FINGERPRINT PATTERN SIMILARITY: A ZYGOSITY TEST CLASSIFIER IN A THAI TWIN STUDY

Wibhu Kutanan, Somsong Nanakorn*

Department of Biology, Faculty of Science, Khon Kaen University, Khon Kaen 40002, Thailand

ABSTRACT: This study aims to establish zygosity determination which is essential in twin studies by using a simple, economical, and rapid method that relies on dermatoglyphic data. Fingerprints (FP) were collected from 138 twin pairs residing in northeastern and central Thailand. The FP patterns were identified and the FP pattern similarity score was measured, after which these scores were utilized to plot the Receiver Operating Characteristic (ROC) curve and to generate the area under the ROC curve (AUC). Results showed that the mean scores of FP pattern similarity for monozygotic (MZ) twins are statistically greater than for dizygotic (DZ) twins. The AUC of both hands with a cut-off point equal to or greater than 5.5 provided excellent accuracy and the highest sensitivity and specificity to differentiate between MZ and DZ twins. The present study explores the usefulness of the FP pattern similarity of both hands to identify the zygosity among Thai twins.

Keywords: Twin, Zygosity, Fingerprint pattern similarity, Receiver Operating Characteristic (ROC), Thailand

INTRODUCTION

The fingerprints (FPs) are the epidermal ridges that form on the fingertips of a foetus between 11 and 25 weeks of gestation and remain unchanged throughout life [1, 2]. Because the FPs are constituted by both genetic and environmental factors during maternal pregnancy [3, 4], no two individuals, including monozygotic twins, share the identical fingerprints [5].

The zygosity determination is a basic and essential requirement in twin studies. The misclassification of zygosity can lead to the generation of biased results [6]. Several empirical studies have been conducted by developing questionnaires for the zygosity determinations with validation [7-14]. These zygosity questionnaires have many advantages, like simplicity and relative accuracy [9, 10, 14], such that they are the preferred method to study twins in large-scale and population-based epidemiological studies. A questionnaire of zygosity determination (QOZD) usually comprises two following sections: the degree of resemblance perception and the confusion by others [11]. Although QOZDs use similar questions among various studies, differences in QOZD accuracy have occurred [9, 10, 12-14]. Therefore, it is necessary to validate study-specific QOZDs and to examine their validity.

* *Correspondence to: Somsong Nanakorn*
E-mail: somnan@kku.ac.th

The Receiver Operating Characteristic (ROC) analysis is a well-established method to ascertain the efficacy of clinical diagnostic and prognostic tests in correctly classifying diseased and non-diseased individuals [15, 16]. The ROC analysis has been applied to formulate questionnaires that discriminate alcohol use disorder (AUD) from non-AUD [17, 18]. The area under the ROC curve (AUC) provides a measurement of how well the questionnaire tests for the classifier. The genetic interpretation of the AUC can be utilized to delineate whether a test classifier is an accurate predictor of genetic risk [19].

In a previous study of dermatoglyphics among Thai twins [20], a modified QOZD coupled with ABO-blood typing was used to determine zygosity. However, a problem arose because numerous participants did not know their blood type. Employing FPs rather than blood group analysis to verify zygosity may be an alternative method for efficiently undertaking large-scale and population-based twin research. -In this study, we intended to investigate the FP pattern similarity between Thai twins and validate a zygosity test classifier for prediction of the zygosity of Thai twins.

MATERIAL AND METHODS

Fingerprints were collected using the modified adhesive tape method [21]. Prior to fingertip printing, the participants signed informed consents, however when the participants were younger than

