Variability of Finger Ridge Density among Thai Adolescents
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Abstract
Finger ridge density (RD) is the number of finger ridges that touch the diagonal line drawn between a square of 25 mm² which is placed on the core of the fingerprint image. It has been useful as a sex determination aid in forensic practice as its values are significantly higher in females than males. The present study was aimed at investigating the RD of Thai adolescents aged between 10 and 12 years old. Subjects were 130 schoolboys and 130 schoolgirls who were randomly selected and signed informed consent forms prior to printing each individual’s ten fingers by using the adhesive transparent tape technique. The Microsoft Word program was applied for precise counting of RD. The mean RD differences between left and right hands, boys and girls, radial and ulnar areas were statistically tested. The likelihood ratio was computed to obtain the probability inferences of sex, and posterior probabilities were estimated using Bayes’ theorem. Results revealed as follows: (1) The mean RDs (ridges per 25 mm²) of boys and girls were not significantly different across the radial (15.89 vs. 16.19, respectively) and ulnar areas (15.84 vs. 16.00, respectively). For each sex, mean RDs in the radial and the ulnar were not statistically different. (2) The mean RDs in both sexes were greater in the left hand fingers compared to the right hand, and were statistically significant only in girls. (3) For the ulnar area, the RD of 13 or less is most likely to be of male origin and that of 17 or more has a low probability of being of female origin. Comparing the radial area, an RD of 14 or less has a low probability of being of male origin while a weak probability of the RD of 17 or more is most likely being of female origin.

Keywords: Fingerprint; Ridge density; Northeast of Thailand; Adolescents; Posterior probability

Introduction
Several empirical studies have been reported dermatoglyphics among various populations. Dermatoglyphics involve investigation of epidermal ridges and pattern types on human fingertips and palms which are useful in medical aids for diagnosis of genetic diseases [1,2]. It has been widely applied to bioanthropology and evolutionary biology to characterize populations and investigate the origin of human variability [3]. There are two types of dermatoglyphic studies, qualitative and quantitative. Qualitative dermatoglyphics is the investigation of fingerprint pattern types, where as finger ridge count on the fingerprint and a-b ridge count on the palmprint are the example of a quantitative dermatoglyphic study. Fingerprint pattern types and various specific characteristics, called minutia, have been utilized worldwide in forensic examinations for determination of individuality. High incidence of crime has made fingerprinting an important evidence for investigating officers. If the sex of suspects can be defined, their work scope could be narrowed down. To facilitate and shorten processes of investigations, finger ridge density (RD) becomes relevantly. The RD has been previously reported for forensic examinations aid in sex determination in multiple populations, for example Caucasian American, African American, Indian, Malaysian, Chinese, and Spanish ethnic groups. Higher RD in females than males in a given area was declared in earlier studies [4-7]. The RD, a number of finger ridges counted on the diagonal line drawn between a square of 25 mm² on the core of fingerprint image, varies among populations and sexes especially in people over 12 years old [8]. Hitherto, a limit of RD observations has been reported in Thailand, thus this study intends to investigate the RD as well as evaluate the influential factors like sex, ages, and ethnicity in a sample of northeastern Thai adolescents.

Materials and Methods
Sample and fingerprint collection
School children residing in the northeastern of Thailand were informed and gave signed consent coupled with permission of their father or mother prior to printing individual’s 10 fingertips. Two hundred and sixty subjects (130 boys and 130 girls aged between 10 and 12 years old) were randomly chosen from the school classes. Each individual’s ten fingers were printed by using an adhesive transparent tape technique [9]. Research ethical approval was reviewed by Khon Kaen University Ethics Committee for Human Research.

Finger ridge density counting
Two counting areas using the radial area [3] coupled with the ulnar area [7] on a fingerprint image above the core were selected. A modified technique for RD counting was performed using the Microsoft Word program to construct two squares of 5 × 5 mm with a diagonal line drawn from each square on a spreadsheet. Images of 10 fingerprints were scanned in a picture format file and pasted on the sheet with two squares constructed. To facilitate more precise RD counting, each fingerprint image with those two squares was enlarged 500%. The finger ridges that touch the diagonal line were counted. This value represents RD of each fingerprint (Figure 1).

