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Closing and Non-closing Sutures in 256 Crania of Known Age and Sex from Amsterdam (A.D. 1883–1909)*

By dividing a Dutch reference collection into two subsamples of different ages, remarkable differences were found in the suture closure process in these subsamples. Spearman rank correlations demonstrated that mean endocranial closure stage is correlated ($P < 0{\cdot}001$) with age in the ages below fifty but not in the ages above fifty. In the latter ages the closure stage of individual suture sections showed positive as well as negative correlations ($0{\cdot}001 \leqslant P < 0{\cdot}05$) with age at death. Therefore two different suture closure indices were introduced as age indicators, one for each subsample. Both indices are correlated ($P < 0{\cdot}001$) with age within their subsample. It is supposed that the required division into subsamples may be realized with the help of other age indicators. As possible age indicator, especially when used together with others in "complex methods", suture closure has not yet served its turn.

1. Introduction

The methods to estimate the age at death of human skeletal remains are still unsatisfactory. Old ages especially pose a problem. One of the most discussed age estimators has always been cranial suture closure. Even nowadays its supporters and opponents can easily be found. On the one hand there are the "Recommendations for age and sex diagnoses of skeletons" (Workshop of European Anthropologists, 1980) accepted at the International Conference on Paleodemography in Sarospáták, Hungary (1978), which recommend the "complex method" of Nemeskéri *et al.* (1960) for age diagnosis of adults. This "complex method", also described in Acsádi & Nemeskéri (1970), combines four age indicators, one of them suture closure. On the other hand there are the critics: Singer (1953), Erankö & Kihlberg (1955), Brooks (1955), Genovés & Messmacher (1959), Powers (1962) and more recently Masset (1971). The last article entitled: "Erreurs systématiques dans la détermination de l'âge par les sutures crâniennes" finally led to the more general article: "Farewell to paleodemography" (Bocquet-Appel & Masset, 1982). Here it is frustratedly stated that "After devoting a few years to this young possibly still-born science, the authors bid farewell to paleodemography".

In this study a not discouraged author renders an account of the still existing obligation to investigate possible age estimators in every unique reference collection. No general statements about the vitality of paleodemography will be found. The article is confined simply and solely to the relation between suture closure and age at death as it is found in 256 crania of known inhabitants from Amsterdam who died between 1883 and 1909.

Science, even paleodemography, will proceed continuously. Still-born sciences do not exist. Only when all problems are solved may one bid farewell. The search for age estimators will continue until they are found.

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2. Material

Skeletal remains of known age and sex are scarce. There are but a few collections available in Europe. The Amsterdam crania, housed at the Laboratory of Anatomy and Embryology of the Municipal University of Amsterdam, form the only Dutch collection of this kind. It consists of dissection material collected in the period A.D. 1883–1909 and involves non-Jewish inhabitants of Amsterdam born in almost all parts of the Netherlands. Name, age, sex, stature and sometimes cause of death are known from the records. According to de Froe (1938), who investigated the relation between cranial measurements and age and sex on this material, it is a rather homogeneous collection (small coefficients of variation for cranial length and cranial breadth). Only the crania of adults (20 years and older) and those without pathological deformations were used. For the age and sex distribution of the 256 examined crania see Table 1.

Table 1 **The distribution of 256 Amsterdam crania according to age and sex**

	Age-group								
	20–29	30–39	40–49	50–59	60–69	70–79	80–89	90–99	Total
Males	2	4	20	34	47	50	17	—	174
Females	3	5	6	14	20	24	8	2	82
Total	5	9	26	48	67	74	25	2	256

3. Methods

In order to be able to compare the data from this study with those of Acsádi & Nemeskéri (1970) it was desirable to use identical methods. Personal communication with one of the authors (Nemeskéri) made it possible to copy their methods almost exactly (when Nemeskéri scored a selected sample of 79 Amsterdam crania no significant inter-observer difference in mean endocranial closure stage was found, $P < 0{\cdot}001$).

The obliteration of the sutures was ascertained endocranially as well as ectocranially. In both cases the degree of ossification was scored in 16 parts of the three main cranial sutures (Figure 1) as has been done by Acsádi & Nemeskéri (1970).* The coronal suture was divided in three parts on the right side (C_1r, C_2r, C_3r) and three parts on the left side (C_1l, C_2l, C_3l), the sagittal suture in four parts (S_1, S_2, S_3, S_4) and the lambdoid suture again in three parts on the right (L_1r, L_2r, L_3r) and on the left side (L_1l, L_2l, L_3l). Ectocranially the different sections can be distinguished by differences in the character of the suture (Figure 2). Endocranially the sutures do not show these differences in character. Consequently the endocranial sutures are simply divided in sections of equal length.

The scale of ossification (0, 1, 2, 3, 4) used by Acsádi & Nemeskéri (1970) was based on the classification presented by Martin & Saller (1957–1966). Because of the fact that in Acsádi & Nemeskéri (1970) the description of these five stadia is rather simple (0 = open, 1 = incipient closure, 2 = closure in process, 3 = advanced closure, 4 = closed) more details of their definitions (personally communicated to the author by Nemeskéri) are presented here (Figure 3).

