Estimation of Life Expectancy at Birth using Brass two Parameters Logit System from Sudan Census (2008)

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Abstract

This study attempted to estimate the expectation of life at birth for males and females using Brass relational model from data of the fifth population census in Sudan (2008). The results of the study showed a remarkable difference in life expectancy at birth between males and females. Life expectancy at birth was calculated at (65years) for males and (70years) for females. The highest life expectancy at birth was calculated at (68.7years) for males in Gezira state and (71.8 years) for females in Northern state, while the lowest were found at (27.5years) and (36.2 years) for males and females respectively in West Darfur State. The results of the paired sample t test showed that the average life expectancy at birth for females was calculated at (60years) compared with (56years) for males, which indicates that the females in Sudan survived -on average- long time compared with males. The results of the paper strongly recommended using the mathematical Brass two Parameters logit model to smooth the data of mortality used in life table construction. Also, this model can be used to overcome the problems of distortion in similar models of nuptiality and migration.

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استخدام نموذج براس النموذجي لتقدير توقع الحياة عند الميلاد من بيانات تعداد السكان الخامس، 2008

الملخص

هدفت هذه الدراسة إلي استخدام نظام برأس النموذجي لتقدير توقع الحياة عند الميلاد للذكور والإناث في السودان استناداً علي بيانات تعداد السكان الخامس (2008). أوضحت نتائج الدراسة وجود فروق واضحة في توقع الحياة عند الميلاد بين الذكور والإناث، حيث بلغ توقع الحياة عند الميلاد للذكور في السودان (65سنة) مقارنة بـ(70 سنة) للإناث. أعلي توقع حياة عند الميلاد بلغ (71.8 سنة) للإناث في الولاية الشمالية و(68.7 سنة) للذكور في ولاية الجزيرة. أقل توقع حياة عند الميلاد بلغ (27.5 سنة) و(36.2 سنة) للذكور والإناث علي التوالي في ولاية غرب دارفور. نتائج اختبارات لعينتين مرتبطين أوضحت وجود فروق ذات دلالة إحصائية بين متوسط توقع الحياة عند الميلاد للإناث مقارنة مع الذكور، حيث بلغ متوسط توقع الحياة عند الميلاد للإناث (60سنة) مقارنة بـ(56سنة) للذكور، مما يدل علي الإناث في السودان يبقون علي قيد الحياة لفترة أطول مقارنة بالذكور. توصي الدراسة بضرورة استخدام نموذج برأس اللوجستي ذو المعلمتين لتدريج بيانات الوفيات المستخدمة في بناء جداول الحياة. كما توصي بتطبيق هذه النموذج لتدريج بيانات الزواجية والهجرة.

1. Introduction:

The life table provides the most complete description of mortality in any population. The basic data input needed for its construction are the age-specific death rates calculated from data on deaths by age and sex and population by age and sex from census data. In many censuses and surveys which conducted in developing countries these basic data are less used because of incompleteness of coverage or errors in reporting. In this case indirect techniques for obtaining mortality measures like expectation of life at birth are employed .William Brass first initiated these techniques in the 1960s, with the aim of employing more reliable features of poor demographic data, so as to provide robust measures (Brass, 1964). Indirect estimation takes into account the most probable sources of errors and minimizes their influence. This is done through use of demographic models or by making assumptions that translate into clear mathematical relationship. In addition, indirect estimation is a divergent from collection of data of uncertain quality, towards the use of information that is indirectly related to the demographic parameters, and which could be collected more reliably (Zlotnik and Hill, 1981). In the study of mortality, model life tables provide the basis for indirect techniques to estimate mortality rate from census date .In practice, these techniques are predicted on the observe similarities in the age-pattern of mortality for different population and may range from the simple adoption of mortality pattern of a neighboring population with similar socio- biological characteristics to use of sophisticate demographic models (Lopez, etal, 2001). The best known are the UN model life tables, Coale-Demeny model life tables, the UN model life tables for developing countries, the Lederman system of model life tables (Guillot, etal, 2001). In1971 Brass discovered that it is possible to achieve a linear representation of the differences in the survivorship probabilities ($\mathbf{l_x}$) in any two life tables with the help of only two parameters.

