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Environmental and Genetic Causes of Variation in Growth Patterns of Najdi Sheep from Birth to Maturity

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Abstract. Data on 23 males and 21 females were analyzed to evaluate the effects of month of birth, age of dam, age of animal and sex on growth patterns of various body characters of Najdi sheep. Body characters used for analysis were body weight, body length, height at withers and chest girth taken at 3 monthly intervals from birth up to 36-month of age. Results showed that month of birth was a significant ($P < 0.01$) source of variation for various body characters up to 9-month of age. The effects of age of dam and age of animal within each interval, were significant ($P < 0.01$) on all body characters at birth and at 3-month of age. At 6-month of age, sex showed significant effects on all body characters except for the body length. Thereafter, the males became longer ($P < 0.01$) than females at 12-month of age.

Fitting Brody's equation to a least-squares mean weight and to the actual observed mean weight at each age consistently underestimated the birth weights by 40% and 25.5% for males and by 46% and 44.5% for females, respectively. The values for asymptotic body weights were close to those of 36-month of age. Also, the Brody model did not yield significant differences for the various body measurements in comparison with the actual observed estimates from birth through maturity.

Introduction

The black Najdi sheep of Saudi Arabia enjoys priority in its meat consumption over other indigenous and exogenous breeds of sheep in the central region of the country. Significant breakthroughs are, however, needed to improve the productivity and to produce and market high quality Najdi lambs. Therefore, rapid growth is a very important character requiring particular attention in any breeding plan aiming at improving this animal. Growth could be evaluated carefully if a profitable combination of growth and ability to finish at an early chronological age are to be realized. However, most attempts to characterize the growth and maturity patterns of animals have involved the use of body weight and/or other body measurements by time func-

tion[1–3]. Knowledge of maturing rate and the point of inflection of the growth curve is therefore imperative since they are the pre-requisites for development of successful sheep operations.

The growth patterns of various breeds of sheep have been studied exclusively [1,4,5], however, studies on these aspects in black Najdi sheep of Saudi Arabia are sparse. This study was undertaken in an attempt to identify the growth patterns of body weight, body length, height at withers and chest girth of male and female Najdi sheep from birth through 36 months of age, and the relationships of these body characters to mature size.

Materials and Methods

This study was conducted over a 3-year period from 1982 to 1985 and involved 44 black Najdi sheep (23 males and 21 females) born in September, October and November, 1982. At lambing, each lamb was identified with an ear tag and information concerning its month of birth, age of dam at lambing as well as the sex of lamb was recorded. The lambs were suckled for 60 ± 5 days then weaned. During the preweaning period they had access to pelleted concentrates (18% crude protein) and green clover offered ad libitum. After weaning, all lambs were fed in accordance with the National Research Council Requirements [6]. The rations consisted of 60% roughage (alfalfa hay, green clover and wheat straw) and 40% commercially pelleted concentrates (14% crude protein). They were kept indoors especially during the summer season and appropriate preventive measures were used against internal and external parasites and clostridial infections.

Each lamb was weighed to the nearest 50 grams and its body dimensions measured for the first time within 24 hours from birth. Then, it was weighed and measured at 3 monthly intervals up to 30-month, and finally at 36-month of age. The numbers of animals by sex and age are shown in Table 1. Three body dimensions, namely body length (the longitudinal distance beween the point of the shoulder to the hip joint), height at withers (the distance from the ground to the top projection of the dorsal vertebrae) and chest girth (the circumference of the body around the chest), were taken at each age and recorded to the nearest millimeter. Any weight or measurement taken from clinically unsound animals or within 45 days before or after parturition was discarded. It was assumed that this edit correction would remove much of the variation due to various stress conditions.

To estimate the growth and maturing rate parameters, the Brody's equation [1] as used by Nadarajah *et al.* [3] was applied:

$$Y_{it} = A_i(1 - B_i e^{-K_i t}) + r_{it}$$

Table 1. Number of black Najdi males and Females at each weighing age

Sex	Age in months											
	0	**3**	**6**	**9**	**12**	**15**	**18**	**21**	**24**	**27**	**30**	**36**
Male	23	23	23	22	22	20	19	19	18	16	14	7
Female	21	21	19	21	20	20	18	19	18	17	19	11

where, Y_{it} is the observed body weight or body measurement of i^{th} sex at t^{th} age, A_i is the asymptotic weight or measurement of the i^{th} sex, B_i is 1 minus the ratio of birth weight or body measurement to the corresponding mature value for the i^{th} sex, K_i is a measure of the rate at which the curve is approaching the asymptote for the i^{th} sex, t is the age in months, e is the base of natural logarithms, and r_{it} is the mean deviation of observed weight or measurement from the predicted value for i^{th} sex at t^{th} age.