* The "Recommendations for age and sex diagnoses of skeletons" (Workshop of European Anthropologists, 1980) incorrectly states 14 sections instead of 16.

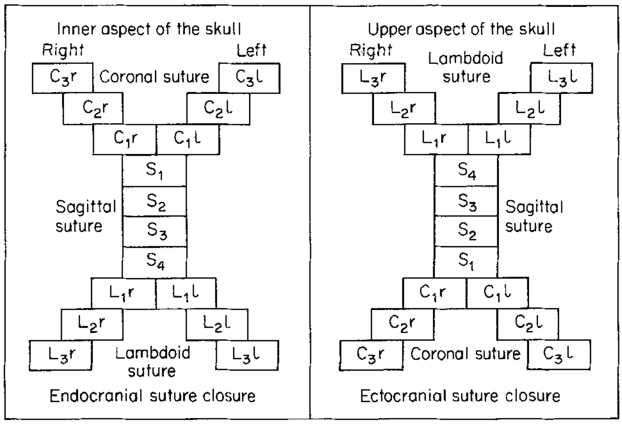


Figure 1. Schematic representation of the 16 endocranial, and 16 ectocranial sections in which suture closure was scored.

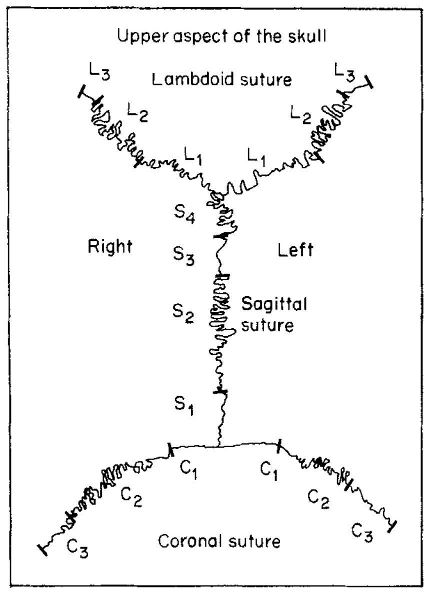


Figure 2. The ectocranial sections corresponding with differences in the character of the sutures (drawing after Oppenheim, 1907).

In imitation of Nemeskéri endocranial suture closure was observed by means of a small lamp put through the foramen magnum. In case of impossibility to inspect completely the endsections of the coronal and/or lambdoid suture through the foramen magnum, the closure stadium of the most lateral part that could still be observed was taken instead.

Mean ectocranial as well as endocranial closure stages were calculated for the three main sutures by adding the scored closure stages of the different sections and dividing the result by the number of sections (six or four) which compose the suture in question. Endocranial closure indices were calculated in the same way, adding the closure stages of all the endocranial sections and dividing the result by 16.*

* The statement in Acsádi & Nemeskéri (1970) that this index had been determined from averages of the individual sutures, is incorrect.

Figure 3. Description of the five stages of suture closure.

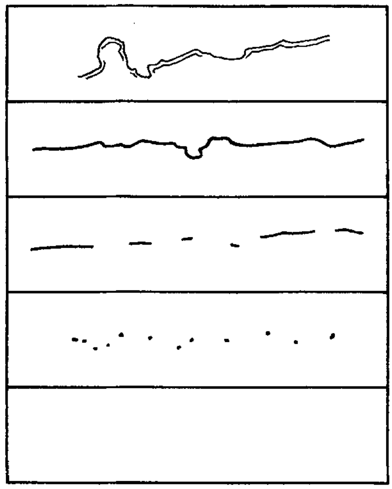
Stage 0. Open suture. There is still a little space left between the edges of the adjoining bones.

Stage 1. Suture is closed, but clearly visible as a continuous, often zigzagging, line.

Stage 2. Suture line becomes thinner, has less zigzags and may be interrupted by complete closure.

Stage 3. Only pits indicate where the suture is located.

Stage 4. Suture completely obliterated, even its location cannot be recognized.



To estimate the possible relation between suture closure and age at death Spearman rank correlation coefficients (one tailed) were calculated. Because of the considerably skewed age distribution of the sample (see Table 1), Pearson correlation coefficients are less appropriate.

4. Results

In order to know whether the two sexes could be treated together, which has the advantage of larger samples, it has first been investigated if a significant sex difference in the speed of the ossification process of the cranial sutures could be found. To that purpose the mean closure stages of the three main sutures in different age classes of ten years each were compared. Ectocranial and endocranial closure stages for males and females are presented in Tables 2 (a,b) and 3 (a,b) respectively. Student *t*-tests demonstrated no significant ($P \geqslant 0{\cdot}05$) differences between the mean closure stages for males and the comparable means for females. This is in agreement with the findings of Acsádi & Nemeskéri (1970). Consequently both sexes were treated together from this moment onward.