2. Objectives:

1- To estimate the values of life expectancy at birth for males and females in Sudan using Brass relational two –parameter logit system.
2- To determine the long – time survived for females compare with males in Sudan.

3. Data and Methods:

3.1 Data:

The study based on secondary data from the fifth population and housing census in Sudan (2008). The main variables from relevant census questionnaire are age, sex by population group and number of deaths during 12 months preceding the census by single and age groups and both sexes. For the purpose of implementing the Brass relational model , the survivorship l_{xs} of African standard was obtained as standard values.

3.2 Methods:

3.2.1 Abridged Life Table:

Before exploring the methodology of Brass relational model, the abridge life table method, as applied in general, is briefly described.

3.2.2 Abridged Life Table Functions:

$_nM_x$ is the Age Specific Death Rates (**ASDRs**).

$$nMx = \frac{\text{Deaths during year of persons aged } x}{\text{Population aged x at mid-year}} \text{....(1)}$$

$_nq_x$ is the probability of dying between exact ages x and x + n.

$$_nq_x = \frac{n \;\; _nM_x}{1+n(1-{_na_x})\cdot{_nM_x}} \text{ ....(2)}$$

The above formula is not valid for q_0 or $_4q_1$, as $_na_x$ is not 0.5 at these ages.

For q_0 and $_4q_1$ the following formula used:

$$q_0 = \frac{M_0}{1+0.7M_0} \text{ ....(3)}$$

$$_4q_1 = \frac{4 \;\; _4M_1}{1+2.7 \;\; _4M_{x1}} \text{ ....(4)}$$

$_np_x$ is the probability of surviving between exact ages x and $x + n$. It is just the complement of $_nq_x$. Thus:

$$_np_x = 1 - {_nq_x} \text{ ....(5)}$$

or

$$_np_x + {_nq_x} = 1 \text{....................................(6)}$$

l_x is the number of persons a live at exact age x. l_0 is an arbitrary number called the *radix*. Usually it will be a round number such as 1 or 1,000 or 100,000.

$$l_x = l_{x-n} \cdot {_nP_{x-n}} \text{ ....(7)}$$

$_nd_x$ is the number of persons dying between exact ages x and $x + n$.

$$_nd_x = l_x - l_{x+n} \text{ ....(8)}$$

$_na_x$ is defined as the average proportion of the time lived in the interval x to $x + n$ by those who die during that interval.

$_nL_x$ is the number of persons-years lived between exact ages x and $x + n$. $_nL_x = \frac{n(l_x+l_{x+n})}{2}$ ....(9)

The above formula is not valid for L_0 or $_4L_1$, as $_na_x$ is not 0.5 at these ages.

For L_0 and $_4L_1$ the following formula used:

$$L_0 = .3\ l_0 + .7\ l_1 \text{ ....(10)}$$

$$_4L_1 = 1.3\ l_1 + 2.7\ l_2 \text{ ....(11)}$$

The last, open-ended is calculated using the following formula:

$$L_{95+} = \frac{d_{95+}}{M_{95+}} \text{ ....(12)}$$

but d_{S5}, = l_{85} since everyone eventually dies so:

$$L_{95+} = \frac{l_{95}}{M_{95+}} \text{ ....(13)}$$

T_x is the total number of person-years lived after exact age *x*. It is thus simply the $_nL_X$ column cumulated from the bottom. That is:

$$T_x = T_{x+n} + {}_nL_x \text{ ....(14)}$$

e_x is the expectation of life at age *x*, or the average number of years a person aged *x* has to live. Since the total number of years left to be lived by l_x people is T_x, the expectation of life is just one divided by the other (Neweel,1988). Thus:

$$e_x = \frac{T_x}{l_x} \text{ ....(15)}$$

e_0 is the expectation of life at birth, and defined as the average number of years that new born would live given a set of death rates observed in calendar year**.**

$$e_0 = \frac{T_0}{l_0} \text{ ....(16)}$$

Where:

e_0: expectation of life at birth.

l_0: radix of life table.

