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Estimating age from the pubic symphysis: A new component-based system

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ABSTRACT

The os pubis is one of the most widely used areas of the skeleton for age estimation. Current pubic symphyseal aging methods for adults combine the morphology associated with the developmental changes that occur into the mid-30s with the degenerative changes that span the latter portion of the age spectrum. The most popular methods are phase-based; however, the definitions currently used to estimate age intervals may not be adequately defined and/or accurately understood by burgeoning researchers and seasoned practitioners alike. This study identifies patterns of growth and maturation in the pubic symphysis to derive more precise age estimates for individuals under 40 years of age. Emphasis is placed on young adults to provide more informative descriptions of epiphyseal changes associated with the final phases of skeletal maturation before degeneration commences. This study investigated macroscopic changes in forensically relevant modern U.S. samples of known age, sex, and ancestry from the Maricopa County Forensic Science Center in Phoenix, Arizona as well as donated individuals from the William M. Bass Forensic and Donated Collections at the University of Tennessee, Knoxville ($n = 237$). Age-related traits at locations with ontogenetic and biomechanical relevance were broken into components and scored. The components included the pubic tubercle, the superior apex of the face, the ventral and dorsal demifaces, and the ventral and dorsal symphyseal margins. Transition analysis was applied to elucidate the transition ages between the morphological states of each component. The categorical scores and transition analysis ages were subjected to multinomial logistic regression and decision tree analysis to derive accurate age interval estimates. Results of these analyses were used to construct a decision tree-style flow chart for practitioner use. High inter-rater agreement of the individual component traits (linear weighted kappa values $\geq$0.665 for all traits in the decision tree) indicates that the method offers unambiguous scoring for age-related changes of the pubic symphysis. Validation of the flow chart on a sample of 47 individuals provided by the Montana State Crime Lab yielded 94% accuracy overall, indicating that the method has the potential to deliver precise and accurate age estimates of individuals prior to the onset of advanced degenerative changes. A pubic symphysis that exhibits epiphyseal changes and/or billowing is suitable for this method; a pubic symphysis that exhibits degenerative changes (i.e. porosity and/or rim erosion) is not suitable.

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1. Introduction

Patterns of bone growth, development, and degeneration are used to estimate skeletal age in forensic and archeological contexts. In particular, the os pubis is used to obtain reliable age estimates for medicolegal practice and forensic identification. Current pubic symphyseal aging methods combine morphological characteristics associated with developmental changes during the period immediately following adolescence with degenerative changes spanning the latter portion of the age spectrum. Phase-based methods are utilized most often [1]; however, the definitions currently used to assign age intervals may not be adequately defined and/or accurately understood by nascent researchers and seasoned practitioners alike. Furthermore, phase-based systems assume that these complex changes occur in lock step, which may not reflect biological reality accurately.

This study identifies patterns of growth and maturation in the pubic symphysis to derive more precise age estimates for

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individuals ≤40 years of age. Emphasis is placed on young adults to provide more informative descriptions of epiphyseal changes associated with the final phases of skeletal maturation before degeneration commences. We hypothesize that teasing out epiphyseal changes from degenerative changes will provide more precise age interval estimates for the younger portion of the adult age spectrum. This approach allows for more precise estimates as opposed to lumping young individuals into unnecessarily broad age intervals associated with the latter portion of adulthood.

To this end, this study documents age-related changes in the pubic symphysis during the first two decades after sexual maturity to provide a categorical scoring method with more precise age estimates for young adults (≤40 years old). A brief overview of symphyseal face development is required to comprehend this approach. Scheuer and Black [2] explain that the os pubis is of particular interest for age estimation because of the range of morphological changes that occur throughout the adult life cycle. The prolonged period of macroscopic changes in the symphyseal face is due to developmental changes initially and then to degenerative changes that begin typically during the fourth decade of life. These changes have been identified by several phase-based methods (e.g. Todd [3,4], Katz and Suchey [5], Brooks and Suchey [6], Berg [7], Hartnett [8]) and are related to the biomechanical function of the pubic symphysis. The pubic symphyseal joint is analogous to the bony median bar in non-primate mammals [3]. The pubic symphyses in all mammal species except humans and some higher primates fuse in the middle via a median bar of bone that is later continuous with the ischial epiphysis [2]. In humans, the symphyseal joint does not fuse as part of the normal developmental process and, as such, the pubic symphysis has been described as a potential site of biomechanical weakness [3]. However, the unique configuration of the joint in humans provides adequate rigidity to accommodate weight-related stresses associated with locomotion while maintaining relative elasticity for birthing large-headed offspring [2].

