

Comparing the Determined Age at Death between Men and Women Based on the Human Bones Excavated from Shahr-e Sokhta¹ Archaeological Site: A Survival Approach Using Life-Table and Kaplan-Meier Methods

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Abstract: Studying the human remains and analyzing demographic problems, sex ratios, and mortality rates in Shahr-e Sokhta (*The Burnt City* in Persian) can prove highly valuable in identifying the ancient peoples of the region, thus shedding light on a significant transitional period between the prehistoric and the historic eras. In this study, a gender-based analysis was conducted on the anthropometric data extracted from the existing reports on Shahr-e Sokhta III via two statistical methods, namely, the life table method and the Kaplan-Meier method. Of the 370 studied skeletons, 218 belonged to women and 152 to men. Two statistical survival analysis methods were used to examine the skeletal remains of men and women over the age of 12. The results (P -value = 0.143) of the Kaplan-Meier method (using the log-rank test) did not reveal a statically significant difference between age at death distributions obtained for men and women. However, the life table method (via the Wilcoxon signed-rank test) indicated a statically significant difference between men and women in terms of age at death distributions (P -value = 0.003). The results of the life table method obtained in this study are in agreement with those indicated in the reports on Shahr-e Sokhta III. Therefore, we concluded that the contradiction in the results obtained through the Kaplan-Meier and the life table methods might be due to the different weightings attributed in the log-rank test and the Wilcoxon test. For this reason, we propose that similar studies be conducted in other ancient sites where cemeteries with skeletal remains have been unearthed.

Keywords: Shahr-e Sokhta, Survival Analysis, Life Table, Kaplan-Meier, Age at Death.

Introduction

Archaeology is the study of ancient peoples and their way of life. As such, examination of skeletal and dental remains is the centerpiece of archaeological studies since these remains provide the archaeologist with important information unmatched by other archaeological finds (Roberts 2009). By producing such information as the mean age of a population, the existing relations among those buried in the same grave, and health of a population,

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1. Considering that the title of the site has been presented with different spellings in publications, here we have adopted the spelling common in Italian publications.

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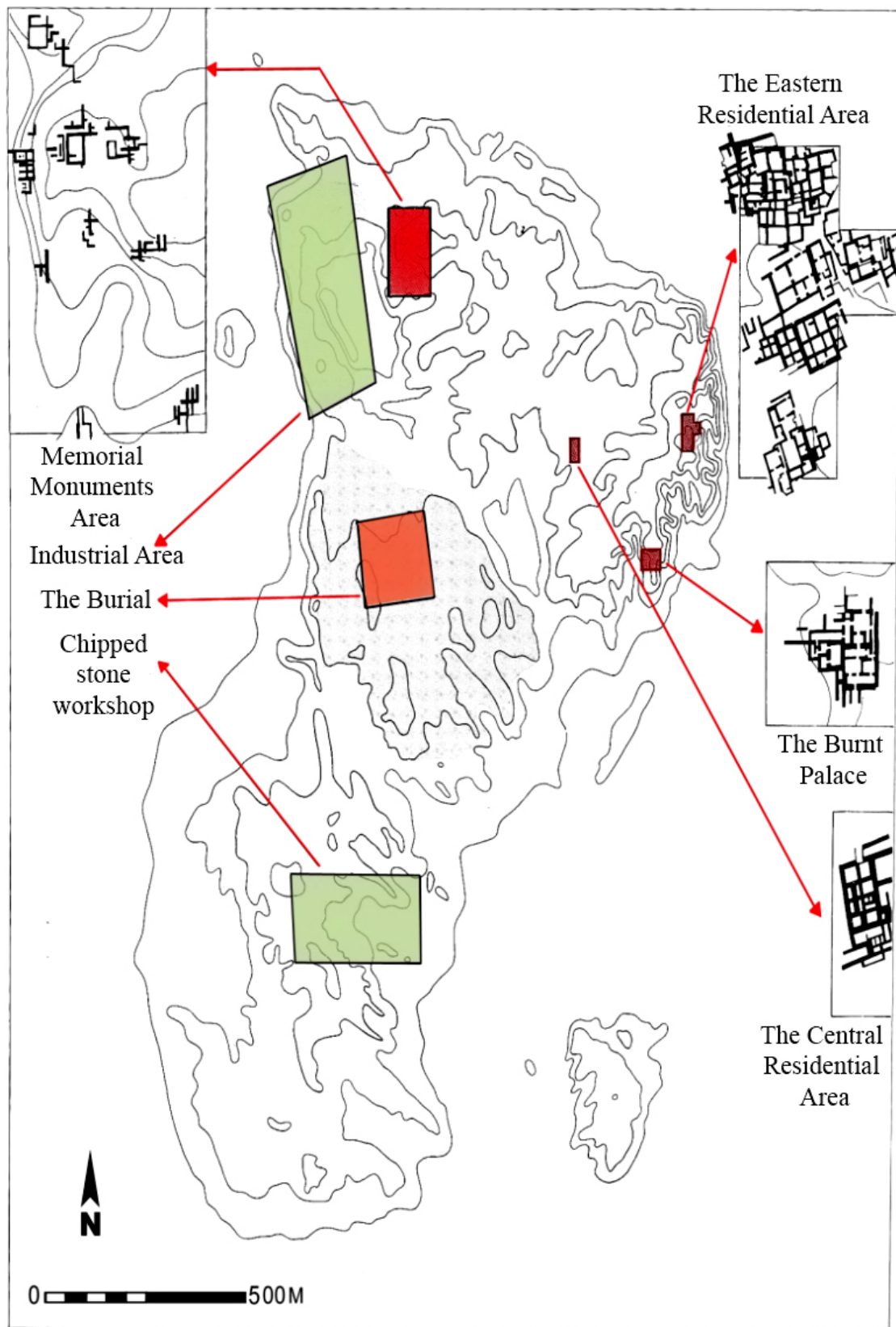