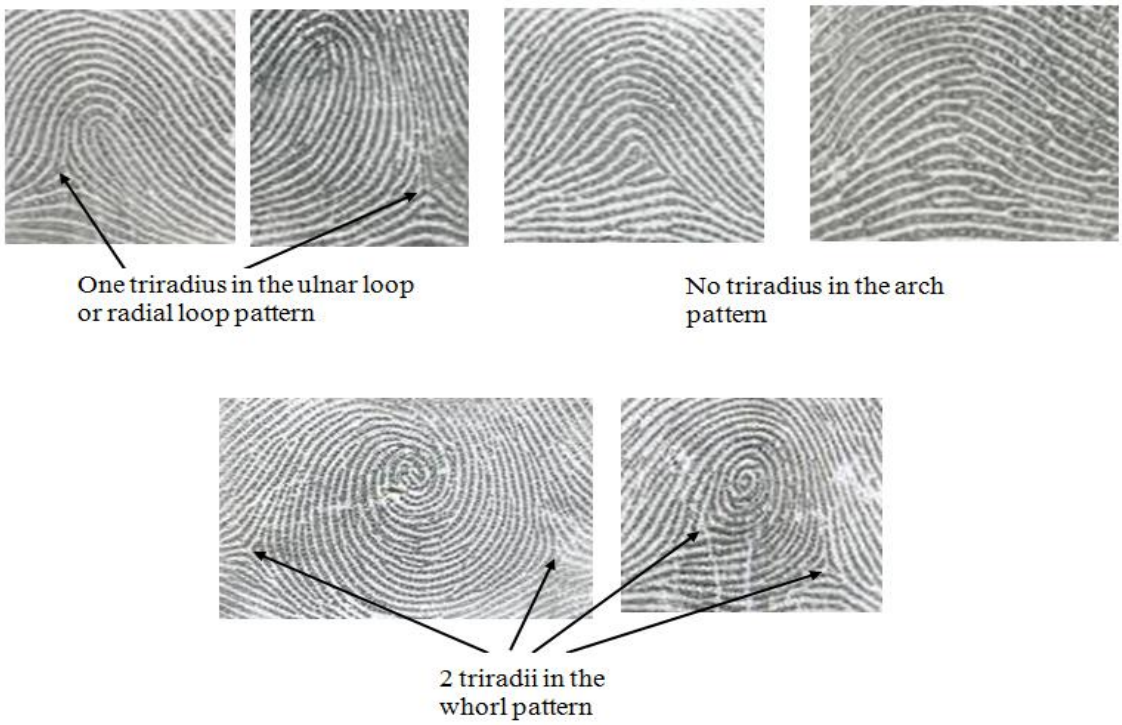

Figure 1 Images of fingerprint patterns obtained from the adhesive-tape technique. The loops (ulnar and radial) have only one triradius, 2 triradii for the whorls and no triradius for the arches.

18 years old, the informed assents were used. Most of the twin pair participants were students in primary or junior high schools located in north-eastern and central Thailand. A snowball technique for recruiting eligible twin pairs was employed. The use of mass media, such as television programs, made it easier to access the availability of the twins to participate in the study.

Ten (10) FPs of each individual were scanned and enlarged using an HP Scanjet G2410 to facilitate the identification of FP patterns. The FP patterns were identified and classified into the 4 basic types: arch (A), radial loop (RL), ulnar loop (UL), and whorl (W) [3, 22, 23]. The various FP patterns were shown in Figure 1.

The FP pattern similarity was evaluated by matching the same type of FP patterns on homologous fingers of co-twins. Thus, when considering the 10 digits of both hands, the minimal FP pattern similarity score was 0, indicating that no compatible FP patterns were observed on the homologous fingers. If the score was 10, all 10 homologous fingers among the co-twins shared the same FP patterns.

The type of twin was classified based on two variables, the biological sex and FP pattern similarity score of 6 or greater. For example, if the twin subjects show similar gender and the FP pattern similarity score greater than or equal to 6, the twin pair was classified as MZ. In contrast, if gender difference of twin subjects was observed but the FP pattern similarity score was greater than or equal to 6, their zygosity status was classified as DZ.

The ROC was plotted by considering two variables, the FP pattern similarity score and twin type. While, the theoretical ROC was plotted by the true positive rate (referred to the sensitivity or the probability of a diseased test), against the false positive rate which can be calculated as 1 minus the specificity [16]. In this study, we modified the ROC analysis between MZ and DZ twins as classified by using the constructed index for zygosity determination (biological sex plus an FP pattern similarity score of 6 or over). Moreover, the area under the ROC curve (AUC) was calculated for the observed twin zygosity scale using SPSS (Serial No. 5068054) [24]. The AUC value yielded an efficient phenotype prediction (MZ or DZ twins) using a test classifier [25]. The test classifier of the FP pattern similarity score among co-twins was considered in this study.

STATISTICAL ANALYSIS

The statistical analyses were carried out by using the SPSS for Windows [24]. Mean values of FP pattern similarity within each twin type (monozygotic, MZ and dizygotic, DZ) as well as the differences among twin types were tested by an independent *t*-test.