Two methods were used to prepare the data for estimating the growth parameters. The first was least-squares analysis [7] at each age to estimate a least-squares mean weight or body measurement for each sex at that age (adjusted data). Each observation on body weight or body measurement was assumed to be the sum of the influences of effects of the other variables as follow:

$$Y_{ijklm} = u + M_i + A_j + G_k + S_l + e_{ijklm}$$

where, Y is the body weight or body measurement of individual sheep, u is the overall mean, M the month of birth effect, A an age of dam at lambing, G an effect due to the age of individual sheep as a continous variable, S is an effect due to sex, and e is the random variation. It was assumed that interactions were non-existent. Duncan's multiple range test was used to make pairwise comparisons among the means for significant effect. Brody's equation was then fitted by Guass-Newton iteration [7] to the least-squares means of body weight or body measurements.

The second method consisted of fitting the Brody's equation by Guass-Newton iteration to each observed mean of body weight or body measurement of both sexes (unadjusted data).

Results and Discussion

Least-squares analyses of variance for the various factors affecting body weight and various body measurements of black Najdi sheep are presented in Table 2 and 3. Month of birth was a significant ($P < 0.01$) source of variation for body weight, body length, height at withers and chest girth from bith to 9-month of age. Also, sig-

nificant ($P < 0.01$) differences in body length due to month of birth were observed at 15- to 21-month of age, indicating that the month of birth continued its significant effect on the length of the body to older ages than the other studied characters. In general, lambs born in September were significantly ($P < 0.01$) lighter in weights and had smaller body measurements during their first 9 months of life in comparison to those born in October and November. Several reports on sheep [8,9] had shown that the prevailing environmental conditions during the latter part of gestation considerably affected post-natal growth and body developments. Abouheif and Alsobayel [10] showed that the month of lambing had the highest contribution to the variability in black Najdi's birth weights. At older ages, however, the significance of month of birth as a source of variation for body weight and various body measurements disap-

Table 2. Mean squares from the least-squares analyses of variance for body weight and various body measurements of black Najdi sheep from birth to 12 months of age.

Source of variation	d.f.	Age in months				
		0	3	6	9	12
				Body weight		
Month of birth	2	1.97**	58.65**	89.47**	42.31**	0.18
Age of dam	2	1.54**	39.53**	1.48	3.82	4.57
Age of animal	1	2.01**	30.01*	2.29	.95	8.24
Sex	1	.14	24.56	148.66**	308.57**	260.91**
				Body length		
Month of birth	2	33.79**	69.46**	54.82**	46.17**	1.12
Age of dam	2	48.60**	57.43**	1.39	8.32	7.18
Age of animal	1	63.59**	42.22**	16.46	2.10	5.68
Sex	1	15.81	39.87	1.73	3.74	343.64**
				Height at withers		
Month of birth	2	48.09**	40.86**	44.66**	51.80**	1.25
Age of dam	2	29.74**	80.39**	.13	1.37	2.71
Age of animal	1	46.44**	37.23**	4.28	2.68	1.68
Sex	1	8.89	23.61	108.95**	60.17**	115.08**
				Chest girth		
Month of birth	2	63.54**	82.94**	66.12**	70.95**	.89
Age of dam	2	106.73**	86.63**	.85	2.07	6.46
Age of animal	1	66.03**	45.62**	6.35	15.92	6.80
Sex	1	5.31	38.69	103.21**	203.67**	357.96**

* $P < .05$, ** $P < .01$

peared. It seems that, because all lambs in this study were born within a 3-month period, the month of birth could be considered to represent a general time-of-year effect at later ages.

Table 3. Mean squares from the least-squares analyses of variance for body weight and various body measurements of black Najdi sheep from 15 months of age to 36 months of age.

