A study on *Minutiae* of Fingerprint from Northeastern Thai Populations

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ABSTRACT

Minutiae, one of the small distinguishing features in fingerprint, has been previously studied in several populations outside Thailand but such study was limited in Thai populations. The present study investigated *minutiae* pattern on 2,195 fingerprints from ten northeastern Thai ethnicities, that is, Khmer, Suay, Mon, So, Chaobon, Phu Thai, Kaleung, Nyaw, Saek and Thai-Isan. The results showed that endingridge, bifurcation and short ridge are the most common types while bridge and miscellaneous are the two lowest frequencies. Variation in *minutiae* pattern was observed among populations. Pairwise population differences calculated by the Chi-square test were detected in exception with two population pairs, that is, Mon-Suay and Seak-Nyaw. Principle component analysis and Dendrogram exhibited three groups of population studied which was not consistent with both linguistic classification and geographic proximity. Current result does not concordant to previous studies using DNA and fingerprint patterns, possibly resulted from a small sample size of some ethnic groups and low frequencies of some *minutiae* types.

Keywords: *Minutiae*, Fingerprint, Population relationship

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Introduction

Dermatoglyphic is the pattern comprising of ridge and furrow of skin on the fingers, palms and soles of primate. The fingerprint, one of the dermatoglyphic patterns, refers to the epidermal ridges formed on the fingertips of a foetus between 11 and 25 weeks of gestation and remains stable throughout lifetime (Penrose and Ohara, 1973; Babler, 1991). The regulation of fingerprint formation was governed by polygenes and environment during embryonic development (Loesch, 1983). Apart from personal identification, the fingerprint variability has been reported to apply in studying of evolution and genetic structure among populations (Gutiérrez-Redomero *et al*., 2012).

Minutiae refer to the characteristics on the finger ridges which are unique to each individual (FBI, 1990). The variation of *minutiae* has been observed in both individual and population levels. The standard method used to identify types of *minutiae* was proposed by Federal Bureau of Investigation (FBI, 1990). There are 5main types of *minutiae* based on FBI classification: endingridge, bifurcation, island (enclosure), short ridge and dot as shown in Figure 1. The miscellaneoustype of *minutiae* i.e. bridge, trifurcation, return and opposited bifurcation had been identified by Gutiérrez-Redomero *et al.* (2011).

Northeastern Thailand or Isan is the geographically, linguistically, and ethnically diversified area. Two geographic distinctions were defined as two wide basins: the Khorat Basin in the southwest and the Sakon Nakhon Basin in the northeast which separated by the Phu Phan Mountain Range. Among approximately eighteen ethnolinguistic groups in northeastern Thailand, the majority approximately 20 million is the Thai-Isan people whose regional identity is completely associated with the Lao language, classified to the Tai-Kadai linguistic family (Premsrirat, 1999; McCargo & Hongladarom, 2004). The other ethnolinguistic groups are the other Tai-Kadaispeaking groups, for example, Phu Thai, Saek, Nyaw, and Kaleung as well as the native Austroasiatic speaking groups, e.g. Khmer, Suay, Mon, Chaobon and So.

Due to the ethnolinguistic diversification in the Northeast of Thailand, this region is of great interest to several scholars studying linguistics (Smalley, 1988; Smalley, 1994), culture, history (Wyatt, 1984; Khanittanan, 2001), archaeology (Welch, 1998; Talbot & Janthed, 2002), genetics (Fuchareon *et al*., 2001; Lertrit *et al*., 2008; Kutanan *et al*., 2014a-b), and dermatoglyphics (Khambhu *et al*., 2014). Our recent literatures by Kutanan *et al* (2014b) and Khambhu (2014) indicated close population relationship among the Tai-Kadai speaking groups while the Austroasiatic speaking populations were genetically diverging. In addition, correlation between genetic and geographic distances was also observed, reflecting that geography is being considered as the primary influential factor to determine population relatedness in Northeastern Thai populations (Kutanan *et al*., 2014b).

