Legal Medicine 16 (2014) 385–389

Contents lists available at ScienceDirect

Legal Medicine

journal homepage: www.elsevier.com/locate/legalmed

Announcement of Population Data

Age estimation from the sternal end of the fourth rib: A study of the validity of İşcan's Method in Tunisian male population

Nidhal Haj Salem [a,*], Abir Aissaoui [a], Mohamed Amine Mesrati [a], Meriem Belhadj [a], Gerald Quatrehomme [b], Ali Chadly [a]

[a] Department of Forensic Medicine, Unity of Research Forensic Anthropology 04/UR/08-06, Faculty of Medicine, University of Monastir, 5000, Tunisia
[b] Department of Forensic Medicine, Laboratory of Forensic Anthropology, Faculty of Medicine Nice, France

ARTICLE INFO

Article history:
Received 4 July 2013
Received in revised form 16 June 2014
Accepted 20 June 2014
Available online 30 June 2014

Keywords:
Age estimation
Anthropology
Forensic medicine
Rib

ABSTRACT

The aim of this study was to assess the fourth rib phase İşcan method on a Tunisian sample.

One hundred and eight (108) specimens of sternal ends of fourth ribs of Tunisian male population were collected during forensic autopsies performed in the Department of Forensic Medicine and Pathology of the University Hospital Fattouma Bourguiba of Monastir. Two operators, independently, assigned each rib to İşcan's phase. The data obtained by the two operators were analyzed using SPSS 17.0 and MedCalc. The repeatability and accuracy of İşcan method was tested by kappa coefficient (κ), for each operator.

Spearman correlation coefficient (R), between estimated İşcan phase and İşcan phase relative to chronological age, was good with values of 0.758 (CI: 0.664–0.828) and 0.717 (CI: 0.611–0.798) for operator 1 and operator 2, respectively. The perfect agreement, between İşcan phase related to chronological age and İşcan phase estimated by both operators, was found for phases fewer than 5. Intra-observer agreement was highest for both operators with kappa value of 0.73 for operator 1 and 0.71 for operator 2. The estimation of the observers fell within one phase from the ideal and there was minimal disparity. A good accuracy between operator 1 and operator 2 was found ($\kappa = 0.747$, $p = 0.057$). In order to improve the results, we have pooled ages in five new phases. The correlation, between new age groups and İşcan phase estimated by both operators, was moderate. We conclude that İşcan method can be applicable in Tunisian population with a good correlation for age ranges under 39 years.

Introduction: Age estimation of unidentified human remains is an indispensable step of identification [1]. Various bones may be used for age assessment, mainly the chronology of dental eruption in children and the epipheseal closure in teenagers [2]. In late teenagers and adults, the macroscopic analysis of the pubis, acetabulum, auricular surface of the innominate, the medial clavicle, the degenerative progression of various bones, and the radicular transparency of the anterior teeth (Lamendin's method) are often used [2].

The morphology of the sternal end of the fourth rib has been considered as an accurate age assessor in skeletonized individuals of both sexes [3]. The use of rib sternal ends for age estimation is relatively easy to implement [3]. No special equipment, training or laboratory is needed. The fourth rib method was introduced in 1983 by İşcan et al. [4–6], and has proven to be a reliable indicator of age at death in the adult skeleton [4–6]. These authors found that the sternal end of the rib shows age related metamorphosis throughout life and described 9 phases based on a sample documented for age, sex and ancestry [7–9]. İşcan and colleagues reported significant differences in the aging process of the ribs in whites and blacks [9]. The method has been tried in various populations such as Turks [10] and South African Blacks [11]. Oettlé et al. [11], in South African Blacks, concluded that using the same phases as those given by İşcan et al. did not seem to release an accurate age estimation. New phases adapted to this population were then described.

Yavuz et al. [10] underlined that the rib phase method established by İşcan et al. can accurately estimate age in Turkish throughout the adult life span, because the metamorphoses in the rib sternal end occur at similar ages to those observed in the original research on American whites.