Fig. 1. Different urban divisions in Shahr-e Sokhta (Seyyed Sajjadi 2005)

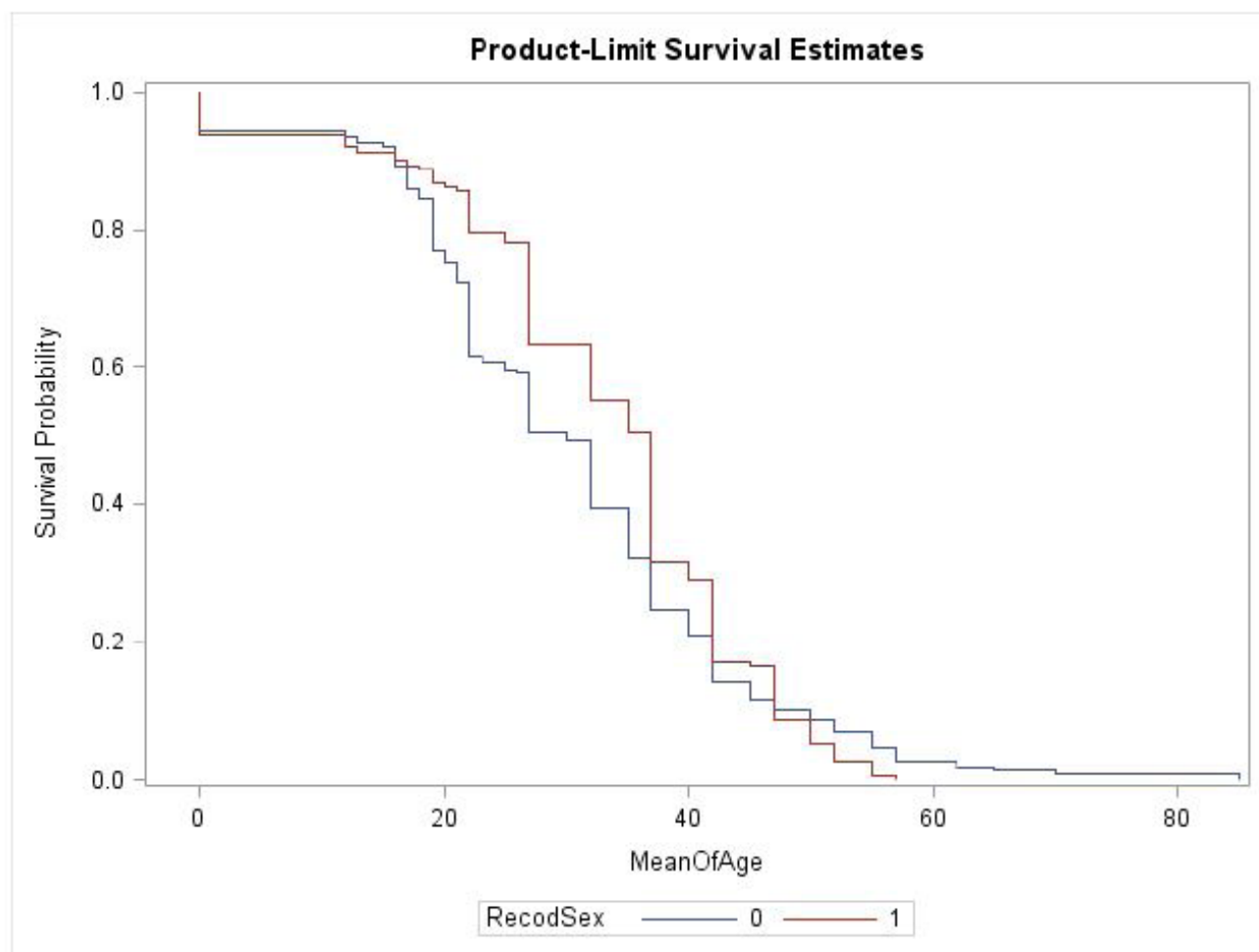


Diagram 1. Comparison of Survival vs. time obtained from the Kaplan–Meier method for women (0) and men (1)

oste archaeological studies can actually reveal an ancient person's identity.

Today, Shahr-e Sokhta is a familiar name in Iranian culture as well as archaeological literature. The information revealed from this ancient site has proved that many of the old theories on absolute centrality of the Mesopotamian civilization are actually unsound (Seyyed Sajjadi 2011). The ancient archaeological site referred to as Shahr-e Sokhta is located 60 km from Zabol, Sistan and Baluchestan Province, Iran. This site has been introduced in different ways to those interested in the Iranian history and civilization. Dating back 5200 years and extending across 152 hectares, Shahr-e Sokhta is a unique historical site representing the first and the greatest urban settlement to the east of the Iranian Plateau (Fig. 1), the inhabitants of which lived in peace without any weaponry tools with a well organized economic and social structure and proper divisions; a perfect city in the ancient world in terms of art, industry, trade, and science (Tosi 1968; Forouzanfar 2009).

The Shahr-e Sokhta cemetery was discovered by accident in 1972 during geological studies in the area.

During five seasons of excavation, an area of about 2500 square meters was unearthed in this cemetery the total area of which is estimated to be between 20 and 25 hectares. The number of graves in the cemetery is estimated between 25,000 and 40,000 (based on excavation results until 1977, a total of 230 graves were excavated, from which 300 skeletons were obtained. After the Islamic Revolution in Iran, the excavations were discontinued for 20 years. New excavations, supervised by Dr. Seyyed Sajjadi, were conducted at this ancient site in 1997 under the supervision of the Iranian Cultural Heritage Organization, producing 758 skeletons. As determining the gender