Table 2(a) **Mean ectocranial closure stages of the three sutures in males**

Age (years) ♂	Mean ectocranial closure stage						*n*
	Coronal suture		Sagittal suture		Lambdoid suture		
20–29	0·92	s.d. 1·06	2·50	s.d. 0·71	1·25	s.d. 0·35	2
30–39	2·08	1·11	3·56	0·72	1·58	1·20	4
40–49	2·33	1·61	2·90	0·72	1·82	0·85	20
50–59	2·68	0·62	3·04	0·84	2·28	0·87	34
60–69	2·54	0·79	2·76	0·86	1·78	0·86	47
70–79	2·89	0·53	3·21	0·66	2·22	0·75	50
80–89	2·79	0·49	2·91	0·63	1·75	0·80	17
90–99	—	—	—	—	—	—	—

Table 2(b) **Mean ectocranial closure stages of the three sutures in females**

Age (years) ♀	Mean ectocranial closure stage						n
	Coronal suture		Sagittal suture		Lambdoid suture		
20–29	1·28	s.d. 0·63	1·08	s.d. 0·76	0·83	s.d. 0·83	3
30–39	1·87	0·87	1·75	0·43	1·20	0·76	5
40–49	2·92	0·65	2·83	0·86	1·78	1·34	6
50–59	2·45	0·83	2·27	1·02	1·74	0·99	14
60–69	2·88	0·57	2·96	0·68	2·18	1·13	20
70–79	2·71	0·74	2·76	0·79	1·75	1·10	24
80–89	2·75	0·68	2·69	0·85	1·75	1·26	8
90–99	2·33	0·24	2·25	0·71	0·92	0·59	2

Table 3(a) **Mean endocranial closure stages of the three sutures in males**

Age (years) ♂	Mean endocranial closure stage						n
	Coronal suture		Sagittal suture		Lambdoid suture		
20–29	0·50	s.d. 0·24	1·50	s.d. 0·00	1·08	s.d. 0·12	2
30–39	2·49	1·61	3·06	1·03	1·54	0·90	4
40–49	3·52	0·63	3·35	0·63	2·70	1 03	20
50–59	3·73	0·58	3·54	0·44	3·05	0·78	34
60–69	3·56	0·97	3·43	0·84	2·89	0·83	47
70–79	3·92	0·17	3·58	0·31	3·30	0·44	50
80–89	3·72	0·50	3·43	0·39	2·99	0·80	17
90–99	—	—	—	—	—	—	—

Table 3(b) **Mean endocranial closure stages of the three sutures in females**

Age (years) ♀	Mean endocranial closure stage						n
	Coronal suture		Sagittal suture		Lambdoid suture		
20–29	1·67	s.d. 1·20	1·50	s.d. 0·66	0·94	s.d. 0·82	3
30–39	2·40	1·01	2·70	0·74	1·23	0·98	5
40–49	3·86	0·34	3·58	0·30	2·75	0·98	6
50–59	3·48	1·11	3·38	0·89	2·57	1·05	14
60–69	3·80	0·42	3·60	0·31	3·08	0·72	20
70–79	3·79	0·61	3·64	0·49	2·48	1·04	24
80–89	3·92	0·13	3·47	0·31	2·42	1·03	8
90–99	3·75	0·35	3·38	1·18	1·33	0·47	2

In Table 4 (a,b) the mean ectocranial and endocranial closure stages of the coronal, sagittal and lambdoid sutures in the successive age-groups are presented. It is obvious that the mean closure stages do increase up to a certain age-group only [indicated in Table 4 (a,b) by a plus]. The phenomenon occurs in each suture ectocranially as well as endocranially. The age-groups concerned are 40–49 years (once), 50–59 years (three times) and 70–79 years (twice). Moreover, from the age-group of 70–79 years onward [marked in Table 4 (a,b) by a minus] the degree of ossification diminishes in all three sutures ectocranially as well as endocranially. Suture obliteration seems to be correlated with age up to a certain age only. Even the possibility of a negative correlation in the higher

Table 4(a) **Mean ectocranial closure stages of the three sutures**

Age (years) ♂ + ♀	Ectocranial closure: Coronal suture		Sagittal suture		Lambdoid suture		n
20–29	1·13	s.d. 0·72	1·65	s.d. 1·01	1·00	s.d. 0·66	5
30–39	1·96	0·92	2·56	1·10	1·37	0·93	9
40–49	2·46	0·66	2·89+	0·74	1·81	0·95	26
50–59	2·61	0·69	2·82	0·95	2·12+	0·93	48
60–69	2·64	0·74	2·82	0·81	1·90	0·95	67
70–79	2·83±	0·61	3·06−	0·73	2·07−	0·90	74
80–89	2·78	0·54	2·84	0·70	1·75	0·94	25
90–99	2·33	0·24	2·25	0·71	0·92	0·59	2

\+ = stages increase up to this age-group.
− = stages decrease from this age-group onward.