The Department of Forensic Medicine of Monastir (Tunisia) receives ten skeletonized human remains yearly, on average, for identification purpose and assessment of cause of death. Sex and age determination are always crucial and usually problematic

* Corresponding author. Tel.: +216 22407630.
E-mail address: nidhal.hajsalem@yahoo.fr (N. Haj Salem).

http://dx.doi.org/10.1016/j.legalmed.2014.06.007
1344-6223/

especially when an incomplete skeleton is available. In addition, Tunisian population has its own specificity and do differ from other populations by nutrition, environment and other life characteristics. Many studies [12,13] suggest that human variability, occupation, general health and diseases are expected to influence rib size and thickness, and probably the metamorphosis of the sternal rib end. These variations impose to check the applicability of İşcan method before its use on actual forensic identification cases in Tunisia, more especially as there is no scientific work studying the applicability of various anthropological methods on Tunisian or North Africa populations. Therefore the aim of this study was to assess the fourth rib phase İşcan method on a Tunisian sample.

Materials and methods: One hundred and eight (108) specimens of sternal ends of fourth ribs of Tunisian male population were collected from September 2006 to January 2010, during forensic autopsies performed in the Department of Forensic Medicine and Pathology of the University Hospital Fattouma Bourguiba of Monastir. Only specimens from individuals with known age, ancestry and sex were included. The age of the individuals varies between 18 and 83 years (mean age of 43 years) (Table 1). Agostino-Pearson test states that the specimen's distribution is normal regarding age ranges, with no significance difference (p: 0.070). None of the individuals composing the sample had obvious skeletal pathology. The specimens were allowed to decompose naturally for a minimum of one month, and then were boiled for about 10 min to remove all soft tissues and costo-sternal cartilage.

Two operators, independently, assigned each rib to İşcan's phase by comparing them with the photographic standard plates and associated descriptions in the original study [4]. Both operators had experience in using fourth rib (referring to İşcan's method) to estimate age. The data obtained by the two operators were analyzed using SPSS 17.0 and MedCalc. The repeatability and accuracy (intra-observer reproducibility calculated by re-examining ribs by each operator fifteen days after the first examination) of İşcan method was tested by kappa coefficient (κ), for each operator. In this study, any p-value less than 0.05 ($p < 0.05$), calculated by Wilcoxon signed rank tests, was considered statistically significant.

Results: Table 2 shows the sample distribution by İşcan phases. Middle age individuals are the most represented (Table 1). Table 2 shows that late İşcan phases (up to phase 5) are more represented.

Tables 3 and 4 show the number of cases correctly classified using İşcan phases. The perfect agreement, between Iscan phase related to chronological age and Iscan phase estimated, was mainly found for phases fewer than 5 by both operators. The estimated İşcan phase was found to underestimate the age for both operators (Tables 3 and 4).

In this study, İşcan phase correlated to chronological age was compared to that estimated by both operators. Spearman correlation coefficient (R), between estimated İşcan phase and İşcan phase relative to chronological age, was good with values of 0.758 (Confidence Interval (CI): 0.664–0.828) and 0.717 (CI: 0.611–0.798) for operator 1 and operator 2, respectively. There was a statistically significant difference observed between the estimated phase and the real phase for both operators ($p < 0.001$).

Intra-observer reproducibility was calculated by re-examining ribs by each operator fifteen days after the first examination. The difference between İşcan phase attributed on the first and the second readings was not significant (p value at 0.12 for operator 1 and 0.23 for operator 2). Intra-observer agreement calculated using kappa was good for both operators with kappa value of 0.73 for operator 1 and 0.71 for operator 2.

Table 5 shows the inter-observer variation for phase data. Approximately, the two operators attributed the same İşcan phase for the rib in 78.7%. The estimation of the observers fell within one

Table 1
Age distribution of specimen.

Age intervals (years)	Number (n = 108)	Percentage (%)
18–20	7	6.4
21–25	16	14.8
26–30	12	11.1
31–35	7	6.4
36–40	11	10.1
41–45	9	8.3
46–50	12	11.1
51–55	10	9.2
56–60	5	4.6
61–65	5	4.6
66–70	9	8.3
>70	5	4.6

Table 2
Specimen distribution referring to Işcan phases.

Işçan phase	Number (n = 108)	Percentage (%)
Phase 1	3	2.78
Phase 2	13	12.03
Phase 3	13	12.03
Phase 4	9	8.35
Phase 5	18	16.66
Phase 6	25	23.15
Phase 7	10	9.25
Phase 8	17	15.75

Table 3
Distribution of the correct phase estimated comparing to real phase for operator1. Black cells show the perfect agreement between estimated Işçan phase and real Işçan phase. The gray cells show a discrepancy within one phase.