Statistical analysis
The RDs for the radial and ulnar areas of all 10 fingers of each subject were used to compute the mean for each area and each hand in both sexes. The mean RD for each area for all 10 fingers was also calculated in each individual. The differences between sexes were examined...
for the radial and ulnar areas and mean for all 10 fingers. Data were statistically analyzed by obtaining total and group descriptive values. The studied areas (radial and ulnar) and sexes (male and female) were compared using the two-way analysis of variance (ANOVA) test. The differences between left and right hands as well as between radial and ulnar areas for each sex are estimated by independent t-test. All tests mentioned above were employed using SPSS version 17.0 [10]. The alpha level of significance was set at 0.05 for all statistical calculations.

The likelihood ratio (LR) was computed to obtain the probability inferences of sex, based on RD values [11]. Let FP be the fingerprint, C the male donor, and C' the female donor:

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LR = \frac{\text{probability of the observed RD given that the FP originates from a male contributor (C)}}{\text{probability of the observed RD given that the FP originates from a female contributor (C')}}
\]

The value of LR yields the strength of support for one of the hypotheses: C or C'.

Posterior probabilities i.e. \( P(C/RD) \) and \( P(C'/RD) \) were estimated using Bayes' theorem [8]. Information obtained from both LR and posterior probabilities are implied for determining the most likely hypothesis for a given ridge density \( P(RD/C) \) and \( P(RD/C') \). The prior probability of male \( P(C) \) and female \( P(C') \) are 0.5 by assuming that male and female are equally committed a crime.

Results and Discussion

The distribution of RD frequencies is shown in Figure 2. Variation in ridge count is restricted within a well-defined range. Of all the 2600 digits, there is no instance of a count less than 9 ridges per 25 mm², nor one exceeding 27 ridges per 25 mm². Ridge count in the radial area varying between 10 and 26 ridges per 25 mm² is in the same ranges as the ulnar area in which the count varies between 9 and 26 ridges per 25 mm².

In both boys and girls, the thumb and index fingers (1 and 2 fingers, respectively) of both hands show lower RD in the radial and the ulnar areas than middle, ring, and little fingers (3, 4 and 5 fingers, respectively), indicating the presence of thicker ridges in the thumb and index. Arranging the digits in order of increasing ridge count, the ranking is fingers 1, 2, 3, 5, 4 for the radial and the ulnar areas of the right and the left hands for both sexes. For each sex, RDs in the radial and the ulnar were not statistically different (\( P = 0.863 \) in boys; \( P = 0.294 \) in girls; Figure 3).

In the right and the left hands, the mean RD in the studied areas followed the same pattern as found for each finger (Figure 4). Mean RD in both sexes is greater in the areas of the left hand, thus showing finer ridges than in the right hand. However, the differences were only statistically significant in girls (\( P = 0.25 \) in boys; \( P = 0.026 \) in girls).
The mean RD for all 10 fingers (Table 1) is not significantly different across the studied areas for both boys and girls (P=0.441). Gender differences are not statistically different in both the radial and the ulnar areas (P =0.124). The probabilities i.e., P(RD/C) and P(RD/C') were calculated by using the relative frequencies of RD from the samples. Then, the likelihood ratio and posterior probability using Bayes’ theorem were obtained. Both values are used to identify the most likely sex, given the number of RD counted in a subject’s sample (Tables 2 and 3). As shown in the ulnar area (Table 2), the posterior probability at a RD of 16 and 19 ridges per 25 mm² is equal between boys and girls, but at a RD of ≥ 13 ridges per 25 mm² boys show higher posterior probability than girls. This result only indicates that a RD of 13 ridges per 25 mm² or less is most likely being from male origin (P=0.61) and a RD of 17 ridges per 25 mm² or more has low probability being from female origin (P=0.55). In the radial area (Table 3), a fingerprint with RD of 14 ridges per 25 mm² or less has low probability being from male origin (P=0.6), whereas the weak probability of a RD of 17 ridges per 25 mm² or more is most likely being from female origin (P=0.55). However, it should be noted that the difference between male and female posterior probability at the RD from both radial and ulnar area is relatively low. Thus, for the real investigating process, this data might be hard to identify personal identification in crime. Since the subjects in this study aged from 10 to 12 years old, male and female do not differ. Our result is concordant to Gutierrez-Redomero et al. [12] which have been reported that female have higher RD than male when older than 12 years, but not when younger.