T_0: total number of person years lived by population of life table to exact age 0 **(**Preston,etal,2001).That is:

$$T_0 = L_O + L_1 + L_2 \text{ ....} + L_W \text{ ....(17)}$$

3.3 The Brass Logit Life Table System:

The Brass Logit Life Table System belongs to a category of mortality models called relational models. This relational system of life tables was built up from the observed structural relationship of survival curves among life table. This system provides a greater degree of flexibility than the empirical models. It rests on the assumption that two distinct age- patterns of mortality can be related to each other by a linear relationship between the logit of their respective survivorship probabilities (Brass, 1971). Thus for any two observed series of survivorship values l_x and l_{xs}, where the latter is the standard, it is possible to find constant α and β such that:

$$Logit(l_x) = \alpha + \beta\ logit(l_{xs}) \text{ ....(18)}$$

$$\text{If } logit\ (l_x) = 0.5 ln\ (1.0 - l_x / l_x) \text{ ....(19)}$$

Then

$$0.5 ln\ (1.0 - l_x / l_x) = \alpha + \beta\ 0.5\ ln\ (1.0 - l_{xs} / l_{xs}) \text{...(20)}$$

for all age x between 1 and ∞, if the above equation holds for every pair of life table, then any life table can be generated from a single standards life table by changing the pairs of (α , β) values used. In reality, the assumption is approximately satisfied by pairs of actual life tables. However, the approximation is close enough to warrant the use of the model to study and fit observed mortality schedules.

The parameter α varies the mortality level of the standard, while β varies the slope of the standard, it governs the relationship between the mortality in children and adults. As β decreases, there is the higher survival in the older ages relative to the standard, and vice versa. Higher values of α at a fixed β lead to lower survival relative to the standard (Guillot, etal, 2001).A question that arises here is at what age the regression should be started. The first should be early enough to include enough data points, but if the regression begins too early then old –age survival will be unduly influenced by mortality at old age. So 25 years were chosen as a reasonable compromise start point, allowing seven data points. Hence, for this study, the parameters α and β are derived either by regressing l_{25}, l_{30},..., l_{55} against the corresponding l_x values in the standard population.

Fitting a logit Model Life Table:

The aim is to discover which one of the infinite family of life tables that can be generated by varying α and β , the raw data are most like , the raw data may be a complete life table or they may be just a handful of values .

The following steps are used to generate a complete life table from dataset (age 25 to 50) for whole and each States in Sudan :

1- The logits of the observed l_x are first plotted on a graph against the logits of the standard life table.(see figure1 and figure2).

2- The intercept and slope of the line, α and β are calculated using the following formulae:

$$\beta = \frac{\sum(Ys(x) - E(Ys(x)))(Yx - E(Yx))}{\sum(Ys(x) - E(Ys(x)))^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots(21)$$

$$\alpha = E(y_x) - \beta E(y_{s(x)}) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(22)$$

Where:

$$Y_x = 0.5 ln (1.0- l_x / l_x) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(23)$$

$$Y_{S(x)} = 0.5\ ln (1.0- l^s_x / l^s_x)) \quad \ldots\ldots\ldots\ldots\ldots\ldots(24)$$

$E(Y_{s(x)})$ and $E(Y_x)$ are the mean values of $Y_{s(x)}$ and Y_x respectively and the sum in the above equation is across the seven values of x upon which the regression is based (from ages 25 to 55).

3- The fitted logits are computed by putting α,β and the standard logits into the straight-line equation.

$$Y_{fit\ (x)} = \alpha + \beta\ Y_{s(x)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(25)$$

4- Anti-logits are taken to produce a set of fitted l_x – the model life table.

$$\text{Fitted } l_x = \frac{1}{1+e^{2Yfit(x)}} \quad \ldots\ldots\ldots\ldots\ldots\ldots(26)$$.(Brass, 1975).