During adolescence, the symphyseal joint is a continuous ischiopubic cap of cartilage extending from the pubic tubercle to the iliac crest and from the ventral aspect of the face to the ischial tuberosity. Ischiopubic cartilage ossification begins in the region of the ischium and progresses to the pubic region. Dividing the symphyseal face into separate regions (i.e. dorsal versus ventral demifaces) reflects anatomical differences between these areas in that fibrocartilage covers only the ventral portion of the face. McKern and Stewart [9] noted that morphological changes in the ventral demiface are epiphyseal in nature, whereas changes in the dorsal demiface are more closely related to the neighboring diaphysis. During juvenile development (subsequent to fusion of the three bony portions comprising the adult os coxa) the pubic symphyseal complex lacks the epiphysis that will form the pubic tubercle in the adult and lacks the ventral rampart, which is the epiphyseal bone that will form the ventral rim of the symphyseal face.

Billows are the quintessential feature of young and adolescent bone. The gradual obliteration of these billows in the pubic symphysis generally begins in the dorsal region and proceeds from the inferior to the superior portion of the face, gradually giving way to a flat, non-crenulated surface. Development of the superior face is complicated by the formation of the superior ossific nodule, which is recognizable as a secondary ossification center. This epiphysis appears and subsequently fuses between 23 and 25 years of age [2]. The ossific nodule assists in forming the rim of the upper apex of the face and separating the pubic tubercle from the symphyseal face. As it develops, the ossific nodule gradually extends inferiorly along the ventral margin of the face to form the upper aspect of the ventral rampart (between 23 and 27 years of age). Maturation of the pubic symphysis can persist until 40 years of age, after which macroscopic changes become dramatically more degenerative in nature [2].

Component scoring allows for morphologies associated with these developmental events to be weighted individually as opposed to forcing the complex variation expressed among skeletal samples into single phases. One critique of phased-based methods is that a pubic symphysis often exhibits morphological characteristics that are intermediate between two phases, making the decision to place the individual into one phase or the other arbitrarily based on subjective weighting of traits. In addition, the wide age ranges associated with some phase-based methods (e.g. sometimes in excess of 30 years) are not useful for narrowing missing persons possibilities in forensic cases (Table 1). This study aims to provide a user-friendly component method that produces more precise and forensically useful age estimates of individuals prior to the onset of advanced degenerative changes. A pubic symphysis that exhibits epiphyseal changes and/or billowing is suitable for this method; a pubic symphysis that exhibits degenerative changes (i.e. porosity and/or rim erosion) is not suitable.

2. Materials and methods

The study sample was derived from four modern US skeletal samples of known age, sex, and ancestry: the Maricopa County Forensic Science Center pubic symphyses (n = 131), the C.A. Pound Human Identification Laboratory at the University of Florida (n = 23), the William M. Bass Forensic and Donated Collections at the University of Tennessee, Knoxville (n = 77), and the Montana State Crime Lab (n = 47). As disparities have been noted in Hispanic population samples with pubic symphyseal aging [10], the present sample is comprised of American Black and White individuals only. The total sample size is 284 pubic symphyses (n = 148 males, 83 females) between the ages of 18 and 40 years (mean age of males = 29.3 years, mode = 27, median = 29, standard deviation = 6.6; mean age of females = 31.1 years, mode = 38, median = 31, standard deviation = 6.6). The right side was used for analyses unless it was unavailable, in which case the left side was substituted. Males and females were scored and analyzed separately; 237 pubic symphyses were used as a training sample, and 47 were used as a validation sample. Inter-observer error was assessed on 51 pubic symphyses using a linear weighted kappa statistic.

Age-related traits with ontogenetic and biomechanical relevance were broken into six components: pubic tubercle, superior apex of the face, ventral and dorsal demiface topography, and ventral and dorsal symphyseal margins. Component categories were based on observed bony changes. Scores for each category ranged from presence/absence to a three-step ordinal option, allowing for simple and unambiguous scoring. The components and scoring are described in Table 2, and exemplars are provided in Figs. 1–5. The authors retained many features of established scoring systems because these features were found to be anatomically relevant and familiar to practitioners (e.g. those outlined by Todd [2], Katz and Suchey [5], McKern and Stewart [9]).

In many instances, the state of expression of a trait is integrally related to that of another trait. For example, the separation of the

Table 1
Comparison of the age ranges provided by two phase-based methods.

Method	Suchey-Brooks (1990)		Hartnett (2010)	
Sex	Male	Female	Male	Female
Phase I	15–23	15–24	18–22	18–22
Phase II	19–34	19–40	20–26	20–25
Phase III	21–46	21–53	21–44	24–44
Phase IV	23–57	26–70	27–61	33–58
Phase V	27–66	25–83	37–72	44–60

Table 2
Component descriptions.