Table 2: Probability densities & likelihood ratios derived from observed RD in the ulnar area.

| RD (ridges per 25 mm²) | probability densities | likelihood ratio | posterior probability |
|------------------------|-----------------------|------------------|----------------------|
|                        | male                  | female           | P(RD/C)              | P(RD/C') | P(RD/C) = 0.5, P(C/RD) | P(RD/C') = 0.5, P(C'/RD) |
| ≤12                    | 0.05                  | 0.03             | 1.71                 | 0.63     | 0.37                  |
| 13                     | 0.09                  | 0.06             | 1.53                 | 0.61     | 0.39                  |
| 14                     | 0.13                  | 0.13             | 1.02                 | 0.51     | 0.49                  |
| 15                     | 0.20                  | 0.19             | 1.04                 | 0.51     | 0.49                  |
| 16                     | 0.21                  | 0.21             | 0.99                 | 0.50     | 0.50                  |
| 17                     | 0.15                  | 0.18             | 0.81                 | 0.45     | 0.55                  |
| 18                     | 0.08                  | 0.11             | 0.74                 | 0.42     | 0.58                  |
| ≥19                    | 0.09                  | 0.09             | 1.02                 | 0.50     | 0.50                  |

Table 4 shows variability of means RD across various populations [4-7, 13-14] including Thai adults [15] and Amerindian ethnic adolescents [16]. Females possess RDs statistically greater than those of males in any population except for Amerindian children [16]. Several reports have been suggested the RD differentiation among ages, sexes, and populations. Subjects in the present study and that of Amerindian children which are in the same age range showed significantly different mean RD. This might be caused by racial differentiation reflected the influence of environmental factors during pubertal growth promoting unequal epidermal ridges. Moreover, when comparing our result to Amerindian (Mataco-Mataguayo) adults, Chinese, Indian, and Malaysian populations, the differences of RDs were also found indicating the substantial influence of ethnic differentiation. Except for ages, sexes, and populations, dermatoglyphic region on finger [17] could be influenced a variability of epidermal ridge breadth [18]. The present study found that the thumb and index had a greater ridge breadth than that of other fingers, which is consistent with a study in Amerindian (Mataco-Mataguayo) adults. Moreover, mean RD of Thai children in this study and other Thai adults were compared to suggest age-related ridge variations. Mean RD of Thai boys seem to be greater than Thai adults (15.89 vs. 14.72 ridges per 25 mm²), respectively, but probably not for girls, implying a variability of epidermal ridge breadth during the growth period. This result confirms the factors of age and ethnicity but not sex in governing RD in northeastern Thai adolescents.
Conclusions

The present study is the first report of RD among Thai adolescents aged between 10 to 12 years old residing in northeastern region of Thailand. The mean RD for all 10 fingers does not significantly differ between the ulnar and radial areas for both sexes. Finer ridges in the left hand than the right hand was observed in both sexes. The thumb and index had a greater ridge breadth than those of other fingers. The mean RD of female is greater than male but it is not statistically different. The identification of the most likely sex could not be succeeded since the relatively lower posterior probability. Mean RD from various populations were compared to evaluate the existence of ages and racial differences in RD, confirming the observations of earlier researchers. Although the present study cannot predict sex determination by RD among Thai adolescent population, further studies on RD from subjects who older than 12 years old and from subjects belonged to different ethnicities in Thailand are proposed. The expectation from further results will be important tool for the forensic experts and law enforcement authorities.

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Table 4: Comparison of mean RD among various populations.

| populations                          | number of subjects | mean RD     |
|--------------------------------------|--------------------|-------------|
|                                      |                    | male        | female      |
| Northeastern Thais * (10-12 years old) | 260                | 15.89(1.80) | 16.19(1.48) |
| Northeastern Thais adults13          | 461                | 14.72(2.11) | 16.53(1.18) |
| Spanish1                             | 200                | 16.23(1.39) | 17.91(1.47) |
| South Indian8                        | 500                | 12.80(0.90) | 14.60(0.08) |
| South Indian13                       | 550                | 12.47(1.49) | 14.15(1.68) |
| Indian14                             | 200                | 11.05(1.11) | 14.20(0.63) |
| Chinese1                              | 200                | 11.73(1.07) | 14.15(1.04) |
| Malaysian1                           | 100                | 11.44(0.99) | 13.63(0.90) |
| African-American1                    | 400                | 10.50(1.15) | 12.61(1.43) |
| Amerindian (Mataco-Mataguayo)15      | 121                | 16.62(2.71) | 17.82(2.87) |
| Amerindian (10-12 years old; Mataco-Mataguayo)16 | 66                  | 20.90(NA)  | 20.27(NA)   |

*Present study standard deviation is in parenthesis.

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