So far, several empirical studies have been reported dermatoglyphic studies of various populations in order to characterize populations and investigate an origin of human variability (Lui *et al*., 2004; Li *et al*., 2006; Zhang *et al*., 2010; Gutiérrez-Redomero *et al*., 2012). Such studies were limited in Thai populations, therefore, this study intends to 1) explore *minutiae* variability in ten linguistically and geographically diverse ethnolinguistic groups from Northeastern Thailand, that is, Khmer, Suay, Mon, So, Chaobon, Phu Thai Kaleung, Nyaw, Saek and Thai-Isan 2) evaluate population relatedness among the studied populations using *minutiae* variability as biological marker.

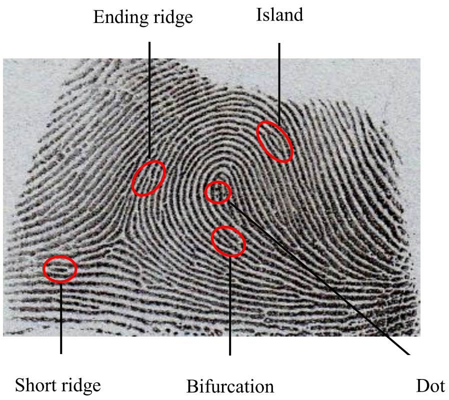

Figure 1 Main types of the *minutiae*.

Materials and methods

Three hundred subjects from ten ethnicities were examined: Khmer, Suay, Mon, So, Chaobon, Phu Thai, Kaleung, Nyaw, Saek and Thai-Isan. Population details were shown in Table 1 and Figure 2. Linguistically, the studied populations were categorized into two different groups, the Austroasiatic (Khmer, Suay, Mon, So, Chaobon) and Tai-Kadaispeaking groups (Phu Thai, Kaleung, Nyaw, Saek and Thai-Isan). Informed consent was obtained after interviewing on linguistic, culture and individual history from each subject in order to ensure that individuals were unrelated at least three generations and had a non-mixed ethnicity. The Khon Kaen University Ethics Committee for Human Research had approved the present study's protocol.

Ten fingerprints of each individual were collected from three hundred subjects of those 10 ethnic groups using the rolled ink print technique. Briefly, printing ink was smeared on fingertips of each subject's finger, and then pressed down gently by rolling the smeared finger from left to right sides on a blank paper. Some of 3,000 fingerprint images showed a blurred finger ridges resulting in unable to see the *minutiae*. Therefore a total of 2,195 fingerprint images were selected for counting the minutiae.

Types of *minutiae* were identified based on FBI (FBI, 1990) and Gutiérrez-Redomero *et al.* (2011). *Minutiae* were quantified visually enlarged by a Microsoft Word program in four sectors within a circleon each fingerprint image, as adaptedfrom Gutiérrez-Redomero *et al.* (2011). Briefly, two perpendicular axes were drawn on the center of the fingerprint image, and then, draw a circle which has a radius, perpendicularly cutting fifteen ridges (Figure 3). This method is the standardized protocol described by Gutiérrez-Redomero *et al.* (2011) which could be eliminate the effect of finger size in order to allow comparison of minutiae frequencies between different fingers, genders and populations.A SPSS software version 17.0 was used to estimate descriptive statistics. Pairwise populationdifferences by the Chi-square test and sex differences by t-test were executedusing the same program. Two clustering analyses, i.e. Principle component analysis (PCA) and dendrogram were also executed by SPSS 17.0.