OPERATOR 1

Real Işçan phase \ Estimated Işçan phase	1	2	3	4	5	6	7	8
1	**2**	1	0	0	0	0	0	0
2	1	**9**	2	1	0	0	0	0
3	0	5	**8**	1	0	0	0	0
4	0	1	3	**3**	1	0	0	0
5	0	0	9	5	**2**	0	2	0
6	0	0	1	6	6	**3**	8	1
7	0	0	0	3	2	3	**2**	1
8	0	0	1	1	5	2	6	**1**

Table 4
Distribution of the correct phase estimated comparing to real phase for operator2. Black cells show the perfect agreement between estimated Işçan phase and real Işçan phase. The gray cells show a discrepancy within one phase.

OPERATOR 2

Real Işçan phase \ Estimated Işçan phase	1	2	3	4	5	6	7	8
1	**2**	0	1	0	0	0	0	0
2	1	**9**	1	2	0	0	0	0
3	0	3	**10**	1	0	0	0	0
4	0	0	4	**3**	1	0	0	0
5	0	0	8	6	**2**	0	1	1
6	0	0	0	4	5	**6**	6	3
7	0	0	0	2	5	2	**2**	1
8	0	1	0	2	5	2	5	**1**

Table 5
Inter-observer agreement in estimated Isçan phase in the specimens between operator 1 and operator 2.

Estimated Isçan phase operator 2 \ Estimated Isçan phase operator 1	1	2	3	4	5	6	7	8
1	**3**	0	1	0	0	0	0	0
2	0	**11**	5	0	0	0	0	0
3	0	2	**19**	3	0	0	0	0
4	0	0	0	**16**	4	0	0	0
5	0	0	0	1	**13**	2	0	0
6	0	0	0	0	2	**6**	0	0
7	0	0	0	0	0	0	**14**	3
8	0	0	0	0	0	0	0	**3**

Table 6
Specimen distribution with new age intervals.

Number attributed to age interval	New age intervals (years)	Number	Percentage (%)
1	<30	32	29.63
2	30–39	18	16.67
3	40–49	22	20.37
4	50–59	16	14.81
5	>59	20	18.52
	TOTAL	108	100

Table 7
One way analysis of variance.

	Source of variation	Sum of squares	Mean square	*df*	*F*	*p*	R^2 (%)
Operator 1	Age interval	212.33	53.08	4	36.31	0.000	58.51
	Error	150.59	1.46	104			
Operator 2	Age interval	197.83	49.46	4	31.02	0.000	54.64
	Error	164.24	1.59	104			

phase from the ideal and there was minimal disparity. A good accuracy between operator 1 and operator 2 was found ($\kappa = 0.747$, $p = 0.057$).

In order to improve the results, we have pooled ages in five new phases (Table 6). The choice of these new phases and age intervals is justified by a normal distribution of the standard deviation of the analyzed variables in these groups. Variations within and between phases is measured with an analysis of variance statistics. *R* square (R^2) calculates how much of the variation in age can be explained by morphological characteristics that feature the phase. Table 7 shows the results of the ANOVA test with one controlled factor. We conclude that the correlation, between new age groups and İşcan phase estimated by both operators, was moderate. Figs. 1 and 2, show that correlation between estimated İşcan phase and new age intervals, exist for three intervals: under 30 (<30) years, between 30 and 39 (30–39) years and over 39 (>39) years.

Discussion: While there are a great deal of techniques developed to estimate age. İşcan [3] suggest that current methods are fairly successful but are limited to only a few parts of the skeleton. The best known of these include the time sequence of cranial sutural closure [14] and metamorphosis in the pubic symphysis [15,16]. Cranial suture closure has been repeatedly criticized [3]. In a study conducted by İşcan et al. [17] to compare between estimating age with the sternal end of the rib and pubic symphysis, the authors suggest that the rib exhibits much less variation than the pubic symphysis and, therefore, is a more consistently accurate indicator of age. As these authors suggested, the pelvis is directly involved in weight bearing, locomotion, pregnancy and parturition [17]. All of these factors don't influence ribs [17].