4 Results and Discussion*:*

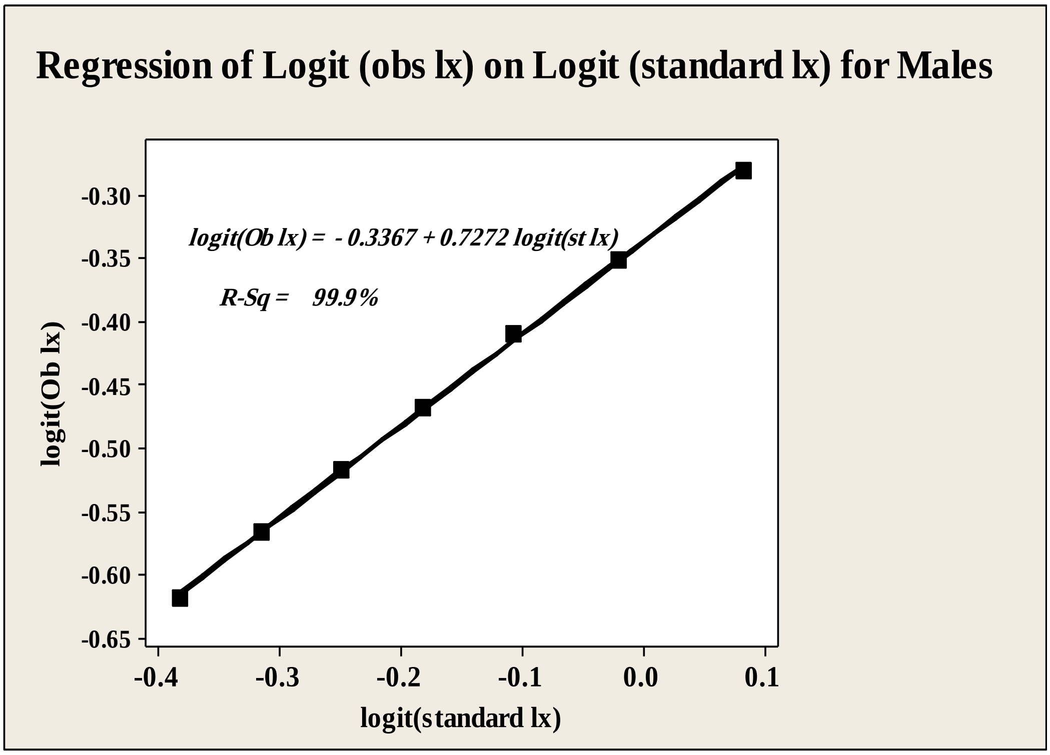
4.1 Fitting Model Life Table for Males and Females:

The following tables (1,2) display the abridge life table functions that were used to generate a complete life table from limit dataset until reaching the survivorship l_x , and then make the logits transformation for the two sets . As has mentioned so far the parameters α and β obtained by linear regression of observed values of l_x against corresponding values of l^s_x. It's clear from linear regression results presented in figure1 and figure2 that the intercept are calculated at -.33 and -.45 for males and females respectively which indicates low mortality relative to the standard, while the slope of the line are calculated at .72 and .64 for males and females respectively which reflect low infant and child mortality and high adult mortality relative to the standard.

Table (1) Estimation of α and β for the estimated l_x for males

Age	P_x	$_nD_x$	$_nM_x$	$_na_x$	$_nq_x$	*obs* l_x	*Logit obs* l_x	*Logit stan* l^s_x
25	1074012	5181	0.005	0.5	0.024	0.78	-0.6184	-0.3829
30	907673	4615	0.005	0.5	0.025	0.76	-0.5669	-0.315
35	865911	4630	0.005	0.5	0.026	0.74	-0.5166	-0.2496
40	706736	4809	0.007	0.5	0.033	0.72	-0.4675	-0.1817
45	524907	3899	0.007	0.5	0.036	0.69	-0.4096	-0.1073
50	464496	4553	0.01	0.5	0.048	0.67	-0.3513	-0.021
55+	276299	3142	0.011	0.5	0.055	0.64	-0.2807	0.0832