of children under 12 years of age is generally difficult and contains a large margin of error, in this study we used only the 370 adult skeletons, the genders of which could be reliably determined. The physical-anthropological information for these skeletal remains has already been published (Forouzanfar 2009).

In terms of providing information and various artifacts, the cemetery is classified as a rich one. A general conclusion is that this cemetery was in active use for about 1000

years (3200-2100 BC). Based on the discovered remains, we conclude that people buried in the cemetery, though similar in general terms, were different in terms of their (historical) eras and their cultural traditions; nevertheless, they managed to live peacefully together in the city. The number of graves in the city is estimated as c. 20,000 (Piperno and Salvatori 2007; Salvatori and Vidale 1997).

This study aims to use the life table and the Kaplan-Meier methods to evaluate distribution of age at death, and compare men and women age at death in Shahr-e Sokhta based on the skeletal remains discovered by the Iranian Archaeological Team between 1997 and 2008. The main event in the survival study is death (or failure) which was experienced by all the studied units. Therefore, the age at death is considered as the time to the Time to Event in the analysis.

Methods and Materials

The present historical study is based on the archaeological finds at the site of the cemetery during 12 seasons of excavation (1997-2008) (Forouzanfar 2009). The presented anthropological material is based on the results obtained from anthropometric measurements conducted on the skeletal remains of adults of both sexes as well as those of children and newborns (Forouzanfar 2009). Of the total 758 released human skeletons, 370 were suitable for examination. The (collective) age at death of these skeletons was estimated to be over 12 years. The age at death estimations used in this study were conducted by an expert in anthropology in accordance with specific standards.