The sternal extremity of the rib is the only bone in the thorax from which there is a widely applicable, tested technique for accurate age assessment from adolescence to the end of the life span [3].

We have carried out a prospective study to assess the applicability of the sternal end of the rib for many reasons. First, the plastron area has been largely studied using radiological [18,19] and histological technique based on osteon counting [20,21]. But macroscopic examination of the sternal end of the rib proves to be of help to make a fast estimation of age [3]. Second, in order to be allowed to use an anthropologic technique, every method has to be checked on a known population [9]. Many investigators [9,12,13] who studied progression of costochondral calcification found some ancestry variations that they ascribed to geographic, environmental, physical activity, genetic and dietary differences among populations. İşcan et al. [9] discovered that the sternal extremity of the ribs differed significantly between populations, both in size and morphology. Consequently the achievement of this technique is limited to a population where the study was checked [9].

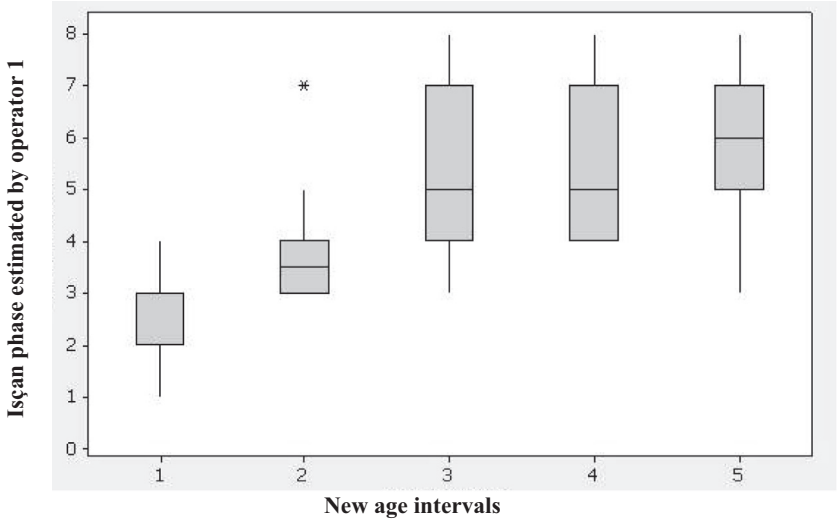

Fig. 1. Box plots representing the correlation between estimated İşcan phase and new age intervals for operator 1. * This case is not included in the confidence interval.

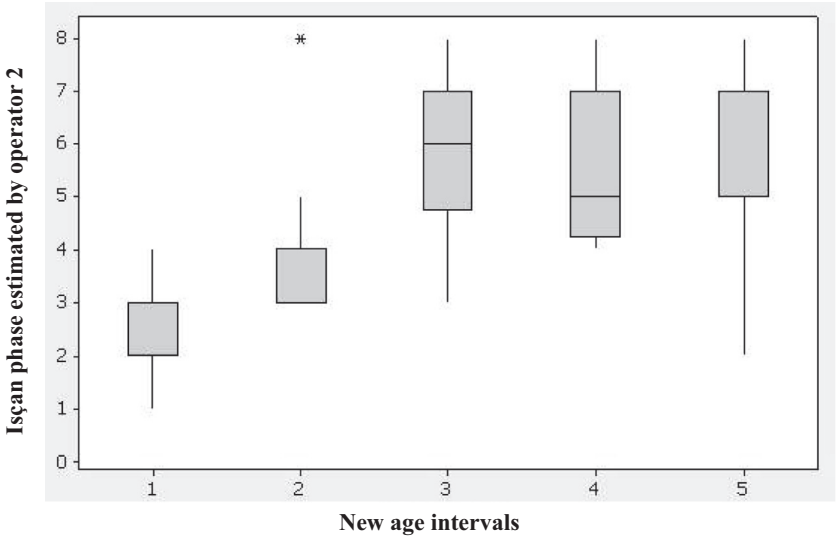

Fig. 2. Box plots representing the correlation between estimated İşcan phase and new age intervals for operator 2. * This case is not included in the confidence interval.

The current study presents the results of the İşcan fourth rib sternal end method in a male Tunisian sample. The studied population was composed of 108 fourth ribs. This sample is mostly concentrated under the age of 56 years. The American samples, however, had more than twice as many individuals over the age of 60 [7]. This would affect the mean ages and standard deviations for phases 6 to 8 in Tunisia.