Source of variation	d.f.	Age in months						
		15	18	21	24	27	30	36
					Body weight			
Month of birth	2	5.31	.04	6.54	9.09	21.97	6.61	1.45
Age of dam	2	10.20	.42	15.90	1.83	.92	8.72	3.18
Age of animal	1	18.04	2.09	6.67	10.23	14.27	9.77	4.80
Sex	1	722.50**	941.92**	1073.79**	1340.78**	1585.62**	1365.71**	1483.97**
					Body length			
Month of birth	2	49.20*	34.94*	30.57*	8.14	4.11	2.35	2.77
Age of dam	2	19.72	.88	1.87	4.23	10.48	9.74	2.46
Age of animal	1	10.67	1.38	3.74	1.00	18.46	5.66	.71
Sex	1	562.50**	599.37**	880.33**	917.08**	874.44**	876.63**	855.15**
					Height at withers			
Month of birth	2	.75	1.01	15.20	12.74	.50	1.44	27.81*
Age of dam	2	.96	3.28	4.90	.10	7.97	3.39	.45
Age of animal	1	11.87	4.92	7.97	1.70	17.11	7.95	38.97**
Sex	1	36.10**	113.94**	331.87**	1015.48**	926.12**	900.24**	797.48**
					Chest girth			
Month of birth	2	19.18	1.78	11.28	17.74	18.53	9.61	27.56
Age of dam	2	2.23	5.28	2.33	8.20	3.78	16.89	1.95
Age of animal	1	5.52	4.27	12.76	7.61	15.78	8.68	8.26
Sex	1	1151.33**	1214.59**	1144.01**	1333.47**	1142.81**	1220.53**	1286.12**

* $P < .05$, ** $P < .01$

Significant effects ($P < 0.01$) of age of dam at lambing on body weight and different studied body measurements were found only at birth and at 3-month of age. Younger ewes, 1-2-year old and 2-3-year old, lambed lighter and smaller lambs, while 4-year old ewes had heavier and larger lambs from birth through 3-months of age. These results are in agreement with the findings of Bhasin and Desai [9] and Abouheif and Alsobayel [10] for birth weights of Indian and Saudi Arabian sheep. It seems that maternal tissues of young dams are not as fully grown as those of older dams, thus providing less favourable uterine conditions for embryonic development.

At subsequent ages, the significant effect of the dam's age on body weight and various body measurements of the lambs had disappeared, indicating that differences in early post-natal growth (until 3-month of age) are caused, to a considerable extent, by maternal factors. This conclusion is in accordance with the results of Widdowson [11, pp. 1-9] who found that variation in body weight produced by size of dam, were likely to be maximal at birth, considerable in early post-natal life and minimal at maturity.

The effect of age variation within each weigh period was a significant source of variation ($P < 0.01$) during the period from birth to 3-month of age and subsequently non-significant.

Sex of animal had no significant effect on body weights or body measurements from birth through 3-month of age. Similar findings were reported by Juma *et al.* [12] who found no sex differences in body weight or body measurements of Awassi sheep from birth to the weaning age. On the other hand, Abouheif and Alsobayel [10] reported that male Najdi lambs were 3.9% heavier in birth weights than females; such differences accounted only for 0.7% of the total variance components of birth weight. Except for body length, the effect of sex on all the studied body characters became significant ($P < 0.01$) at the age of 6 months. Thereafter, the length of body of males became significantly ($P < 0.01$) longer than the females only at 12 months of age. The latter findings disagree with the results reported by Asker *et al.* [13] who found that males were significantly longer at birth and at weaning age than the females.

Results showed a tendency for black Najdi males to increase significantly ($P < 0.01$) in body weight from birth up to 21-24-month of age, and up to 21-month of age for Najdi females. Thereafter, the body weights of both males and females underwent slight increases up to 36-month of age. It is relevant to notice that the total gains in body weights during the second and third years of animal's life, as an average of the unadjusted and adjusted data, were approximately 14.65 kg and 0.9 kg in Najdi rams, and 7.45 kg and 0.25 kg in Najdi ewes, respectively. It is not possible, however, to estimate how much to this increase could have been due to increasing lean mass or to fat deposition since no data are available for fat cover of the individual sheep. Further results indicated a gradual and significant ($P < 0.01$) increase in body length for male and female Najdi sheep from birth through 21-month of age. Likewise, height at withers and chest girth were significantly ($P < 0.01$) increased up to 24- and 15-month of age for the rams, and up to 15-month of age and 12-month of age for ewes respectively. These results showed that the growth patterns of body weights and various studied body measurements for males differed in their amplitude from those patterns of females.