Table 1. Mean and median survival in women and men obtained from the Kaplan-Meier Method

Mean (Years)					Median (Years)	Log-Rank Test Probability Value
Gender	Value	Standard Deviation	Confidence Interval			
			Lower Limit	Upper Limit		
Woman	30.23	0/99	28.29	32.17	30	0.143
Man	32.83	1.05	30.77	34.89	37	
Overall	31.30	0.73	29.87	32.73	32	

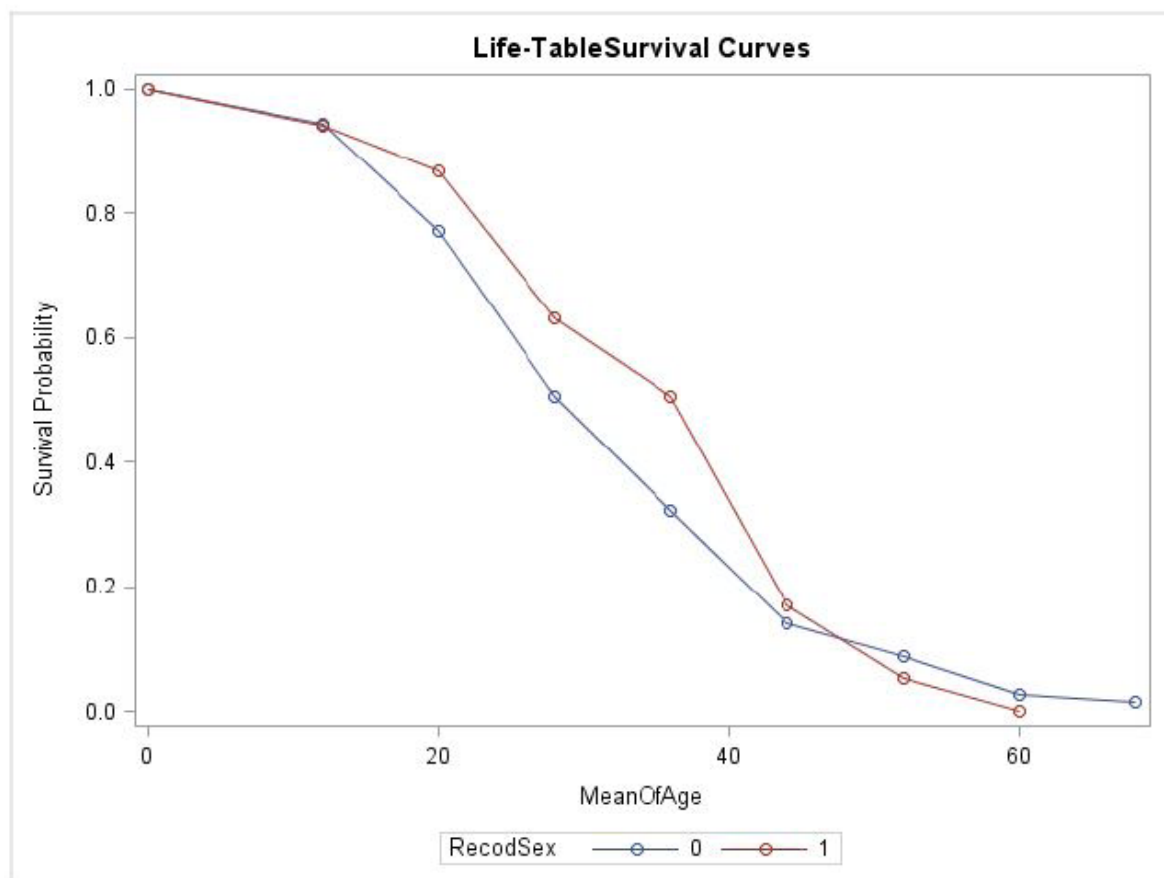


Diagram 2. Comparison of Survival vs. time obtained from the life table method for women (0) and men (1)

Table 2. Survival rate in women and men obtained from the Wilcoxon test

Gender	Women			Men		
Age Groups	Estimate	Confidence Interval		Estimate	Confidence Interval	
		Lower Limit	Upper Limit		Lower Limit	Upper Limit
0-12	1	1	1	1	1	1
12-20	0.945	0.914	0.975	0.940	0.903	0.978
20-28	0.770	0.714	0.826	0.868	0.814	0.922
28-36	0.504	0.438	0.571	0.631	0.554	0.708
36-44	0.321	0.259	0.383	0.506	0.427	0.586
44-52	0.142	0.095	0.188	0.171	0.111	0.230
52-60	0.087	0.049	0.124	0.052	0.017	0.088
60-68	0.027	0.005	0.049	-	-	-
Over 68	0.013	<0.0001	0.029	-	-	-
Wilcoxon Test	P-Value=0.0036					

Survival analysis is a set of statistical methods where the response variable is assumed to be the Time to Event (e.g., death) (Kleinbaum and Klein 2006). In this study, the non-parametric life table method and the Kaplan-Meier method were used.