Pubic tubercle
1 = billows extending to/encompassing pubic tubercle
2 = tubercle is a separate bony knob; billows do not extend to encompass the pubic tubercle
Superior apex
1 = the ossific nodule has not yet formed and is scored as absent; the surface is billowed
2 = the ossific nodule is present and resembles an epiphysis
3 = the ossific nodule has become integrated into the symphyseal rim; the surface is flat
Billowing
1 = billowing is present and well-defined over both demifaces
2 = billowing does not encompass the entire symphyseal demiface and/or billowing is not as well-defined; residual billowing may be present; or face is flat
Dorsal plateau margin
1 = there is no bony build up forming the dorsal margin; billows extend to the edge of the face along the entire length of the dorsal rim
2 = a bony margin is forming (i.e. billows have flattened along at least one portion of the rim to form a partial margin)
3 = complete margin is formed
Ventral rampart margin
1 = there is no bony build-up to form the rampart; billows extend to the edge of the face for the entire length of the ventral rim
2 = a bony rampart is forming (bony nodules are present and appear epiphyseal in nature)
3 = complete margin is formed
NOTE: a persistent hiatus should be scored as complete.

pubic tubercle from the symphyseal face is accomplished when the ossific nodule forms at the superior apex. Formation of the ventral margin is achieved when the ossific nodule begins to flatten and extend distally (assuming a "comma-like" appearance) and unites with the epiphyseal bone on the ventral margin. Likewise, the formation of the dorsal margin is accomplished with the flattening of the dorsal billows. For this reason, it was necessary to employ statistical methods that select for the most meaningful variables and eliminate superfluous information. Due to the categorical nature of the data, two methods were chosen for comparison: multinomial logistic regression and classification trees.

These methods require data screening to detect the underlying structure of the data. Transition analysis was used to elucidate the transition ages between the morphological states of each component. LaGrange multiplier specification tests were performed in R [11] to test assumptions of a restricted cumulative probit (i.e. parallel lines). Since some indicators failed this assumption and were not log normal, an unrestricted cumulative probit model was used for the transition analyses [12]. The unrestricted cumulative probit fits the slopes of each distribution separately (i.e. it assigns separate standard deviations for the transition distributions). Transition analyses were performed with the VGAM package in R. Transition ages were then used to refine the scoring system and to inform the logistic regression and classification trees.

The data was screened for outliers and tested for normality. Although the data is not representative of a normal distribution, logistic regression and classification trees do not require the assumptions of general linear models. A Pearson's correlation

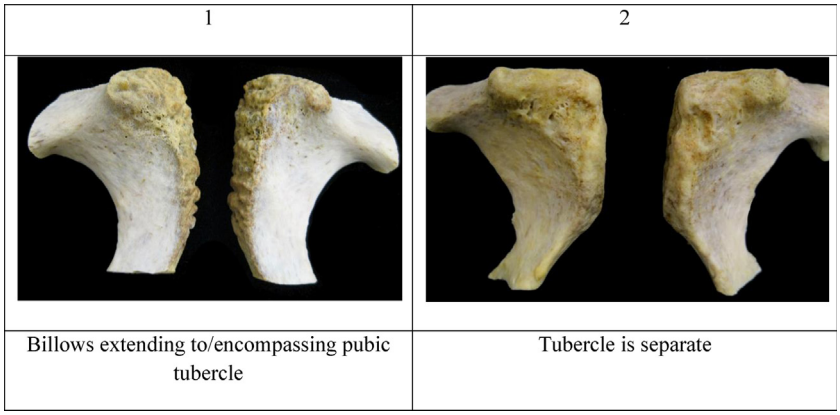

Fig. 1. Comparison of categories 1 and 2 for pubic tubercle.

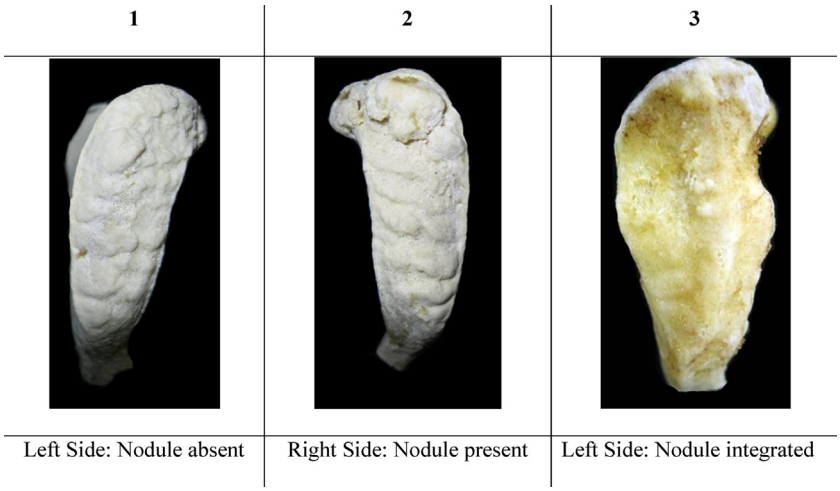

Fig. 2. Comparison of categories 1, 2 and 3 for the ossific nodule.