Table 4(b) **Mean endocranial closure stages of the three sutures**

Age (years) ♂ + ♀	Endocranial closure: Coronal suture		Sagittal suture		Lambdoid suture		n
20–29	1·20	s.d. 1·07	1·50	s.d. 0·47	1·00	s.d. 0·59	5
30–39	2·43	1·22	2·86	0·84	1·37	0·90	9
40–49	3·60	0·59	3·40	0·57	2·71	1·00	26
50–59	3·65+	0·77	3·49+	0·60	2·91	0·89	48
60–69	3·63	0·85	3·48	0·72	2·95	0·80	67
70–79	3·88−	0·38	3·60−	0·37	3·04±	0·79	74
80–89	3·78	0·43	3·44	0·36	2·81	0·90	25
90–99	3·75	0·35	3·38	0·18	1·33	0·47	2

\+ = stages increase up to this age-group.
− = stages decrease from this age-group onward.

age-groups has to be taken into account. For this reason Spearman rank correlations between mean suture closure stage and age were calculated not only for the sample as a whole but also for subsamples of different age. The original sample was divided into two subsamples. In order to find out at what age the sample had to be divided to get the most clear differences in correlation, four different divisions were made, so that subsamples of 20–39 and 40–99 years, 20–49 and 50–99 years, 20–59 and 60–99 years and 20–69 and 70–99 years could be compared [Table 5 (a,b)]. In the total sample (20–99 years) the ossification of the coronal sutures shows a significant ($P < 0{\cdot}001$) correlation with age ectocranially as well as endocranially. As far as the subsamples are concerned, the best correlations with age are found in the 20–49 subsample. Here the mean endocranial closure of each suture is significantly ($P < 0{\cdot}001$) correlated with age, while in the complementary 50–99 subsample no significant correlations with age can be found, not even at the $0{\cdot}001 \leqslant P < 0{\cdot}05$ level. Therefore these two complementary subsamples of 40 and 216 crania respectively were chosen for further investigation.

As described under Methods, suture closure was scored ectocranially as well as endocranially in 16 suture sections. In order to get more detailed information Spearman

Table 5(a) **Spearman rank correlation coefficients of the mean ectocranial closure stages of each suture with age**

Age (years) ♂ + ♀	Ectocranial closure						n
	Coronal suture		Sagittal suture		Lambdoid suture		
20–99	0·23*	P 0·001	0·09	P 0·074	0·03	P 0·302	256
20–39	0·43	0·065	0·11	0·352	0·17	0·287	14
40–99	0·15†	0·009	0·03	0·296	−0·04	0·284	242
20–49	0·44†	0·003	0·24	0·069	0·24	0·072	40
50–99	0·08	0·112	0·03	0·317	−0·09	0·097	216
20–59	0·29†	0·003	0·05	0·317	0·23†	0·017	88
60–99	0·06	0·205	0·04	0·325	−0·03	0·331	168
20–69	0·22†	0·003	0·05	0·284	0·05	0·284	155
70–99	−0·00	0·484	−0·10	0·154	−0·13	0·090	101

* $P < 0{\cdot}001$. † $0{\cdot}001 \leqslant P < 0{\cdot}05$.

Table 5(b) **Spearman rank correlation coefficients of the mean endocranial closure stages of each suture with age**

Age (years) ♂ + ♀	Endocranial closure						n
	Coronal suture		Sagittal suture		Lambdoid suture		
20–99	0·24*	P 0·001	0·11†	P 0·041	0·14†	P 0·012	256
20–39	0·50†	0·033	0·58†	0·015	0·22	0·226	14
40–99	0·12†	0·033	0·01	0·454	0·01	0·411	242
20–49	0·71*	0·001	0·53*	0·001	0·50*	0·001	40
50–99	0·08	0·117	−0·04	0·302	−0·02	0·365	216
20–59	0·38*	0·001	0·32†	0·002	0·35*	0·001	88
60–99	0·02	0·387	−0·07	0·182	−0·04	0·301	168
20–69	0·25*	0·001	0·21†	0·005	0·24†	0·002	155
70–99	−0·15	0·071	−0·00	0·484	−0·12	0·108	101

* $P < 0{\cdot}001$. † $0{\cdot}001 \leqslant P < 0{\cdot}05$.

rank correlations were calculated also between the obliteration stage of each section and age [Table 6 (a,b)]. Within the 20–49 subgroup of 40 crania, ten suture sections, all endocranial, show an obliteration correlated with age at the $P < 0{\cdot}001$ level of significance [Table 6 (a)]. All sections of the coronal suture and the two endsections of the sagittal and lambdoid sutures are concerned. In the remaining six endocranial sections as well as in nine ectocranial sections correlation is significant at the $0{\cdot}001 \leqslant P < 0{\cdot}05$ level. In the complementary 50–99 subgroup no sections with a correlation at the $P < 0{\cdot}001$ level of significance occur and there are only five sections whose closure stage is correlated with age

Table 6(a) **Spearman rank correlation coefficients of the closure stages in the various suture sections with age in the 20–49 subsample**

♂ +♀ (*n* = 40)