The life table can be used to determine the survival time distribution based on such variables as gender, race, region, profession, and disease (Mohammad and Malekafzali 2013). The Kaplan-Meier is also a non-parametric method for estimating the survival function. Note that both the non-parametric methods used here are based on the product limit (Hajizadeh and Asqari 2011).

The variable used in this study was the approximated mean age. Three hundred and seventy adult skeletons (the age and gender of which had already been determined) were duly analyzed via univariate, i. e. Kaplan-Meier, and life table methods and their ages at death determined. To compare the respective survival rates in the women and men gender groups, we used the log-rank test (in the Kaplan-Meier method) and the Wilcoxon test (in the life table method). The statistical analysis system (SAS) was used for analyzing the obtained data. A statistical significance level of $\alpha=0.05$ was assumed and the results were represented in the form of tables and diagrams.

Findings

Of the 370 skeletons with known genders, 218 (59%) were women and 152 (49%) were men. The mean and median survival times for women and men were 30.23 and 30 years and 32.83 and 37 years respectively, as shown in Table 1. This table also presents the information obtained from the log-rank test (to compare the skeletal remains of women and men) as well as the descriptive information obtained for the two gender groups. These are discussed in the following section.

Diagram 1 shows the curves obtained for the studied skeletons in terms of their gender. As can be observed in this diagram, until the age of about 50, men have a higher chance of survival than women. After the age of 50, however, the survival rate among women is (according to our estimates) greater than that of men. These intuitive findings are analyzed via the log-rank test in the next paragraphs (Table 1).

In the data used for evaluating the survival function via the Kaplan-Meier method, the estimated age limits for women and men were 12-85 and 12-57 years respectively. According to the results obtained from the log-rank test, there is no significant difference between men and women in terms of age at death ($P=0.143$), as shown in Table 1.

The findings obtained from the life table method are presented below (Diagram 2).

Similarly to Diagram 1, Diagram 2 shows that before the age of 50, the survival rate among men is greater than that among women, but after this age, the reverse occurs, i.e., women survive better than men. The Wilcoxon test was subsequently used to verify this difference analytically.

Table 2 shows the survival rates calculated based on the life table method. The results of the Wilcoxon test indicate that the difference in survival (i.e., age at death) between women and men is statistically significant ($P = 0.0036$).

Discussion and Conclusion

Sistan and Baluchestan Province is a center of civilization in the eastern Iranian Plateau. Obtaining better knowledge of this center in terms of culture and civilization is essential not only because it reveals the origins of culture and civilization on the Iranian Plateau, but also because it identifies the cultural, social, and economic relations that existed between the different cultures and civilizations in the Indian Subcontinent and Central Asia and those in the

Persian Gulf and the Mesopotamia (Seyyed Sajjadi and Kostantini 2008). Studying the vast ancient cemetery of this once great city can be regarded as a significant step in identifying the ancient peoples and recording their biological and physical characteristics. In view of this, the present study used the life table and Kaplan–Meier methods to analyze the age at death (survival rate) distribution in terms of gender of the inhabitants of Shahr-e Sokhta. The results showed that, in spite of the slight differences obtained, there is no significant (statistically) difference between survival rates in this 5000-year-old city.

The demographic statistics of this city showed that women were more vulnerable than men when they were young, and that their life density was greater than those of men. Instead, due to the hardships they encountered in terms of having to go on long trips and earning a livelihood, men underwent premature aging and lost their earlier abilities, thus being succumbing to death more frequently between the ages of 36 and 43. In addition, a review of the obtained life tables and diagrams, reveals that although women were more vulnerable at younger ages, they lived longer in their middle years as compared to men, and many of those who survived their youth reach old age.

This is the first study conducted on survival rate using the Kaplan-Meier and the life table methods to study skeletal remains in Iranian archaeological sites. According to the exact and credible results of this study, there was an intuitional difference between age at deaths obtained for the two genders at different ages. These results agreed with those published by Forouzanfar (2009).

Although the results obtained from the life table and the Kaplan-Meier methods were different in terms of statistical significance, this difference can be attributed to the weightings used in the log-test and the Wilcoxon test (using an estimated rather than a mean age interval in the life table). Therefore, we suggest that more advanced methods should be used for evaluating survival rate including the exponential model and the Weibull model via using distance sensors. We also propose that similar studies be conducted in other ancient sites which have cemeteries, so that, ultimately, a clearer picture can be obtained from the mortality and method of life among ancient peoples.

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