Model.

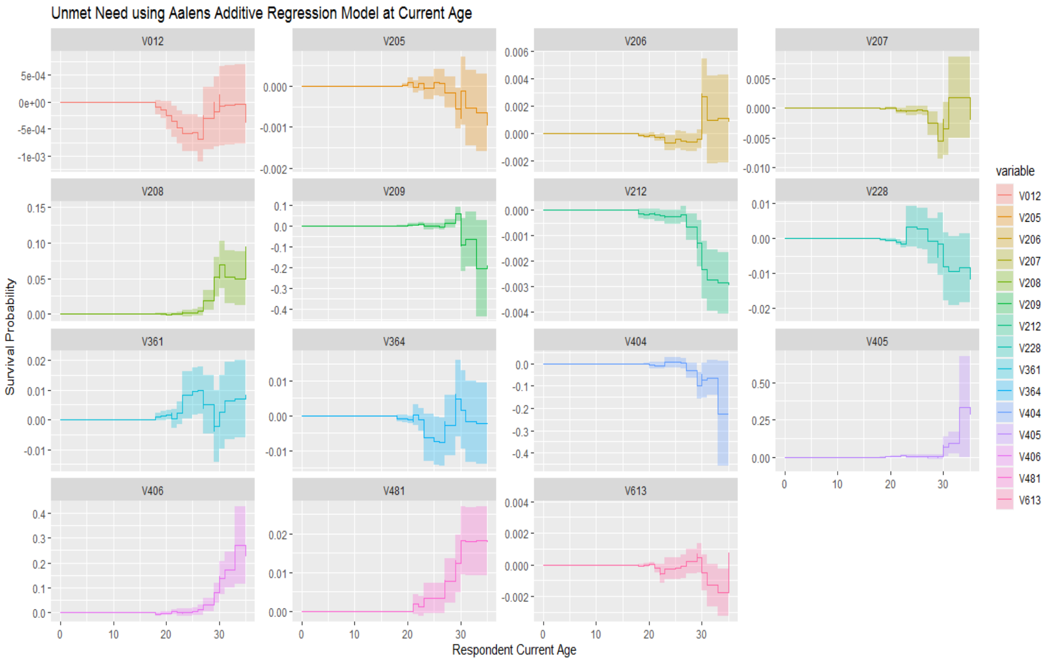


Journal of Chemical Health Risks

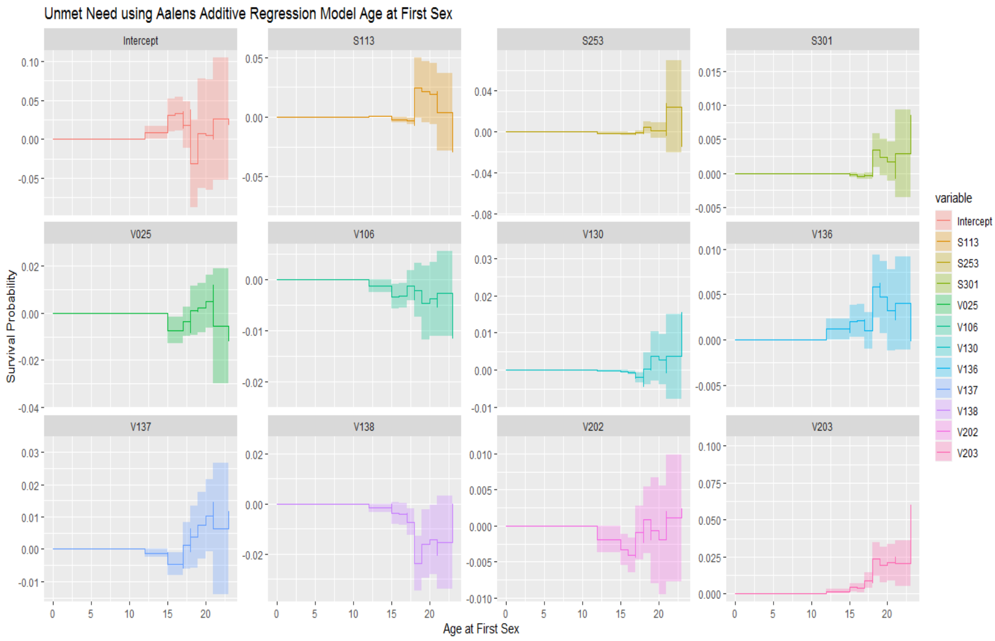
www.jchr.org

JCHR (2023) 13(6), 2560-2568 | ISSN:2251-6727

Graph 1: Continued …



Graph 2: Survival Curve of Age at First Sex on Unmet Need using Aalen Additive Regression Model.



Graph 2: Continued ….

Journal of Chemical Health Risks
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