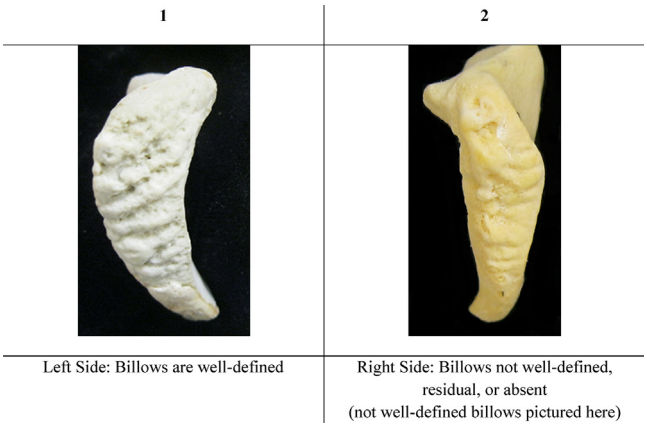

Fig. 3. Comparison of categories 1 and 2 for defined and residual/absent billows.

matrix was constructed as an initial step for variable selection and to identify correlated variables. As all variables are correlated with age, age was controlled by computing partial correlation coefficients.

Regression formulae were calculated using multinomial logistic regression and classification (decision) trees were constructed in NCSS [13] and SPSS Data Modeler 14.1 [14]. Multinomial logistic regression was utilized to predict age interval membership using the categorical scores of each symphyseal component. This preliminary analysis informed how accurately the age intervals provided by the transition analysis could be estimated. Age groups were compared in two steps. First, multinomial logistic regression was carried out with age groups as the dependent variable and the component scores as the independent variables. Alpha was set at 0.10, and the χ^2 of the likelihood estimates indicated that the model was significant ($p = 0.0007$).

Decision trees were employed to further examine the validity of the classifications provided by the logistic regression. Decision trees are useful for classifying observations in datasets with two or more predictor variables because estimates are reported in tree form in lieu of multi-variable regression equations. In addition, these methods do not require normal distribution of the variables. Decision trees can be constructed with algorithms that split and stop branches based on statistical significance, allowing for the researcher to refine the trees using a priori knowledge of the data [15]. The final output is a simple diagram that presents the decisions made by the algorithm and/or researcher. The CHAID (Chi-Squared Automatic Interaction Detection) method handles categorical data and thus was implemented in this study. Due to the relatively small sample sizes, stopping rules were set to $n = 2$ for parent nodes and $n = 1$ for child nodes, and significance was set at $\alpha = 0.10$. Performance of the CHAID approach is reported as risk calculation, which translates to misclassification matrices.

Table 3
Inter-rater agreement for each component.

Component	Kappa	95% Lower CI	95% Upper CI	SE
Pubic tubercle	0.865	0.683	1.000	0.093
Superior apex	0.944	0.866	1.000	0.040
Ventral billowing	0.546	0.102	0.990	0.227
Dorsal billowing	0.897	0.758	1.000	0.071
Ventral rampart	0.665	0.497	0.832	0.086
Dorsal plateau	0.856	0.744	0.968	0.057

CI = confidence interval; SE = standard error; Kappa = linear weighted kappa for variables with >2 component states and unweighted kappa for variables with ≤2 component states.

3. Results

Inter-rater agreement was highest for superior apex, dorsal billowing, pubic tubercle, dorsal plateau, ventral demiface, and ventral rampart, respectively (Table 3). The component with the lowest inter-rater agreement is ventral billowing (kappa = 0.546), which is addressed in method development.