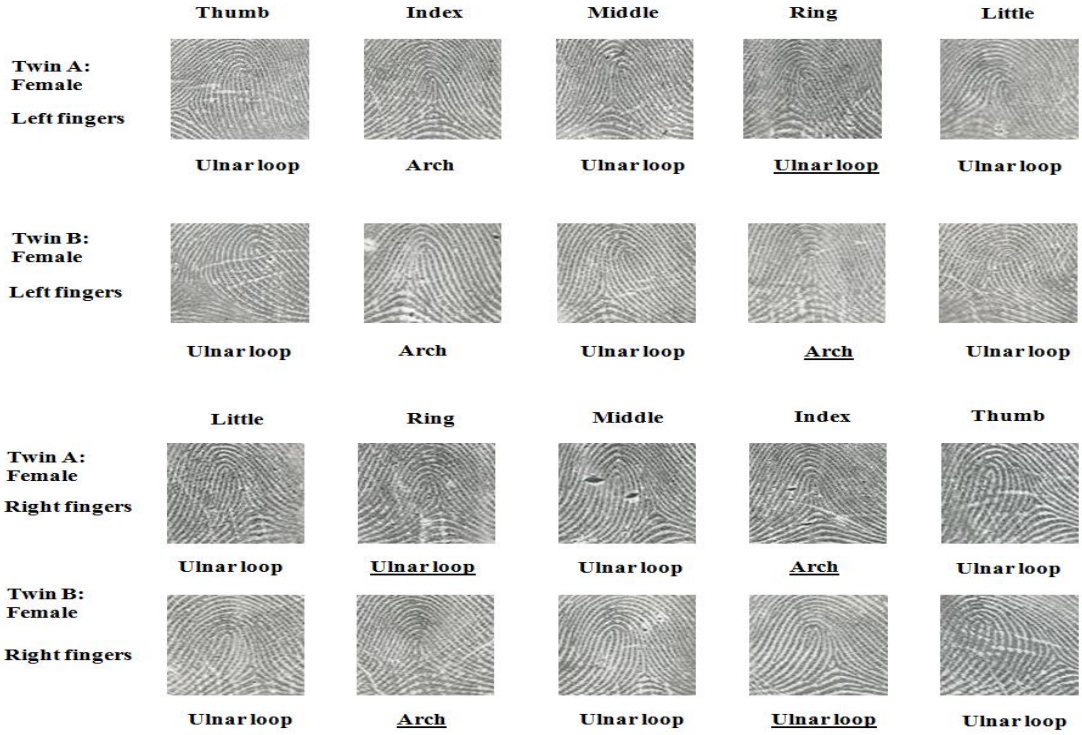

Figure 2 Fingerprint (FP) pattern similarity of female twins-A and B: 7 homologous fingers are the same FP patterns while the other three fingers (marked in underline) are different in FP patterns (adhesive-tape technique = up-side palm looking).