Endocranial closure: section	R	L	Ectocranial closure: section	R	L
C_3	0·63*	0·60*	L_3	0·27†	0·27†
C_2	0·59*	0·62*	L_2	n.s.	n.s.
C_1	0·64*	0·66*	L_1	n.s.	n.s.
S_1	0·54*		S_4	0·30†	
S_2	0·43†		S_3	n.s.	
S_3	0·47†		S_2	n.s.	
S_4	0·56*		S_1	n.s.	
L_1	0·46†	0·46†	C_1	0·36†	0·44†
L_2	0·44†	0·40†	C_2	0·36†	0·42†
L_3	0·59*	0·51*	C_3	0·41†	0·44†

* $P < 0{\cdot}001$. † $0{\cdot}001 \leq P < 0{\cdot}05$. n.s. = not significant.

at the $0{\cdot}001 \leq P < 0{\cdot}05$ level of significance [Table 6 (b)]. In three of these five sections (C_3r and S_1 endocranial and C_2r ectocranial) the correlation is positive, as are all above-mentioned correlations. However in two of these five sections (both ectocranial endsections of the lambdoid suture) a negative correlation was found.

On basis of these findings two new suture closure indices were introduced. One, called selsec young (selected suture sections 20–49 age-group), is defined as the mean closure stage of the ten sections in the 20–49 subsample with an obliteration significantly correlated with age at the $P < 0{\cdot}001$ level [Figure 4(a)]. The other, called selsec old (selected suture sections 50–99 age-group), is defined as the mean closure stage of five sections (the three sections, C_3r and S_1 endocranial and C_2r ectocranial, with a positive correlation, together with the two sections, C_3l endocranial and C_2l ectocranial, which are the right or left counterpart of two of these three) minus the mean closure stage of the two sections (L_3r and L_3l ectocranial) with a negative correlation [Figure 4(b)]. This last index will reach its maximum value of four when the five positively correlated sections have a closure stage of four and the two negatively correlated sections a closure stage of zero. It can also become negative with a minimum of minus four.

In order to compare the utility of the indices selsec young and selsec old with that of the endocranial closure index used by Acsádi & Nemeskéri (1970) and recommended by the Workshop of European Anthropologists (1980) Spearman rank correlations between these three indices and age were calculated for the total sample as well as for the two subsamples

Table 6(b) **Spearman rank correlation coefficients of the closure stages in the various suture sections with age in the 50–99 subsample**

♂ + ♀ (n = 216)

Endocranial closure: section	R	L	Ectocranial closure: section	R	L
C_3	0·13†	n.s.	L_3	−0·15†	−0·15†
C_2	n.s.	n.s.	L_2	n.s.	n.s.
C_1	n.s.	n.s.	L_1	n.s.	n.s.
S_1	0·13†		S_4	n.s.	
S_2	n.s.		S_3	n.s.	
S_3	n.s.		S_2	n.s.	
S_4	n.s.		S_1	n.s.	
L_1	n.s.	n.s.	C_1	n.s.	n.s.
L_2	n.s.	n.s.	C_2	0·12†	n.s.
L_3	n.s.	n.s.	C_3	n.s.	n.s.

† $0·001 \leq P < 0·05$. n.s. = not significant.

Table 7 **Spearman rank correlation coefficients of three suture closure indices with age**

Age (years) ♂ + ♀	Endocranial closure index (see text)		Selsec young (see Figure 4)		Selsec old (see Figure 4)		n
20–99	0·17†	P 0·003	0·15†	P 0·008	0·26*	P 0·001	256
20–49	0·67*	0·001	0·70*	0·001	0·25	0·057	40
50–99	−0·01	0·445	−0·02	0·378	0·26*	0·001	216

* $P < 0·001$. † $0·001 \leq P < 0·05$.

(Table 7). It is evident that the endocranial closure index is without any meaning in the 50–99 subgroup, while selsec old has a low (0·26) but significant ($P < 0·001$) positive correlation with age in this subgroup. In the 20–49 subgroup both the endocranial closure index and selsec young are significantly ($P < 0·001$) and positively correlated with age, selsec young having a slightly higher correlation (0·70) than the endocranial closure index (0·67). In the total sample (20–99 years) only selsec old has a significant ($P < 0·001$) positive correlation with age. This is in agreement with the fact that this index is already

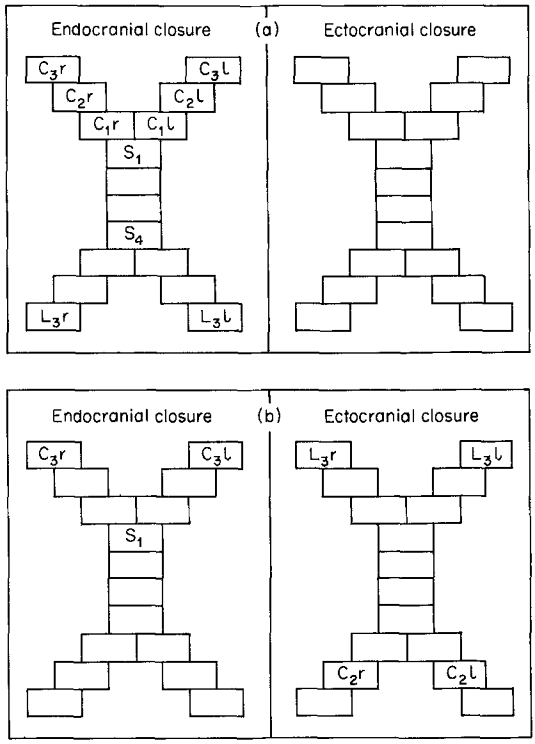


Figure 4. The suture sections on which the indices selsec young and selsec old are based. (a) Ten suture sections comprising the index selsec young (20–49 years). (b) Seven suture sections comprising the index selsec old (50–99 years).