The transition ages for the categorical states agree with the documented literature [4] (Table 4). There were significant sex differences ($\alpha = .05$) in transition ages for all categorical traits, with males transitioning from one state to the next roughly 1–4 years earlier than females. Interestingly, this is contrary to the norm with regard to developmental traits, where females are usually precocious. The transition analysis results were used to construct three age categories (1, 2, and 3) with intervals of 6–7 years each (Table 5). The sex differences were not large enough to warrant different age categories, as the variation was subsumed into the categories provided; however, males and females were analyzed

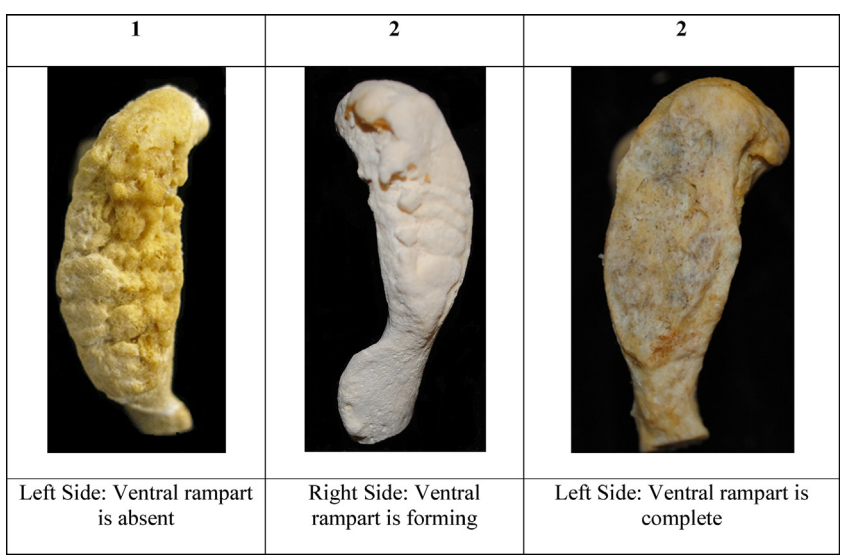

Fig. 4. Comparison of categories 1, 2 and 3 for ventral rampart formation.

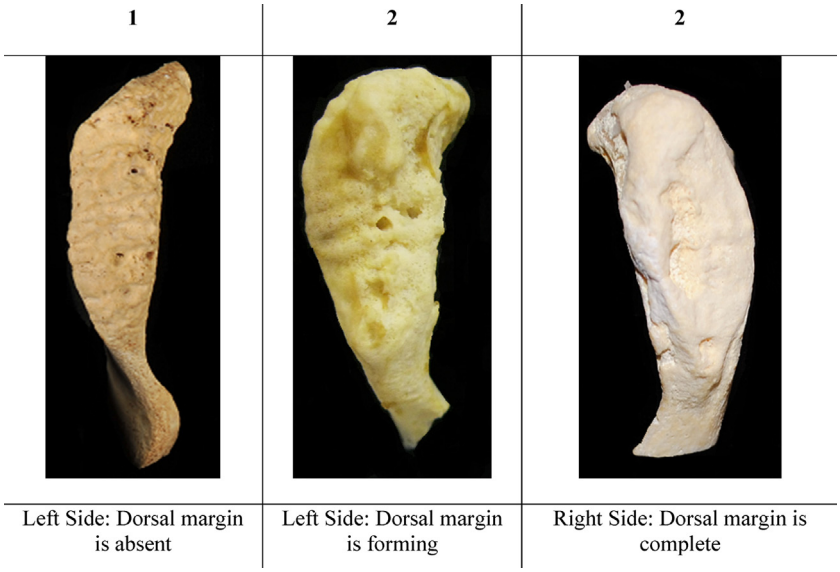

Fig. 5. Comparison of categories 1, 2 and 3 for dorsal plateau formation.

separately for method development. The first step in this process was to assign each individual to one of the age categories in Table 5.

Initially, the three age categories were analyzed simultaneously, but achieving correct classification for individuals in the 25–32 years age interval (category 2) was extremely difficult. Higher classification accuracy was achieved when categories 1 and 2 were analyzed separately from the combination of categories 2 and 3. This additional step provided higher percentages of correct classifications between categories 1 and 2 both for the multinomial logistic regression and CHAID decision trees. Ventral and dorsal billowing are strongly correlated ($r = 0.868$), indicating that the use of one demiface to score the amount of billowing is appropriate (Table 6). Since dorsal demiface billowing flattens more rapidly and at a more predictable rate than ventral billowing, this portion of the face was employed. Ventral billowing is also highly correlated with the development of the ossific nodule ($r = 0.808$), which further supports the removal of this variable from the decision tree. Furthermore, ventral billowing is the component with the lowest inter-rater agreement (kappa = 0.546), so removing this component effectively reduces potential observer error associated with the method.