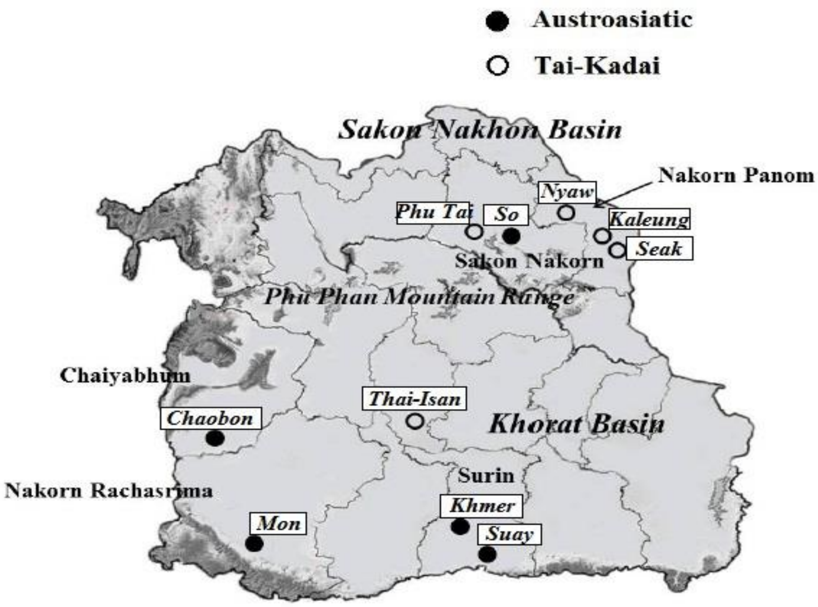

Figure 2 Map of Northeastern Thailand showing the locations of the studied populations in different geographic areas between Austroasiatic and Tai-Kadai speaking groups. (Adapted from Khambhu *et al*., 2014)

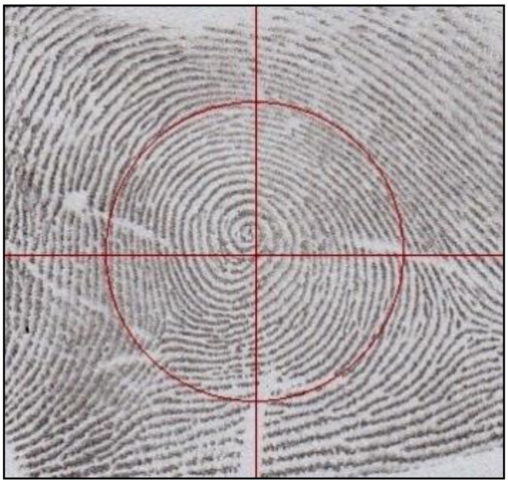

Figure 3 Four sector areas in a circle for counting *minutiae* according to the method described by Gutiérrez-Redomero *et al*. (2011).

Results and discussion

Frequencies of *minutiae* types

Frequency of each type of *minutiae* in the studied populations was presented in Table 1. In all populations: ending ridge, bifurcation and short ridge are the most three common types, while miscellaneous are the lowest frequencies. Island and dot exhibited intermediate frequent values. With respect to the common types, Nyaw and Seak had the largest frequency of ending ridge but smallest of bifurcation.

Table 1 The frequencies of *minutiae* by population.

Population	N	Living Location (Province)	Frequency						
			E	Bi	S	I	D	Br	M
Khmer	193	Surin	54.90	24.05	15.2	2.23	3.02	0.22	0.32
Suay	208	Surin	53.12	32.28	7.81	2.29	3.35	0.49	0.66
Mon	145	Nakhon Ratchasima	53.00	30.11	10.0	2.08	3.63	0.44	0.70
So	133	Sakon Nakhon	48.77	18.72	16.7	1.95	12.88	0.37	0.52
Chaobon	180	Chaiyabhum	43.69	22.17	18.1	1.79	13.40	0.37	0.49
Phu Thai	218	Sakon Nakhon	48.19	23.03	16.9	1.22	9.62	0.34	0.65
Kaleung	206	Sakon Nakhon	52.93	33.41	7.74	3.49	1.85	0.15	0.43
Nyaw	108	Nakorn Phanom	61.86	19.91	13.0	1.19	3.11	0.27	0.58
Seak	33	Nakorn Phanom	66.38	18.57	11.9	1.18	1.65	0.08	0.24
Thai-Isan	771	Roi-Et, Buriram, Ubon Ratchathani, Chaiyaphum	56.17	29.98	6.81	2.02	4.34	0.36	0.32

N = number of fingerprints; E = Ending ridge; Bi = Bifurcation; S = Short ridge; I = Island; D =Dot; Br = Bridge; M = trifurcation, return and opposited bifurcation were included.

Table 2 The frequencies of *minutiae* by sex. Numbers of fingerprints are presented in parentheses.