Females were excluded in this study because of hormonal differences between male and female. These differences between male and female were stated by İşcan and Loth [22]. The authors conclude that the age-related patterns are significantly different between male and female [22].

Usually it is said that aging methods are relatively reliable and that accuracy increases with the investigator's experience and the combination of multiple age indicators used together [23]. In the current study, the inter-observer and intra-observer correlations were high. Many factors can reduce intra and inter observer variability such as the experience of the examiners and the calibration and training of phase assessment [24]. Hartnett [25] concluded that while the correlation for all three observers was somewhat strong and significant, it was not as robust as originally hoped, suggesting that the İşcan and Loth system does work but that it could be improved. Supporting this claim is Taylor's research demonstrated a poor agreement between estimated phase and actual phase in the ribs. In her study, only 49 of the 155 cases were assigned the real age phase [25]. Russel et al. [26] claimed that the changes in the morphology of the sternal end of the fourth rib could be used to predict age-at-death with minimal inaccuracy.

Some of these differences of appreciation could be explained by the fact that the İşcan and Loth phase descriptions leave considerable room for interpretation when it comes to bone weight and quality [26]. This study suggests that bone weight and quality play a significant role in phase assignment, and the revisions to the phase's system reflect this fact [26]. Many of the following features associated with older individuals involve the "feel" of the bone, which can only be ascertained by picking up the bone to assess relative "weight" and by palpating the surfaces of the bone to determine its texture [26]. Bone weight is a major deciding factor between age phases [3]. Often, a set of ribs will have a younger morphology than what the weight of the bone suggests, but the feature of bone weight alone can be used to move a set of specimens up or down a phase [3]. Loth [27] noted that, in the Spitalfields collection, there was an apparent contradiction between bone mass and morphology in the rib ends. She quoted her own notes as stating, "rib looks phase 8, but feels younger" [27]. In the current study, these findings are also found and can explain the discrepancies between observers.

Despite a good correlation between both operators, the accuracy of İşcan method was not good in Tunisian population, especially for age ranged over 56 years. This can be explained by the fact that for these age groups, changes in costal cartilage and rib maturation are less important and there are little differences between one age group to another.

Like most age-at-death assessment methods, the age of individuals over 60 years old is under-estimated [3]. The new classification of the current sample into five age ranges, demonstrate that correlation between estimated İşcan phase and new age ranges, exist for three intervals: under 30 years (<30), between 30 and 39 (30–39) years and over 39 (>39) years. İşcan and Fatih Yavuz [10] found that variability increased with age taking a sharp jump from phase 5 onward. İşcan et al. concluded that age at death can be estimated from a rib within about 2 years in the second decade to about 7 years in the 5th and 6th decades of life [3]. Singh et al. [28] revealed that age can be estimated from sternal end of fourth rib with an accuracy ranging between ±2 years up to third decade and about ±8 years in the older age. So far, in the field of Forensic Medicine, we remain handicapped to exactly pinpoint the accurate age from one single factor, as metamorphic changes in the sternal end of the fourth rib alone [24]. In agreement with Baccino et al. [24], we think that a single variable to age assessment raises a great deal of uncertainty. Therefore multivariable metric and morphology assessment, and a more comprehensive approach, should be the hallmark for a better assessment. In addition many anthropological studies recommended the use of the Lamendin method for older phases [29].

References

[1] Iscan MY. Global forensic anthropology in the 21st century. Forensic Sci Int 2001;117:1–6.
[2] Cunha E, Baccino E, Martrille L, et al. The problem of aging human remains and living individuals: a review. Forensic Sci Int 2009;193:1–13.
[3] Iscan MY. Age Markers in the Human Skeleton, Charles C. Thomas publisher, Springfield, Illinois. USA 1989.
[4] Iscan MY, Loth SR, Wright RK. Age estimation from the rib by phase analysis: white males. J Forensic Sci 1984;29:1094–104.
[5] Iscan MY, Loth SR, Wright RK. Age estimation from the rib by phase analysis: white females. J Forensic Sci 1985;30:853–63.