Table 8 **Means of three suture closure indices in various age-groups**

Age (years) ♂ + ♀	Endocranial closure index		Selsec young		Selsec old		*n*
20–29	1·20	s.d. 0·36	1·20	s.d. 0·51	0·86	s.d. 0·90	5
30–39	2·14	0·75	2·27	0·87	1·39	0·65	9
40–49	3·22	0·60	3·41	0·60	1·62	0·94	26
50–59	3·34	0·68	3·46	0·76	1·48	0·89	48
60–69	3·34	0·71	3·46	0·78	1·70	0·99	67
70–79	3·49	0·38	3·66	0·39	1·87	0·84	74
80–89	3·33	0·46	3·48	0·45	2·16	0·75	25
90–99	2·75	0·35	3·00	0·42	2·85	0·21	2

significantly correlated with age in the 50–99 subgroup, which constitutes 84% of the total sample.

In addition Table 8 presents the means of the same three indices in successive age-groups of ten years each. In the three age-groups below 50 the mean of selsec young increases from 1·20 to 3·41 against 1·20 to 3·22 for the endocranial closure index. In the five age-groups above 50 the mean of selsec old increases from 1·48 to 2·85. Here the endocranial closure index is almost stationary and decreases in the two older age-groups.

In the following Tables 9 and 10 selsec young is only applied to the 20–49 subsample of 40 Amsterdam crania and selsec old only to the 50–99 subsample of 216 Amsterdam crania. Average ages and their standard deviations are presented belonging to successive

Table 9 **Average ages belonging to successive index stages (selsec young is only applied to the 20–49 subgroup and selsec old only to the 50–99 subgroup)**

Index stage	Index selsec young (20–49 years)			Index selsec old (50–99 years)		
	Average age		n	Average age		n
<0.0(00)	—	s.d. —	—	59·3	s.d. 6·9	4
0·0(00) – 0·1(99)	—	—	—	54·0	5·3	3
0·2 – 0·3	—	—	—	63·8	3·7	4
0·4 – 0·5	—	—	—	—	—	—
0·6 – 0·7	29·0	—	1	64·6	10·3	12
0·8 – 0·9	22·5	0·7	2	66·1	9·1	11
1·0 – 1·1	31·0	—	1	65·0	9·4	17
1·2 – 1·3	—	—	—	70·4	8·4	29
1·4 – 1·5	37·0	—	1	68·8	7·7	10
1·6 – 1·7	29·0	—	1	66·4	9·9	31
1·8 – 1·9	33·0	6·2	3	66·6	7·4	7
2·0 – 2·1	42·7	4·5	3	67·6	10·6	9
2·2 – 2·3	39·0	—	1	67·9	9·5	16
2·4 – 2·5	—	—	—	66·5	13·4	2
2·6 – 2·7	43·5	2·1	2	70·5	11·5	22
2·8 – 2·9	41·3	5·7	4	72·3	13·1	8
3·0 – 3·1	45·0	—	1	81·6	5·1	11
3·2 – 3·3	37·0	—	1	69·4	7·5	16
3·4 – 3·5	45·6	3·1	5	65·5	2·1	2
3·6 – 3·7	46·3	2·2	4	70·0	5·7	2
3·8 – 3·9	44·0	4·2	6	—	—	—
4·0	46·8	3·2	4	—	—	—
Total			40			216

Table 10 **Average ages belonging to successive index stages (selsec young is only applied to the 20–49 years subgroup and selsec old only to the 50–99 years subgroup)**

Index stage	Index selsec young (20–49 years)			Index selsec old (50–99 years)		
	Average age		n	Average age		n
<0.0(00)	—	s.d. —	—	59·3	s.d. 6.9	4
0·0(00) – 0·5(99)	—	—	—	59·6	6·6	7
0·6 – 1·1	26·3	4·4	4	65·2	9·4	40
1·2 – 1·7	33·0	5·7	2	68·4	9·1	70
1·8 – 2·3	38·0	6·6	7	67·5	9·2	32
2·4 – 2·9	42·0	4·7	6	70·7	11·7	32
3·0 – 3·5	44·3	4·1	7	73·8	8·9	29
3·6 – 4·0	45·4	3·5	14	70·0	5·7	2
Total	40·9	7·4	40	68·3	9·9	216

stages of the two indices. The two tables differ only in detail: the range from 0 to 4 is divided into 21 classes in Table 9 and into seven classes in Table 10. This last table clearly demonstrates how the average ages increase parallel with the index stages, especially in the case of selsec young. A comparison with Table 12, which presents similar data for the endocranial closure index but applied to the whole sample, shows that here the average ages have much higher standard deviations (up to 18·7 years). Another difference is the fact that selsec old offers the possibility to estimate ages of about 74 years (s.d. ± 9 years), the oldest possible age estimation based on the endocranial closure index being 66 years (s.d. ± 11 years).