3.1. Multinomial logistic regression results

Classification accuracy was high between age categories 1 and 2, with an overall classification of roughly 91% and 88% for males and females, respectively (Tables 7 and 8). Likewise, correct classification of group 1 versus group 3 was extremely high at 97% for males and 91% for females. However, when age categories 2 and 3 were compared, the highest percentage of correctly classified individuals that could be achieved for age group 2 was roughly 72% for males and 69% for females. These results suggest that considerable morphological variation and overlap in samples aged 25–40 years makes accurate discrimination among these age groups impossible without employing overlapping age categories. The classification matrix indicates that for males, age category 2 was most often misclassified as age category 3, yet category 3 rarely was misclassified as group 2 (Table 7). The misclassifications in groups 2 and 3 for the female

Table 4
Maximum likelihood estimates (in years) from unrestricted cumulative probit transition analysis.

	Pubic tubercle	Superior apex	Ventral billowing	Dorsal billowing	Dorsal plateau	Ventral rampart
Females						
Transition 1	21.6	24.2	24.3	23.4	23.4	25.5
SD	5.0	2.0	2.3	3.3	2.6	2.1
Transition 2	–	24.9	–	–	29.8	32.6
SD	–	2.3	–	–	6.1	4.7
Males						
Transition 1	20.6	20.6	21.1	20.8	20.9	21.8
SD	1.6	3.3	1.7	1.9	2.3	2.7
Transition 2	–	23.6	–	–	26.2	27.2
SD	–	4.8	–	–	4.9	3.7
t-statistic (male MLE vs. female MLE)						
Transition 1	3.47	15.73	14.72	10.63	10.55	15.85
Transition 2	–	4.90	–	–	10.13	17.28
Two-tailed t-test p-values (male MLE vs. female MLE)						
Transition 1	<0.001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Transition 2	–	<0.0001	–	–	<0.0001	<0.0001

Transition 1 = most probable age of transition from a score of 1 to 2; transition 2 = transition age from a score of 2 to 3; SD = standard deviation; MLE = maximum likelihood estimate.

Table 5
Age categories and corresponding ranges derived from transition analysis results.

Age category	Age interval
1	18–24
2	25–32
3	33–40

Table 6
Partial correlation matrix for component variables.

Right side	Pubic tubercle	Superior apex	Ventral billowing	Dorsal billowing	Dorsal plateau
Pubic tubercle	1	0.698	0.740	0.737	0.578
Superior apex	0.698	1	0.808	0.838	0.773
Ventral billowing	0.740	0.808	1	0.868	0.755
Dorsal billowing	0.737	0.838	0.868	1	0.786
Dorsal plateau	0.578	0.773	0.755	0.786	1
Ventral rampart	0.573	0.752	0.680	0.748	0.839

Table 8
Classification matrix for females using multinomial logistic regression approach.

From group	To group			% Correct
	1	2	Total	
1	19	0	19	100.0
2	6	26	32	81.2
Total	25	26	51	88.2
From group	To group			% Correct
	2	3	Total	
2	18	10	28	64.3
3	8	22	30	73.3
Total	26	32	58	68.9
From group	To group			% Correct
	1	3	Total	
1	21	4	25	84.0
3	4	31	35	88.6
Total	25	32	57	91.2

Group 1 = 18–24 years; group 2 = 25–32 years; group 3 = 33–40 years.

sample are more evenly distributed, and the overall classification of females is higher than males (Table 8).

3.2. Decision tree results

Results of the CHAID decision tree approach generally supported the prediction patterns identified with multinomial logistic regression. Classification accuracy using categories 1 and 2 was nearly 77% for males and 82.4% for females (Tables 9 and 10). High correct classification percentages were also achieved between age categories 1 and 3, as was found with the logistic regression approach. Overall classification between categories 1 and 3 was 96% for males and 91.2% for females. Discrimination between age categories 2 and 3 improved slightly for females with decision trees versus logistic regression: the lowest percent correctly classified for age category 2 (25–32 years) was nearly 71.0%, compared to 69% with logistic regression. However, classification of this age group stayed relatively the same for males when comparing groups 2 and 3, and was just over 71%. In general, as was found with the logistic regression approach, individuals belonging to age category 3 were misclassified as belonging to age category 2 in both the male and female samples. The most likely reason for the discrepancy is the use of discrete, non-overlapping age categories. Therefore, this issue was addressed in developing the flow chart for the method (see next subsection).

3.3. Implemented flow chart for practitioners

The multinomial logistic regression and decision tree results were used to design a flow chart for estimating skeletal age-at-death without the use of software or complex equations. If a pubic symphysis exhibits billowing and/or epiphyseal changes at the ventral rampart, superior apex, or pubic tubercle, then the flow chart in Fig. 6 may be used to obtain an age estimate. A pubic symphysis that exhibits degenerative changes (i.e. porosity and/or rim erosion) is not suitable. The flow chart guides the practitioner through the scoring process and returns an age category and corresponding age interval estimate. As dictated by the low classification accuracies between categories 2 and 3 for both methods, overlapping age categories are imperative to capture the range of morphological variation and achieve an accuracy rate that is effective for forensic purposes. The revised age categories are provided in Table 11. Figs. 7 and 8 provide the correct classification percentages for the male and female samples at each level of the flow chart.