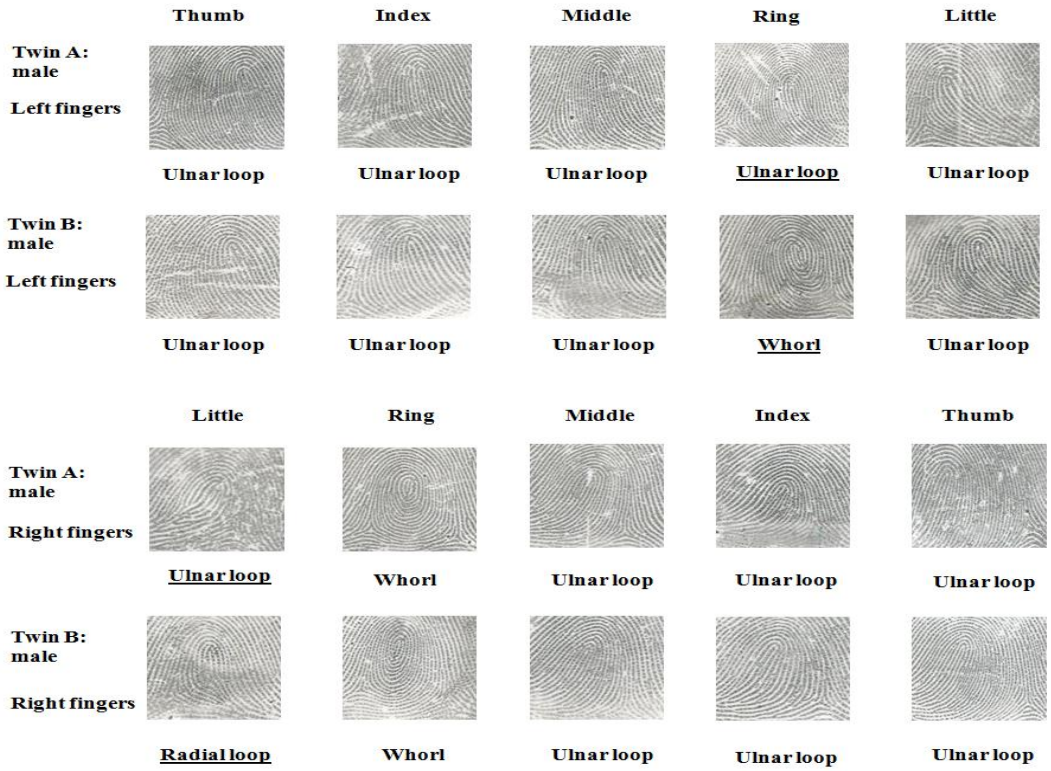

Figure 3 Fingerprint (FP) pattern similarity of male twins-A and B: 8 homologous fingers are the same FP patterns while the other two fingers (marked in underline) are different in FP patterns (adhesive-tape technique = up-side palm looking).

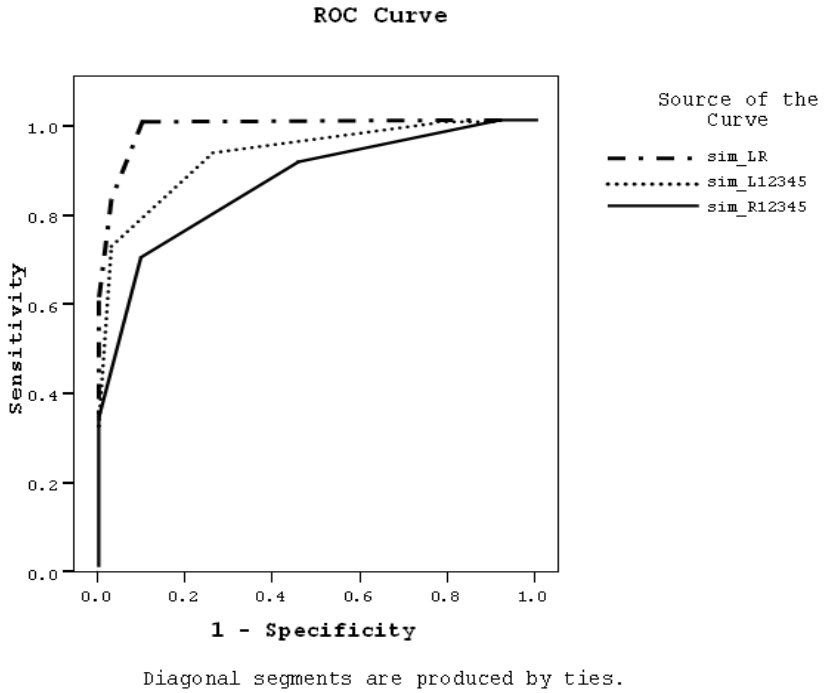

Figure 4 The AUCs were calculated to evaluate the efficiency of test classifiers: (1) 2-hands FP pattern similarities; (2) left-hand FP pattern similarities; (3) right-hand FP pattern similarities. The values were 0.985, 0.920, and 0.858, respectively.

Table 1 The cut-off point, sensitivity, and specificity of each test classifier

Test classifier (fingerprint pattern similarity score)	Cut-off point that give positive if greater than or equal to	Sensitivity (%)	Specificity (%)
10 homologous fingers of 2-hands (sim_LR)	5.5	100.0	90.3
	6.5	83.2	96.8
5 homologous fingers of the left-hand	2.5	92.5	74.2
(sim_L12345)	3.5	72.0	96.8
5 homologous fingers of the right-hand	2.5	90.7	54.8
(sim_R12345)	3.5	69.2	90.3

RESULTS

In this study, 138 twin pairs were classified as 107 pairs of MZ twins and 31 pairs of DZ twins using the constructed index for zygosity determination. Subject ages ranged from 5 to 66 years.