Of course the indices selsec young and selsec old can only be used as age indicators if first a division is made between those younger and older than fifty years. It should be investigated to what degree and with the help of which age estimators such a division may be realized. Unfortunately the present reference collection, because of its uneven distribution (84% being fifty years or older), is not appropriate to such an investigation.

5. Comparison with the Hungarian Data

The fact that scoring methods were copied from Acsádi & Nemeskéri (1970) makes it possible to compare some of the above results with their data. The endocranial closure data of the Amsterdam and the Hungarian crania can be found in Tables 12 and 13 respectively. Both the average ages per mean endocranial closure stage and the mean endocranial closure stages per age-group are presented.

Because of the fact that only crania with symmetrically closing sutures were examined by Acsádi & Nemeskéri (although they do state that suture closure of asymmetrically ossified crania does not show "substantial departure from the normal", p. 116), it has first been investigated by means of Student *t*-tests whether significant differences existed between the Amsterdam crania with symmetrical endocranial closure stages (i.e. identical stages in symmetrical endocranial sections) and those with asymmetrical endocranial closure stages (Table 11). No significant differences in mean endocranial closure stage per age-group were found. Consequently Table 12 is based on both the symmetrically and asymmetrically ossified Amsterdam crania.

Table 11 **Mean endocranial closure stage per age-group in 87 Amsterdam crania with symmetrical and 169 Amsterdam crania with asymmetrical endocranial suture closure**

Age (years) ♂ + ♀	Mean endocranial closure stage					
	Symmetrical suture closure		*n*	Asymmetrical suture closure		*n*
20–29	1·13	s.d. 0·09	2	1·25	s.d. 0·50	3
30–39	3·50	—	1	1·97	0·59	8
40–49	3·32	0·62	10	3·15	0·60	16
50–59	3·51	0·38	12	3·28	0·74	36
60–69	3·52	0·76	23	3·24	0·67	44
70–79	3·67	0·17	29	3·38	0·43	45
80–89	3·39	0·35	10	3·29	0·53	15
90–99	—	—	—	2·75	0·35	2

Table 12 **Mean endocranial suture closure and age in 256 crania from Amsterdam A.D. 1883–1909**

Stages of endocranial suture closure	Age (years) 15–19	20–29	30–39	40–49	50–59	60–69	70–79	80–89	90–95	Total	Average age (years)	s.d	Total	Average age (years)	s.d
0·2(00)–0·3(99)	—	—	—	—	—	1	—	—	—	1	63·0	—	2	65·0	2·8
0·4 –0·5	—	—	—	—	—	1	—	—	—	1	67·0	—			
0·6 –0·7	—	—	—	—	—	—	—	—	—	—	—	—			
0·8 –0·9	—	1	—	—	1	—	—	—	—	2	44·0	21·2	8	38·8	15·6
1·0 –1·1	—	3	1	—	2	—	—	—	—	6	37·0	15·3			
1·2 –1·3	—	—	1	—	—	—	—	—	—	1	31·0	—			
1·4 –1·5	—	—	—	—	—	—	—	—	—	—	—	—	4	43·0	14·2
1·6 –1·7	—	—	1	1	—	1	—	—	—	3	47·0	14·4			
1·8 –1·9	—	1	1	—	—	—	1	—	—	3	46·0	25·0			
2·0 –2·1	—	—	2	1	—	2	1	—	—	6	54·5	15·0	11	55·5	18·7
2·2 –2·3	—	—	—	—	—	1	—	1	—	2	73·0	15·6			
2·4 –2·5	—	—	—	1	1	—	1	1	1	5	70·6	18·0			
2·6 –2·7	—	—	1	3	—	2	2	1	—	9	59·2	18·5	26	61·1	17·3
2·8 –2·9	—	—	1	4	1	3	—	3	—	12	58·6	16·1			
3·0 –3·1	—	—	—	3	8	6	7	5	1	30	66·7	13·5			
3·2 –3·3	—	—	—	1	7	9	10	1	—	28	66·4	9·4	102	66·1	11·8
3·4 –3·5	—	—	1	3	9	10	17	4	—	44	65·6	12·2			
3·6 –3·7	—	—	—	3	11	14	22	5	—	55	67·1	10·5			
3·8 –3·9	—	—	—	6	8	14	13	4	—	45	65·6	11·8	103	66·3	10·9
4·0	—	—	—	—	—	3	—	—	—	3	62·3	2·1			
Total	—	5	9	26	48	67	74	25	2	256	64·0	13·8			
Mean closure stage		1·2	2·1	3·2	3·3	3·3	3·5	3·3	2·8						
s.d.		0·36	0·75	0·60	0·68	0·71	0·38	0·46	0·35						

Table 13 **Mean endocranial suture closure and age in 285 crania from Hungary A.D. 1955/56 (based on Acsádi & Nemeskéri, 1970)**