Source: own calculation from population census data 2008

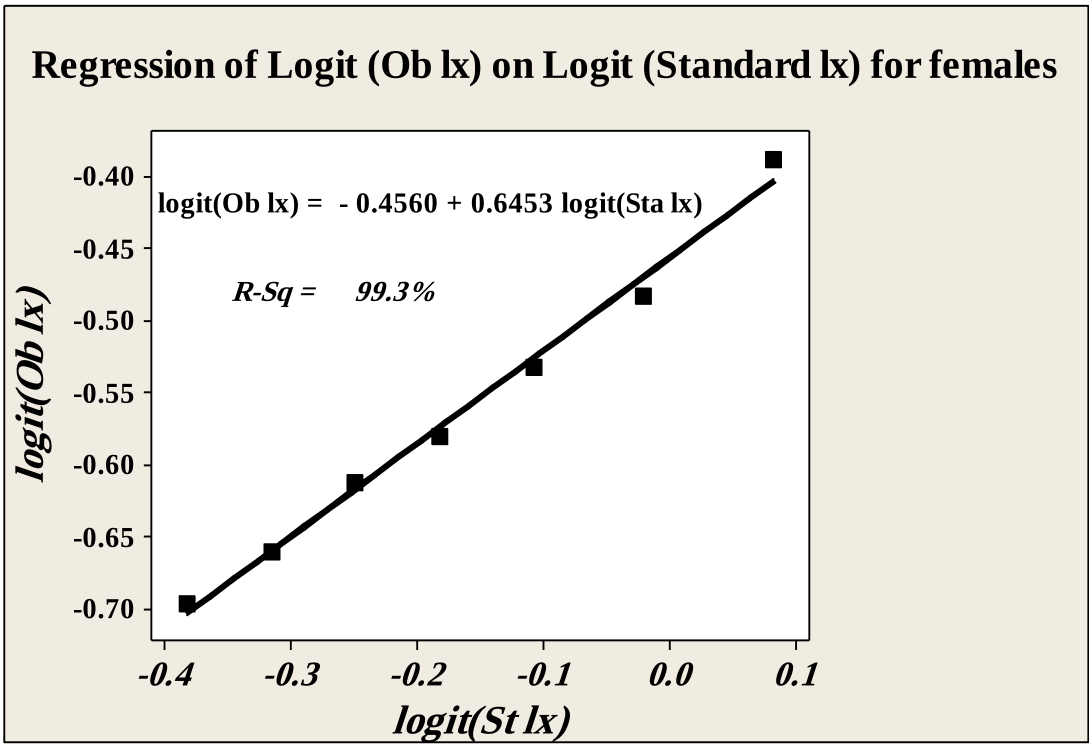


Source: own calculation from table

Table (2) Estimation of α and β for the estimated l_x for females

Age	P_x	$_nD_x$	$_nM_x$	$_na_x$	$_nq_x$	*obs* l_x	*Logit obs* l_x	*Logit stan* l_x
25	1293935	3945	0.003	0.5	0.0151	0.8013	-0.697	-0.3829
30	1013647	4273	0.004	0.5	0.0209	0.7892	-0.66	-0.315
35	943430	2842	0.003	0.5	0.0149	0.7727	-0.612	-0.2496
40	698091	3305	0.005	0.5	0.0234	0.7612	-0.579	-0.1817
45	488117	2597	0.005	0.5	0.0263	0.7433	-0.532	-0.1073
50	420874	4685	0.011	0.5	0.0542	0.7238	-0.482	-0.021
55+	231231	1917	0.008	0.5	0.0406	0.6846	-0.388	0.0832

Source: own calculation from population census data 2008



Source: own calculation from table2

Figure(1) regression of logits (obs lx) on logit (standard lx) for females

4.2 Expectation of Life at Birth for Males and Females using Brass Logit System:

The values of life expectancy at birth disaggregated by sex which presented in tables 3,4 and 5 were produced by Brass relational model. Life expectancy at birth for whole Sudan was calculated at (65.2 years) for males compared with (70 years) for females, the highest females life expectancy was higher than the highest males life expectancy, where the highest were found at (71.8 years) for females in Gezira state and (68.7 years) for males in Northern state. Some states had particularly low value of life expectancy especially among males, the minimum value presented at (27.5 years) and (36.2 years) for males and females respectively in West Darfur state. Indeed, the life expectancy at birth is a summary indicator most widely used to describe

population health and have long been used as a measure of socioeconomic development, or as indices of the quality of life (Robine 2006; Dublin 1923; Dubline and Lotak 1934), these results demonstrate the health inequality between states. The states with the highest values located in the middle and north part of the country where the health services are available, while the state with lowest values located in the west of the country which suffer from the poor health services.