[6] Iscan MY, Loth SR, Wright RK. Metamorphosis at the sternal rib end: a new method to estimate age at death in white males. Am J Phys Anthropol 1984;65:147–56.
[7] Iscan MY, Loth SR. Determination of age from the sternal rib in white males: a test of the phase method. J Forensic Sci 1986;1(31):122–32.
[8] Iscan MY, Loth SR. Determination of age from the sternal rib in white females: a test of the phase method. J Forensic Sci 1986;31(3):990–9.
[9] Iscan MY, Loth SR, Wright RK. Racial variation in the sternal extremity of the rib and its effect on age determination. J Forensic Sci 1987;2:452–66.
[10] Yavuz MF, Iscan MY, Côloglu AS. Age assessment by rib phase analysis in Turkis. Forensic Sci Int 1998;98:47–54.
[11] Oettlé AC, Steyn M. Age estimation from sternal ends of ribs by phase analysis in South African Blacks. J Forensic Sci 2000;45(5):1071–9.
[12] Vastine JH, Vastine MF, Arango O. Genetit influence on osseous development with particular reference to the deposition of calcium in the costal cartilage. Am J Roentgenol Radium Ther 1948;59(2):213–21.
[13] Riebel F. Ossification of the costal cartilage: their relation to habitus and disease. Am J Roentgenol Radium Ther 1929;21:44–7.
[14] Meindl RS, Lovejoy CO. Ectocranial suture closure: a revised method for the determination of skeletal age at death based on the latero-anterior suture. Am. J. Phys. Anthropol 1985;68:57–66.
[15] Todd TW. Age changes in the pubic bone I: the male white pubis. Am. J. Phys. Anthropol. 1920;3:285–334.
[16] Brooks S, Suchey J. Skeletal age determination base on the os pubis: a comparison of the Acsadi-Nemeskeri and Suchey-Brooks methods. Hum. Evol. 1990;5:227–38.
[17] İşcan MY, Scheuerman EH, Loth SR. Assessment of age from the combine duse of the sternal end of the rib and pubic symphysis. Am Acad Forensic Sci Program 1989:116. 1989b (abstract).
[18] McCormick WF, Stewart JH. Age related changes in the human plastron a roentgenographic and morphologic study. J Forensic Sci 1988;33(1):100–20.
[19] Barrès D, Durigon M, Parraire F. Age estimation from quantitation of features of "chest plate" X-Rays. J Forensic Sci 1989;34(1):228–33.
[20] Dudar JC, Pfeiffer S, Saunders SR. Evaluation of morphological and histological adult skeletal age-at-death estimation techniques using ribs. J Forensic Sci 1993;38(3):677–85.
[21] Telmon N, Allery J-P, Blanc A, Gainza D, Rougé D. Comparaison de méthodes de détermination histologique et scopique de l'âge à partir de l'extrémité sternale de la 4ème côte. Antropo 2004;7:203–9.
[22] Iscan MY. Osteometric analysis of sexual dimorphism in the sternal end of the rib. J Forensic Sci 1985;30(4):1090–9.
[23] Kimmerle EH, Prince DA, Berg GE. Inter-observer variation in methodologies involving the pubic symphysis, sterna ribs and teeth. J Forensic Sci 2008;53(3):594–600.
[24] Baccino E, Ubelaker DH, Hayek L-AC, Zerilli A. Evaluation of seven methods of estimating age at death from mature human remains. J Forensic Sci 1999;44(5):931–6.
[25] Hartnett KM. Analysis of age-at-death estimation using data from a new, modern autopsy sample – part II: sternal end of the fourth rib. J Forensic Sci. 2010;55(5):1152–6.
[26] Russel KF, Simpson SW, Genovese J, Kinkel MD, Richard S, Lovejoy CO. Independent test of the fourth rib aging technique. Am J Phys Anthrop 1993;92:53–6.
[27] Loth SR. Age assessment of the Spitalfields cemetery population by rib phase analysis. Am J Human Biol 1995;7:465–71.
[28] Singh D, Parkash C, Tyagi S, Pandey AN. Determination of age from the metamorphosis at sternal end of right 4th rib in North West Indian males. J Indian Acad Forensic Med 1999;21:77–85.
[29] Martrille M, Ubelaker DH, Cattaneo C, Seguret F, Tremblay M, Baccino E. Comparaison of four skeletal methods for the estimation of age at death on white and black adults. J Forensic Sci 2007;52(2):302–7.