The FP pattern similarity mean scores from 10 homologous fingers ranged from 1 to 10, with an average score of 7.01 (SD = 1.83) for all of the twin subjects. In Figure 2, FP pattern similarity score is 7 of female twins while 8 homologous fingers of male twins exhibited similar FP pattern which score is 8 were shown in Figure 3. The mean scores of 7.77 (1.17) for the MZ twins and 4.39 (1.12) for the DZ twins were significantly different (t = 14.30, df = 136, p = 0.000). When comparing FP pattern similarity for the 5 homologous fingers of the left-hand, mean FP pattern similarity scores of MZ twins was statistically greater than in DZ twins [3.87 (0.88) and 2.03 (0.84), respectively; t = 10.34, df = 136, p = 0.000]. For the right-hand, the MZ twins show a statistically higher mean FP pattern similarity score than the DZ twins [3.90 (0.97) and 2.35 (0.98), respectively; t = 7.76, df = 136, p = 0.000].

The ROCs of the 3 following classifiers: the FP pattern similarities of 10 homologous fingers (sim_LR), 5 homologous fingers on the left-hand (sim_L12345), and 5 homologous fingers on the right-hand (sim_R12345) were shown in Figure 4. The AUCs were 0.985, 0.920, and 0.858, respectively, indicating satisfactory efficiency for differentiating between MZ and DZ twins. Table 1 showed the cut-off point along with the sensitivity and the specificity of each classifier. It can be seen that the classifier named sim_LR (the FP pattern similarities of 10 homologous fingers) yields the best sensitivity and specificity (100.0% and 90.3%, respectively) at a cut-off point of equal to or greater

than 5.5.

DISCUSSION

In twin research, an efficient determination for zygosity is essential. Currently, genetic markers are applied to several biological analyses, including twin studies. Zygosity is usually used to determine from either placenta types [13, 26] or polymorphic blood types system [27] or DNA types [9, 10, 28]. However, DNA or blood type analyses to specify zygosity are not generally feasible in most twin studies if the volunteers do not consent for the researcher to take biological samples from them. Thus, other methods to assess zygosity are chosen, such as QOZD [7-14], and dermatoglyphic variables [9, 26-28]. However, QOZD is time-consuming. Therefore, the alternative method in this study to differentiate between MZ and DZ twins was the utility of dermatoglyphic variables especially the FP pattern similarity scores. This goal was achieved by plotting the ROC using the different twin types as determined by the construction of an index that included requirements for individuals of the same sex and an FP pattern similarity score of 6 for both hands. The AUC that yielded an excellent accuracy and demonstrated sensitivity and specificity values as high as 100.0% and 90.3%, respectively, was the FP pattern similarity of both hands with a cut-off point of 5.5. This meant that if the unknown co-twins show FP pattern similarity equal to or greater than 6 for homologous fingers on their both hands, they might be MZ twins, with a 95% confidence interval from 0.96 to 1.00. Thus, dermatoglyphic variables (e.g., FP pattern similarity) might be an alternative way of identifying zygosity with a simple, practical, economical, and reliable method in population-based and large-scale twin studies. Previous study [9, 26-28] used dermatoglyphic variables and correctly classified MZ and DZ twins between 87% to 100% compared to DNA fingerprint or placental types. However, it should be cautioned that this validation is not regarded as a gold standard of zygosity testing, like placental examination or DNA fingerprint. Therefore, in a future study, the true discrimination power of this test classifier would be explored to affirm this dermatoglyphic characteristic in determining the zygosity.

CONCLUSIONS

A dermatoglyphic data of 138 pairs of twins was investigated with the intention of delineating MZ twins from DZ twins by using FP pattern similarity. The ROC analysis that yielded the AUCs was the statistical tool used to accomplish this purpose. The FP pattern similarity scores of both hands with a cut-off point equal or greater than 5.5 provided an excellent accuracy and the highest sensitivity and specificity in differentiating between MZ and DZ twins.

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DECLARATION OF CONFLICTING INTERESTS

No financial or other conflicts of interest exist.

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