Stages of endocranial suture closure	Age (years) 15–19	20–29	30–39	40–49	50–59	60–69	70–79	80–89	90–95	Total	Average age (years)	Total	Average age (years)	
0·2(00)–0·3(99)	—	—	—	—	—	—	—	—	—	—	—			
0·4 –0·5	1	1	—	—	—	—	—	—	—	2	22			
0·6 –0·7	1	1	—	—	1	—	—	—	—	3	32			
0·8 –0·9	1	—	—	—	1	—	—	—	—	2	35	16	28·6	s.d.13.1
1·0 –1·1	1	2	—	—	—	—	—	—	—	3	24			
1·2 –1·3	1	1	1	—	—	—	—	—	—	3	35			
1·4 –1·5	—	1	1	—	1	—	—	—	—	3	35			
1·6 –1·7	—	1	—	2	1	—	—	—	—	4	43			
1·8 –1·9	—	1	1	5	—	—	1	—	—	8	45			
2·0 –2·1	—	2	1	—	1	—	—	—	—	4	35	29	43·7	14·5
2·2 –2·3	—	3	1	—	1	1	—	—	—	6	40			
2·4 –2·5	—	1	1	—	3	1	1	—	—	7	51			
2·6 –2·7	—	—	4	—	2	—	1	1	—	8	49	17	49·1	16·4
2·8 –2·9	—	1	—	5	1	1	—	1	—	9	49			
3·0 –3·1	—	—	1	2	—	6	2	1	—	12	62			
3·2 –3·3	—	—	1	2	5	8	2	—	—	18	60			
3·4 –3·5	—	—	1	3	8	5	3	3	—	23	60	162	60·0	13·2
3·6 –3·7	—	1	3	4	6	9	4	1	—	28	57			
3·8 –3·9	—	1	4	10	17	26	18	5	—	81	61			
4·0	—	2	1	5	10	14	23	6	—	61	65	61	65·4	14·1
Total	5	19	21	38	58	71	55	18	—	285	57·2			
Mean closure stage	0·9	2·6	2·9	3·3	3·4	3·6	3·7	3·7	—					

In comparing Tables 12 and 13 it can first be noticed that the Hungarian sample is composed of younger individuals. The average age of the total sample is almost seven years lower (57·2 against 64·0) and the percentage of individuals younger than fifty is higher (83/285 = 29% against 40/256 = 16%) than in the Amsterdam sample. If the average ages belonging to the successive endocranial closure stages are compared it appears that with the Hungarian sample the ages increase with the stages in a more parallel way. This may be in agreement with the fact that the endocranial closure index is only positively correlated with age in the categories below fifty (Table 7). For this reason the better parallel can indeed be expected with the younger Hungarian sample.

Another difference between both samples is more difficult to explain, namely that in the Hungarian crania higher mean closure stages are found in every age-group. This may be related to the fact that the Hungarians died in 1955/56 while the Amsterdam inhabitants died between 1883 and 1909. The possibility of a secular trend caused by the rapidly changing way of life in the 20th century cannot be excluded (Bocquet-Appel & Masset, 1982). If so, the Amsterdam material is a better reference collection for the study of historic and prehistoric crania than the Hungarian sample.

6. Discussion

The fact that suture closure is found not to be (positively) correlated with age in individuals who died after fifty need not be a surprise. Many authors have pointed to discrepancies and some have consequently doubted the reliability of suture closure as an age indicator. However, none of these critics abandoned the starting-point that if any correlation with age at death existed it had to be a positive one. This is even more noteworthy because in several publications the phenomenon of extremely old individuals with many open sutures is discussed. There are, for example, the crania of four Dutchmen, aged over hundred years, but with open sutures, described by J. B. Davis (1867), a case recently referred to by Powers (1962). Also Bolk (1926) has noticed and discussed the same feature. The above results suggest that these aged individuals with open sutures were not merely rare exceptions. There must be some underlying mechanism. The cranium may become thinner, but sutures, once ossified, do not open again. The question forces itself whether selection does occur. Do individuals with open sutures have more chance to grow old? And if so, to what extent do similar selective mechanisms occur in relation to other age indicators? Is that why the ninety year olds are always missing from (pre)historic populations? There are too many questions to answer at this moment. Other reference collections should be studied first in order to determine whether the above findings do have a more general validity.

7. Conclusion

The present study indicates new possibilities for suture closure to contribute to one of the essential foundations of paleodemography: age estimation. The study illustrates that by more detailed studies (in this case the examination of different subsamples and of individual suture sections) some new life can be breathed even into a subject like suture closure. It is evident that, before several age indicators are combined into "complex methods" (Acsádi & Nemeskéri, 1970), as much information as possible about the separate age indicators has to be accumulated. This information can be obtained only by investigating skeletal material of known age. The few unique reference collections at our disposal still contain a lot of important data, which, once revealed, may lead to the formation of better "complex methods" in which not only morphological but also histological (Stout & Simmons, 1979) and biochemical (Lengyel, 1974/75) age indicators may participate. In this context the importance of collections of skeletal remains of known age and sex cannot be emphasized enough.

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