Means (unadjusted data) and least-squares means (adjusted data) were used to estimate the asymptotic growth curve parameters for body weight and various body measurements using Brody's equation (Table 4). Estimates of mature body characters (A) from adjusted data were slightly higher than those of unadjusted data. The values for asymptotic A were invariably very close to those of 36-month of age. On the other hand, the Brody model consistently underestimated the birth weights of male and female black Najdi lambs by 25.5% and 44.5% for unadjusted weights, and by 40% and 46% for adjusted weights, respectively. Moreover, the Brody model did not yield consistently biased estimates for the various studied body measurements at birth, and the average absolute error of estimation was reduced to ± 2.36%. Therefore, it seems that the Brody model described later body weights growth more accurately than early growth, while the studied body measurements were well fitted with this model from birth through maturity.

Table 4. Estimates of asymptotic growth curve parameters[a] for male and female black Najdi sheep as determined by each method of analysis.

	Parameter[b]					
Character[c]	**A**	**B**	**K**	**A**	**B**	**K**
Male:	unadjusted data			adjusted data		
Body weight	72.9 ± 1.1	.96 ± .02	.11 ± .01	73.4 ± 1.0	.97 ± .02	.12 ± .01
Body length	84.2 ± .6	.61 ± .02	.19 ± .01	84.6 ± .7	.60 ± .02	.19 ± .01
Height at withers	83.7 ± 1.8	.48 ± .03	.11 ± .02	85.8 ± 1.7	.48 ± 0.3	.12 ± .02
Chest girth	107.2 ± .4	.64 ± .01	.17 ± .01	108.9 ± .5	.63 ± .01	.17 ± .01
Female:						
Body weight	56.7 ± .9	.96 ± .03	.15 ± .01	58.7 ± 1.0	.97 ± .03	.15 ± .01
Body length	74.1 ± .4	.58 ± .01	.30 ± .02	74.5 ± .5	.58 ± .02	.31 ± .03
Height at withers	74.6 ± .3	.45 ± .01	.21 ± .01	75.0 ± .4	.45 ± .01	.21 ± .01
Chest girth	96.2 ± .8	.60 ± .02	.22 ± .02	96.4 ± .9	.60 ± .02	.23 ± .02

[a] based on Brody's equation. [b] parameter ± standard error. [c] body weight in Kg, other characters in cm.

Growth curves obtained using Brody's parameters are shown in Figures 1, 2, 3 and 4. Estimates of asymptotic body characters (A) indicated that black Najdi rams were considerably heavier in weights and bigger in body dimensions than ewes. On the other hand, the females matured more rapidly (K) than males in all body characters studied. The correlations between the respective asymptotic A and K values were significantly negative ($P < 0.01$) for body weight and other body measurements of both sexes. Similar negative relationship between mature weight (A) and maturing rate (K) has been reported in cattle [2,14].

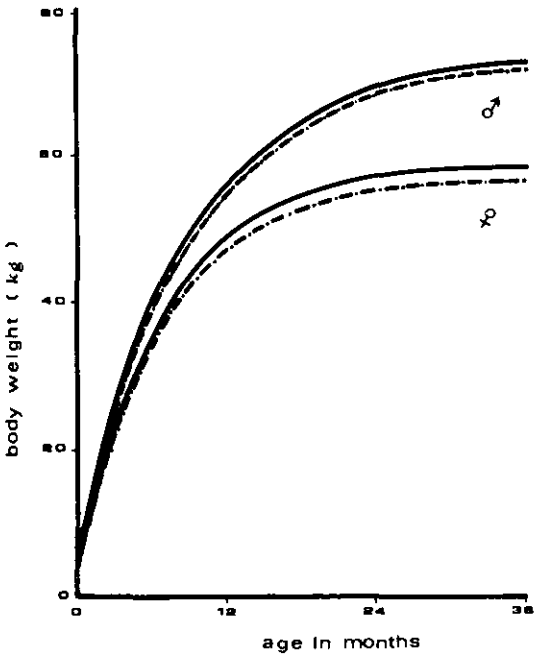

Fig. 1. Comparison of body weights of male and female Najdi sheep using Brody parameters. ——— adjusted data; –.–.–.–.– unadjusted data.