Table(3)Expectation of Life at Birth for Males using Brass Logit System Sudan 2008:

Age	Y_{sx}	$Y_{fiited\ x}$	Proportion fitted l_x	Fitted l_x	${}_nd_x$	${}_nL_x$	T_x	e_x
0			1	10000000	1075545	4737516	651636207	65.2
1	-0.9972	-1.058	0.892	8924455	295403	34900232	646898692	72.5
2	-0.8053	-0.92	0.863	8629052	142064	34132636	611998460	70.9
3	-0.7253	-0.862	0.849	8486988	81818	33727044	577865824	68.1
4	-0.682	-0.831	0.841	8405170	59956.9	33458797	544138780	64.7
5	-0.6514	-0.809	0.835	8345213	212039	41195970	510679983	61.2
10	-0.5498	-0.736	0.813	8133175	81572	40461943	469484013	57.7
15	-0.5131	-0.709	0.805	8051603	134370	39922087	429022070	53.3
20	-0.4551	-0.668	0.792	7917232	176639	39144563	389099983	49.1
25	-0.3829	-0.616	0.774	7740593	175567	38264049	349955419	45.2
30	-0.315	-0.567	0.757	7565027	177638	37381038	311691370	41.2
35	-0.2496	-0.52	0.739	7387389	193064	36454282	274310332	37.1
40	-0.1817	-0.471	0.719	7194324	221243	35418514	237856051	33.1
45	-0.1073	-0.417	0.697	6973081	268539	34194058	202437537	29
50	-0.021	-0.355	0.67	6704542	339572	32673779	168243479	25.1

55	0.0832	-0.28	0.636	6364970	432028	30744777	135569700	21.3
60	0.21	-0.189	0.593	5932941	582079	28209509	104824923	17.7
65	0.3746	-0.07	0.535	5350862	744526	24892997	76615414	14.3
70	0.5818	0.079	0.461	4606336	970825	20604620	51722417	11.2
75	0.8611	0.28	0.364	3635512	1157459	15283911	31117797	8.56
80	1.2433	0.555	0.248	2478053	1159484	9491552	15833886	6.39
85	1.781	0.942	0.132	1318568	849387	4469375	6342333.6	4.81
90	2.5634	1.506	0.047	469181.6	375494	1407173	1872959.1	3.99
95+	3.709	2.33	0.009	93687.75	93687.7	465785.8	465785.77	4.97

Source: own calculation from population census data 2008

Table(4) Expectation of Life at Birth for Females using Brass Logit System Sudan 2008:

Age	Y_{sx}	$Y_{fiited\ x}$	Proportion on fitted l_x	Fitted l_x	$_nd_x$	$_nL_x$	T_x	e_x
0			1	10000000	1018884	9286781	700186837	70
1	−0.9972	−1.088	0.8981	8981116	247754.1	35255527	690900056	76.9
2	−0.8053	−0.965	0.8733	8733362	117670.7	34615736	655644528	75.1
3	−0.7253	−0.914	0.8616	8615691	67437.13	34280684	621028792	72.1
4	−0.682	−0.886	0.8548	8548254	49285.74	34059944	586748109	68.6
5	−0.6514	−0.867	0.8499	8498968	173558.1	42060946	552688164	65
10	−0.5498	−0.802	0.8325	8325410	66519.18	41460753	510627219	61.3