Minutiae types	frequencies		
	Male (1,206)	Female (989)	Total (2,195)
Ending ridge	53.68	52.79	53.20
Bifurcation	26.71	26.63	26.67
Short ridge	11.23	11.66	11.46
Island	2.10	2.00	2.05
Dot	5.54	6.10	5.85
Bridge	0.31	0.34	0.33
Miscellaneous (trifurcation, return and opposited bifurcation)	0.43	0.48	0.46

Minimum percentage of ending ridge but maximum frequency of short ridge was detected in Chaobon. In contrast, the Suay and Kaleung had the highest and lowest frequency of bifurcation and short ridge, respectively. When considering the percentage of uncommon *minutiae* types. So, Chaobon and Phu Thai showed the greatest percentage of dot while this type was very rare in the Kaleung and Seak. Again, the peculiarity of the Kaleung was observed with the greatest occurrence of island. A comparison between the sexes exhibited that sex-wise frequency of each *minutiae* type was shown in Table 2. Males presented significantly greater ending ridge and bifurcation than females (P<0.01). The remaining *minutiae* types were not statistically different.

Population relatedness

The Chi-square test was performed to evaluate pairwise population differences. Among 45 pairwise comparisons, most (43pairwises) were statistically different (P<0.001) (Table 3) with exception of Suay-Mon and Nyaw-Seak. This result indicates closely related in *minutiae* pattern in these two pairs of populations. Population relationship depicted by PCA and median clustering dendrogram as shown in Figures 4-5, respectively, agrees with pairwise population tested by the Chi-square. The PCA based on PC1 and PC2 (Figure 4) indicated that the Mon, Suay, Thai-Isan and Khmer were located in the center of the plots and formed a tight cluster in PC1 and PC2, exhibiting close population affinity. Although the Kaleung situated in the upper of the plot based on PC2 but the location based on PC1 is quite close to the central cluster. For the remaining populations, two differentiated clusters were identified by PC1, that is, cluster of Saek and Nyaw and cluster of Phu Thai, So, and Chaobon. In dendrogram plotted from *minutiae* distribution (Figure 5), the result seems similar to PCA. The Suay was closest to the Mon, indicating highly dermatoglyphic similarity. These two populations were fallen into the same cluster with the Khmer, Thai-Isan, and Kaleung, while the So, Chaobon and Phu Thai formed another cluster. The outside branch is composed of the Nyaw and Seak, reflected distantly dermatoglyphic relatedness.

The non-genetic factors like geography and language are considered of the influential factor to drive genetic variation among populations within regional, continental, and worldwide scales (Pardiñas *et al*., 2012; Coia *et al*., 2012; Kutanan *et al*., 2014b). These earlier studies employed various types of DNA as genetic markers to answer whether geography or language is the determining factor. Theoretically, if geography is the relevant factor, populations are clustering based on geographic proximity, whereas if language is considered as a predominant factor, population clustering is patterned by linguistic classification. The present results from PCA and dendrogram did not show any population clustering base on geography or language. In addition, the present results of population relationship apparently differ from our previous studies utilizing mitochondrial DNA (Kutanan *et al*., 2014b) as well as fingerprint pattern (Khambhu *et al.,* 2014) albeit the same sets of populations were analyzed. For example, the close relationships between the Suay and Mon as well as Seak and Nyaw did not detect in both previous studies.

Since dermatoglyphic triats have a complex background governed by both gene and environment, it could be generally accepted that results of studying genetics and dermatoglyphics might be not parallel. However, a comparison between the results of fingerprint pattern and *minutiae* distribution is also inconsistent. This might be resulted from the small sample size in *minutiae* types. Both dermatoglyphic studies employed the same set of fingerprints, however, the pattern of fingerprint can be classified even though from the blurred image, but types of *minutiae* cannot be correctly identified. Thus, in the future study of population relationship in the Northeast of Thailand using *minutiae,*the clear image of fingerprints and greater sample size are needed.

Table 3 Chi-square values among pairwise population.