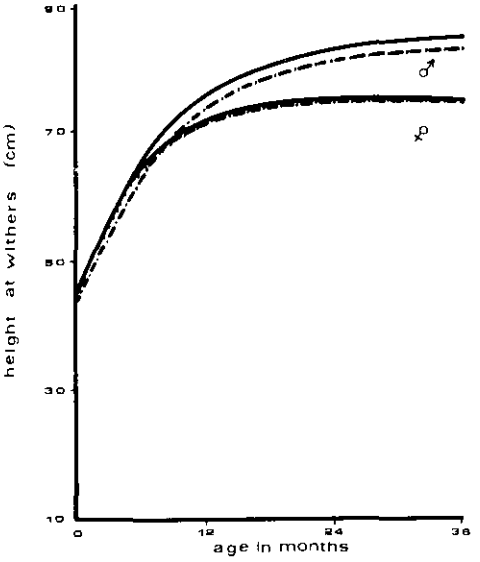

Fig. 2. Comparison of body lengths of male and female Najdi sheep using Brody parameters. ——— adjusted data; –.–.–.–.– unadjusted data.

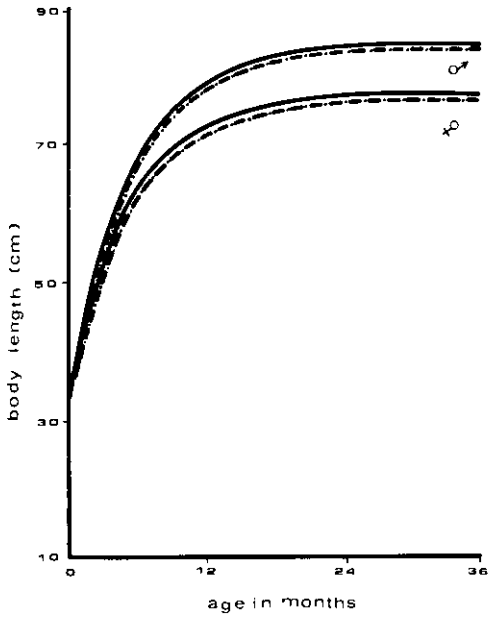

Fig. 3. Comparison of height at withers of male and female Najdi sheep using Brody parameters. —— adjusted data; –.–.–.– unadjusted data.

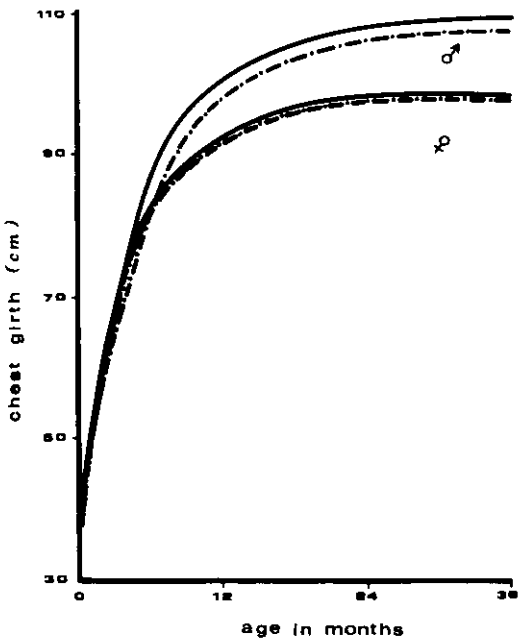

Fig. 4. Comparison of chest girths of male and female Najdi sheep using Brody parameters. —— adjusted data; –.–.–.– unadjusted data.

Estimation of growth curve parameters from adjusted data did not change the general shape of the growth curves of both sexes, although ranges in estimated asymptotic body weights and various body measurements were increased by only 1.04% after adjustment. In terms of residual mean squares from the non-linear least-squares analyses, the adjusted and unadjusted data were similar in all cases. Both methods were probably quite adequate to describe the data.