Table 7
Classification matrix for males using multinomial logistic regression approach.

From group	To group			% Correct
	1	2	Total	
1	36	4	40	90.0
2	4	44	48	91.7
Total	40	48	88	90.9
From group	To group			% Correct
	2	3	Total	
2	21	4	25	84.0
3	27	57	84	67.9
Total	48	61	109	71.5
From group	To group			% Correct
	1	3	Total	
1	39	2	41	95.1
3	1	59	60	98.3
Total	40	61	101	97.0

Group 1 = 18–24 years; group 2 = 25–32 years; group 3 = 33–40 years.

Table 9
Classification matrix for males using decision tree approach.

From group	To group			% Correct
	1	2	Total	
1	29	1	30	96.7
2	11	47	58	81.0
Total	40	48	99	76.8
From group	To group			% Correct
	2	3	Total	
2	21	4	25	84.0
3	27	57	84	67.9
Total	48	61	109	71.5
From group	To group			% Correct
	1	3	Total	
1	39	3	42	92.9
3	1	58	59	98.3
Total	40	61	101	96.0

Group 1 = 18–24 years; group 2 = 25–32 years; group 3 = 33–40 years.

Table 10
Classification matrix for females using decision tree approach.

From group	To group			% Correct
	1	2	Total	
1	20	4	24	83.3
2	5	22	27	81.5
Total	25	26	51	82.4
From group	To group			% Correct
	2	3	Total	
2	19	10	29	65.5
3	7	22	29	75.9
Total	26	32	58	70.7
From group	To group			% Correct
	1	3	Total	
1	21	1	22	95.5
3	4	31	35	88.6
Total	25	32	57	91.2

Group 1 = 18–24 years; group 2 = 25–32 years; group 3 = 33–40 years.

Table 11
Overlapping age categories for flow chart in Fig. 6.

Age category	Age interval
1	18–26
2	22–32
3	29–40

Table 12
Correct classification percentages reported for the validation sample.

Age category	Age interval	*n*	Percent correct (%)
1	18–26	18	94.4
2	22–32	12	83.3
3	29–40	17	100.0
Total	–	47	94.0

4. Validation results

A sample of 47 individuals provided by the Montana State Crime Lab was used to assess the accuracy of the flow chart in Fig. 6. This holdout sample yielded 94% accuracy overall, with high correct classifications (80–100%) for each of the three overlapping age categories (Table 12). The high accuracy rates indicate that the model is performing well; however, larger validation samples and the implementation of the method by researchers and practitioners are recommended to further validate the method.

5. Discussion

This study has provided a component scoring system for the pubic symphysis with more precise and accurate age estimates for individuals at the younger end of the age spectrum (≤40 years) than is possible with current methods. Morphological features described in frequently used phase-based methods were used to develop a component system with simple and straightforward categories. First, transition analysis was employed to elucidate the age structure of the individual components. Next, a Pearson's correlation matrix was used for variable selection and to identify correlated variables. Finally, multinomial logistic regression and CHAID decision trees were evaluated separately for their effectiveness in constructing more precise age estimates of individuals aged 40 and under. Results of the logistic regression and the decision trees were comparable and provided favorable classification rates. The combined results of the two approaches provided the a priori knowledge necessary to construct a flow chart (Fig. 6) that is easily implemented using the component definitions (Table 2) and exemplar images (Figs. 1–5). The target age categories overlap slightly by 3–4 years, facilitating more accurate age estimates than discreet age ranges. Validation of the flow chart