	Khmer	Suay	Mon	SO	Chaobon	Phu Tai	Kaleung	Nyaw	Seak	Thai-Isan
Khmer										
Suay	242.87									
Mon	96.98	16.38								
So	520.64	717.35	395.96							
Bon	624.26	779.65	420.26	41.80						
Phu Thai	325.39	506.41	249.11	70.07	72.26					
Kaleung	345.45	60.66	80.06	1131.79	1236.06	867.81				
Nyaw	76.16	262.28	137.82	395.06	548.92	295.47	379.41			
Seak	62.38	142.17	101.35	208.15	285.35	183.47	155.43	16.79		
Thai-Isan	548.95	47.68	63.31	1335.52	1700.71	1021.67	191.00	375.04	148.19	

Underline indicates p values <0.001

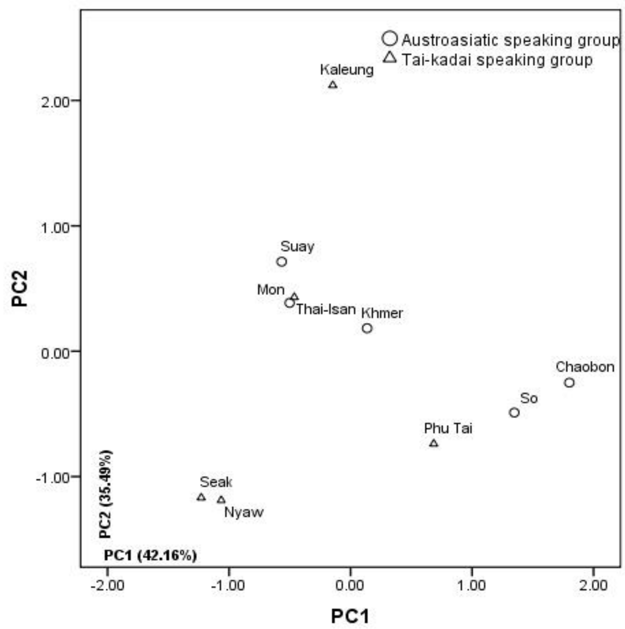

Figure 4 Principal component plots of Mon-Khmer and Tai-Kadai.

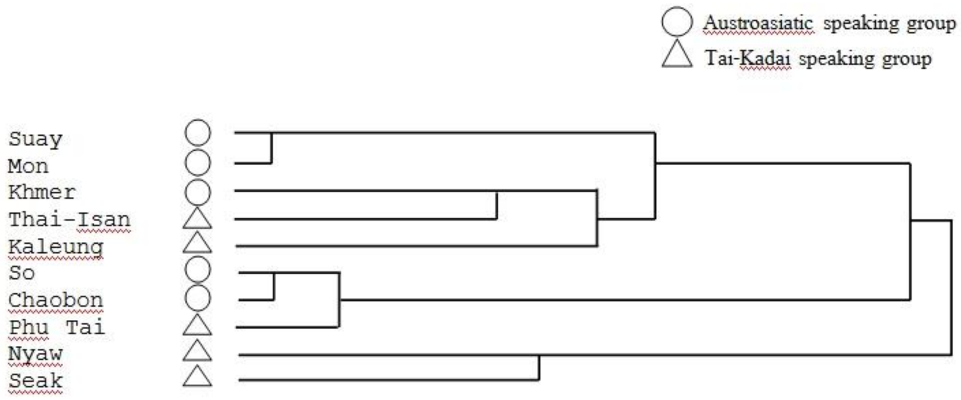

Figure 5 Dendrogram using percentages linkage between Mon-Khmer and Tai-Kadai.

Conclusion

Our investigation of the *minutiae* in ten northeastern Thai ethnicities showed that the studied populations have a unique *minutiae* frequency in exception with two pairs of Suay-Mon and Seak-Nyaw which do not differ in *minutiae* pattern. Population clustering revealed by PCA and dendrogram indicated that neither geographic proximity nor linguistic classification corresponds to population relatedness. The present result is not concordant to previous studies on fingerprint pattern and mitochondrial DNA by the same group of subjects, possibly resulted by the small sample size of some ethnic group. Although the investigation of *minutiae* as a biological marker to elucidate the relatedness between populations was unsuccessful, future study on *minutiae* with greater number of sample sizes as well as other parameters in dermatoglyphic parameters, such as finger ridge count, palm or sole patterns could reveal population structure in northeastern Thailand.

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