It is valid, however, to interpolate values for age at different degrees of maturity within the ranges of data set. On the basis of Brody function with unadjusted data for males, body weight, body length, height at withers and chest girth reached 50% of their asymptotic (.5A) values after 5.8, 1.0, –0.4 and 1.4 months, while females attained the same ratio at 4.5, 0.5, –0.5 and 0.8 month of age, respectively. Further studies showed that the time needed to reach 98% of the mature values (unadjusted) of body weight, body length, height at withers and chest girth were 34.5, 17.5, 29 and 20.5 months of age for males, and 26.3, 11.2, 15.2 and 15.2 months of age for females, respectively. In general, black Najdi females reached 50% or 98% of their mature body characters considerably faster than males. Although the Najdi sheep at birth were little higher at withers than those estimated 50% asymptotic values, they attained 98% of their asymptotic height at withers at relatively older ages than body length or chest girth. It could be concluded therefore that height at withers in comparison to other studied body measurements was the most matured character at birth, followed by length of body, chest girth and finally by body weight. These results are in general agreement with Hammond [15] who found that lambs were born with legs more developed than the different parts of the trunk. After birth the cannon bones grew at a slower rate than the parts forming the trunk of the animal. On a functional basis, the early maturing pattern of legs, which is partly responsible for the height of the animal, was not surprising for an element which is so vital to the survival of the lamb at birth.

Previous studies (unpublished data) showed that the black Najdi sheep enjoys a priority in its meat consumption among other indigenous and exogenous sheep in Saudi Arabia. Live weights at slaughter for Najdi males ranged widely according to the consumer preference, but 40–45 kg is considered best for marketing and slaughtering. Comparing this value with mature weight, it seems that the stage of maturity at which the ram lambs achieved weight and age sufficient for slaughter ranged from 0.55A to 0.60A and 6.6 to 8 months of age, respectively. On the other hand, it is a common practice among the breeders of Saudi Arabia to introduce the ewe lambs to the rams when they attain 35–40 kg in weight, which is in turn equivalent to 0.6–0.7A and 6 to 7.5 months of age. These observations permit some useful valid generalizations about black Najdi sheep, but further studies are needed to

explore the effects of various nutritional circumstances on mature weight and to identify the body composition of the gains made by Najdi sheep after attaining puberty.

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المسببات البيئية والوراثية للاختلافات في أنماط النمو للأغنام النجدي من الولادة وحتى النضج الجسمي

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ملخص البحث. فحصت البيانات المتحصلة من ٢٣ كبشًا ومن ٢١ نعجةً بغرض دراسة تأثير كل من شهر الميلاد وعمر الأم وعمر الحيوان وجنسه على أنماط النمو لصفات الجسم المختلفة في الأغنام النجدي السوداء. وقد اشتملت صفات الجسم المدروسة بتتبع قياسات وزن الجسم وطوله وارتفاعه عند منطقة الغارب ومحيط الصدر على فترات متتابعة كل ثلاثة أشهر منذ الميلاد وحتى عمر ٣٦ شهرًا. وقد أوضحت النتائج أن شهر الميلاد كان له تأثير معنوي إحصائيًا على صفات الجسم المختلفة وحتى عمر ٩ أشهر بينما كان تأثير عمر الأم معنويًا فقط عند الميلاد وعند عمر ٣ أشهر. وظهر تأثير جنس الحيوان بوضوح عند عمر ٦ أشهر على جميع صفات الجسم المدروسة ما عدا صفة طول الجسم والتي أصبحت الذكور أطول معنويًا عن الإناث ابتداءً من عمر العام.

وقد أوضحت النتائج أيضًا أن تطبيق معادلة برودي لوصف التغير في وزن الجسم المعدّل والوزن الحقيقي قد أعطت بيانات أقل من الواقع بحوالي ٤٠٪ و٥,٢٥٪ لذكور الحملان و٤٦٪ و٥,٤٤٪ لإناث الحملان على التوالي، بينما كانت تلك البيانات متقاربة مع بعضها عند عمر ٣٦ شهرًا. وأظهرت النتائج أن تطبيق معادلة برودي لوصف التغير في مقاييس الجسم المعدّلة والحقيقية ومقارنتها بالبيانات الحقيقية لم تعطِ أية فروقات معنوية.