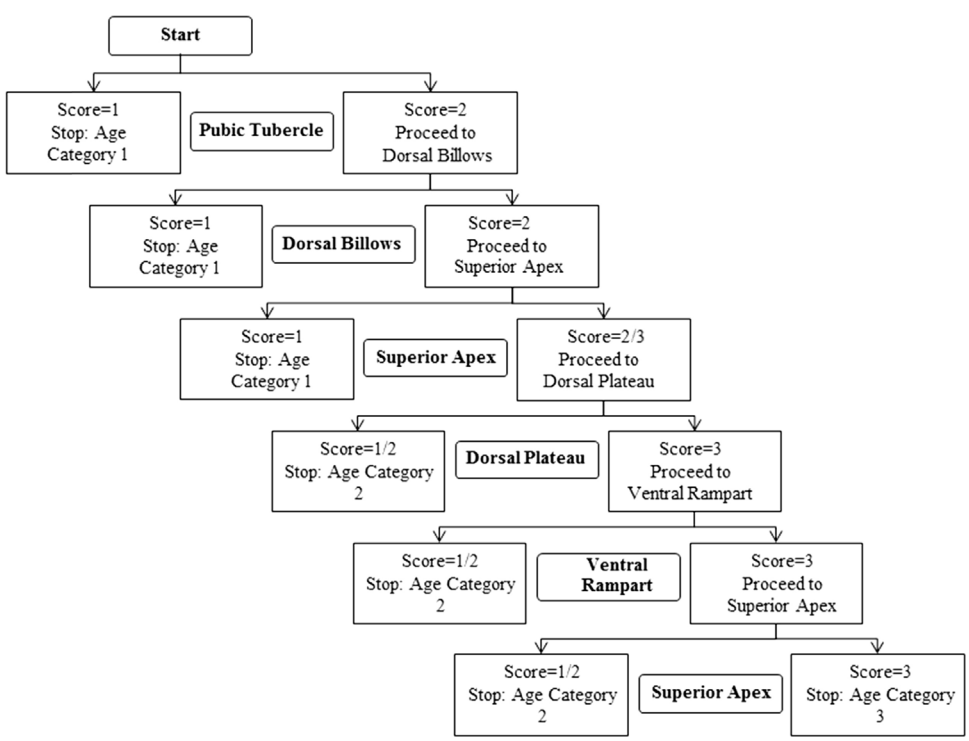

Fig. 6. Flow chart to be implemented by the practitioner.

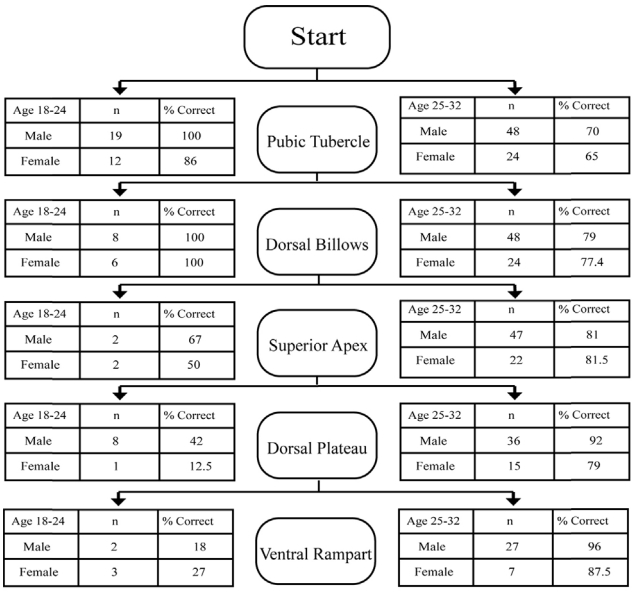

Fig. 7. Classification percentages for decision trees for age categories 1 and 2.

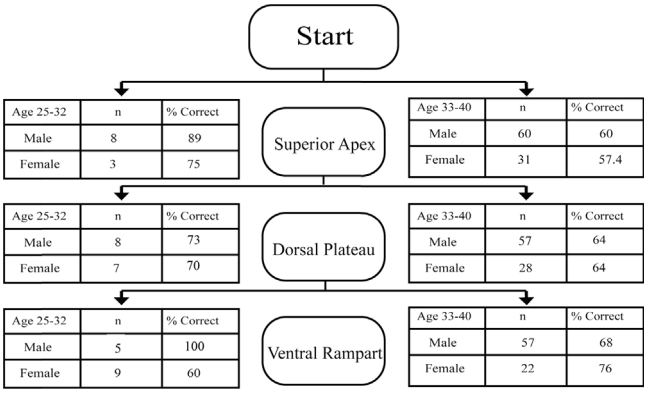

Fig. 8. Classification percentages for decision trees for age categories 2 and 3.

demonstrated high percentages of correct classification for all age categories (83–100%).

While an understanding of the morphological variation expressed in the pubic symphysis is highly recommended, practitioners are encouraged to reference the descriptions and images provided to implement the method correctly. The authors hypothesize that adding more data to the training and validation samples will improve the classification matrices and provide a true assessment of method performance. Furthermore, this method was created using modern American White and Black samples and should be validated on populations of varying ethnicities and life styles prior to wide-span implementation. Future research will focus on developing a component system based on degenerative changes in the pubic symphysis of older adults (>40 years) that can be integrated with the presently proposed method to encompass the entire lifespan.

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