15	−0.5131	−0.778	0.8259	8258891	109349.8	41021080	469166466	56.8
20	−0.4551	−0.741	0.815	8149541	143439.9	40389106	428145386	52.5
25	−0.3829	−0.695	0.8006	8006101	142370.8	39674579	387756280	48.4
30	−0.315	−0.652	0.7864	7863730	143996.1	38958662	348081701	44.3
35	−0.2496	−0.61	0.772	7719734	156594.6	38207185	309123039	40
40	−0.1817	−0.566	0.7563	7563140	179767.7	37366280	270915854	35.8
45	−0.1073	−0.519	0.7383	7383372	218953.3	36369477	233549574	31.6
50	−0.021	−0.463	0.7164	7164419	278586.6	35125627	197180097	27.5
55	0.0832	−0.397	0.6886	6885832	358217	33533618	162054470	23.5
60	0.21	−0.316	0.6528	6527615	491557.5	31409182	128520852	19.7
65	0.3746	−0.21	0.6036	6036058	648596	28558798	97111670	16.1
70	0.5818	−0.078	0.5387	5387462	891266.2	24709143	68552872	12.7
75	0.8611	0.101	0.4496	4496195	1159032	19583398	43843729.3	9.75
80	1.2433	0.346	0.3337	3337164	1326560	13369419	24260331.3	7.27
85	1.781	0.69	0.2011	2010604	1164391	7142042	10890912.1	5.42
90	2.5634	1.191	0.0846	846212.9	637342.9	2637707	3748869.9	4.43

95 +	3.709	1.924	0.0209	208870	208870	1111163	1111162 .64	5.3 2

Source: own calculation from population census data 2008

Table (5) e_0 calculated from Brass Relational Two Parameter Logit System for Sudan by States

States	Brass logit System e_0	
	Males	Females
Northern	68.7	69.6
Nahr ElNil	68.5	69.7
Red sea	54.7	55.5
Kassala	57.8	58.2
ALgadaref	63.6	70.6
Khartoum	62.8	63.4
Aljazeera	67.5	71.8
White Nil	64	66.5
Sinnar	61.6	70.4
Blue Nil	52.6	52.9
North Kordfan	60.7	61.5
South Kordfan	55.1	59.2
North Darfur	45	49.9
West Darfur	27.5	36.2
South Darfur	44.2	49.8

Source: own calculation from population census data 2008

4.3 Difference between Females and Males Longevity:

Physicians, epidemiologists, biologists, demographer, actuaries, and laymen have long been aware of lower mortality rates among females compared with males in every age group (Price, 1772). In humans, females live longer than males in the majority of countries and this pattern has been attributed in part to testosterone – driven mortality in males (Book, etal, 2001). As it is clear that most of the evidence supporting the claim of females surviving more than males, the present study examined the difference in life expectancy at birth between males and females in Sudanese states using paired samples t test as shown in table (6) below:

Table (6) Difference between Females and Males Longevity Sudan 2008:

Group	N	Mean	Standard deviation	Mean different	T Statistic	Df	T Table	P.value
Females	***15***	***60***	***10.16***	***3.39***	***-4.3***	***14***	***-2.14***	***0.000***
Males	***15***	***56***	***11.17***					

Source: own calculate from table 5

The results in the table (6) above conclude statistical significant difference between males and females in term of life expectancy of birth. The mean (e_0) for females was calculated (60) years which greater than the mean (e_0) for males, which indicates that females in Sudan survived on average long time rather than males.

5. Conclusion:

The mortality level in population is an important indicator of its health and well- being; summary measure of mortality condition like life expectancy at birth have long been used as a

measure of socioeconomic development, or as indices of the quality of life. Sudan has a poor demographic data hat need to be carefully adjusted in order to get robust estimate for demographic measures. This study used the Brass relational two parameters logit life table system to estimate e_0 for both sexes from the fifth population census Sudan (2008). The study found that the values of life expectancy at birth were calculated at (65.1 years) and (70 years) for males and females respectively. The results of the paired sample t test explained that the average of e_0 for females was calculated at (60years) compare with (56years) for males, which indicates that the females in Sudan survived on average long time compare with males. The results of the paper strongly recommended using the mathematical Brass two Parameters logit model to smooth the data of mortality used in life table construction. Also, this model can be used to overcome the problems of distortion in similar models of nuptiality and migration.

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