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Relative studies between hair index, hair area, and medullary index with age and sex in Thai scalp hair

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ABSTRACT

Human scalp hair is one of the most common trace materials found at violent crime scenes. Accordingly, scalp hair is critical evidential material in forensic investigations for identifying relations and persons, which could result in solving cases. Knowledge about micro-morphological variations of scalp hair in the Thai population, however, is scarce, and information on age changes and sex differences with respect to these traits is limited. The present study was thus undertaken to explore three micro-morphological parameters of Thai scalp hair—hair index (HI), hair area (HA), medullary index (MI)—relative to age and sex differences. Scalp hair samples were collected from 340 unrelated Thai cadavers (170 male, 170 female) of all ages, which were divided into seventeen age groups, 5-year-old interval per group beginning with 0–5 years and ending up with ≥80 years. Approximately 30 hair strands at the posterior vertex region of the scalp were cut with scissors as close to the scalp as possible. The hair samples were subsequently used to make permanent slides, and the mounted hairs were examined for microscopic cross-sectional characteristics. The authors found that the HI and MI were similar in the male and female cadavers and did not significantly differ ($p > 0.05$) according to age. In contrast, the HA was significantly different between the male and female cadavers at 50–69 years of age ($p < 0.05$). There were other differences according to age as well. That is, the HA increased abruptly during their early twenties and then decreased gradually until ≥80 years of age. Thus, Thai scalp hair shows some age and sex variations that are reflected in the HA and might be useful for forensic, medical, and anthropological investigations.

1. Introduction

It is well recognized that prosecution of individuals suspected of being involved in violent crimes, including homicides, sexual assaults, and aggravated assaults, often includes the identification and comparison of human trace evidence found at the crime scene. Human scalp hair has a certain life cycle, so it regularly and automatically falls out, making it frequently found at a crime scene [1]. Accordingly, such hairs are critical evidential materials in forensic investigations, especially for identifying relations and persons, which could result in solving cases [2]. Hair might not, by itself, provide enough information to establish identity, but it can rule out certain criminals or scenarios [3]. It can also be used to corroborate other evidence during an investigation, thus providing investigators with valuable information for potential leads [4]. Hair evidence can provide useful clues to the site of the body, race, sex, age, geographic origin, and the health of the person [5–7]. Some studies have shown that various histomorphological hair parameters (e.g., medullation, hair index, medullary index, scale count index) have forensic applications for individualization [7,8–11].

Knowledge about micro-morphological variations of scalp hair among the Thai population, however, has been scanty. Additionally, information on age changes and sex differences with respect to these parameters is limited. The present study was therefore undertaken to explore three micro-morphological parameters of Thai scalp hair: the hair index (HI) or hair shape in terms of the degree of ellipticity of the hair cross-section; hair area (HA) or hair size; and the medullary index (MI). The authors also considered age and sex differences relative to these parameters for possible forensic significance.

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2. Materials and methods

2.1. Materials

The scalp hair samples were collected from 340 unrelated cadavers (170 male, 170 female) of all ages, which were divided into seventeen age groups: 0–5, 6–9, 10–15, 16–19, 20–25, 26–29, 30–35, 36–39, 40–45, 46–49, 50–55, 56–59, 60–65, 66–69, 70–75, 76–79, and ≥80 years for equal age distribution. All cadavers were undergoing medico-legal death examinations at the Department of Forensic Medicine, Faculty of Medicine Siriraj Hospital, Mahidol University and the Institute of Forensic Medicine, Police General Hospital during October 2010 to December 2011. Care was taken when selecting the subjects. Only those who were of Thai nationality, who had physically normal scalp hair, and who had died within 24 h were included in the study. Subjects with hair disease, hair damage from either physical or chemical processes, regenerated hair after treatment with radiotherapy or chemotherapy, and hairs shorter than 2 cm were excluded from the study. The reference autopsy number, sex, date of birth, date of death, and cause of death were recorded. Proper care was taken to ascertain the correct dates of birth and death of each subject.

2.2. Methods

Approximately 30 scalp hair stands in the posterior vertex region were collected from each cadaver by cutting the hair as close to the scalp as possible with scissors. The cut hair samples were then tightly wrapped by a rope at their distal end and dried. The hair samples were separately stored in a Ziploc® plastic bag along with a slip containing the reference autopsy number, age, and sex before being transferred to the laboratory. All samples were kept at room temperature until used for the study.

All hair samples were processed in the laboratory to make permanent slides for further microscopic examination as previously described [12]. Prior to examination, the hair samples were cleaned with 1% shampoo in ultrasonic cleaners (Sonorex®; Bandelin, Berlin, Germany) for 3 min to remove dust and debris and then thoroughly rinsed with tap water three times to ensure that all of the shampoo was removed. The hair samples were then soaked with equal parts of ether (23811.326; BDH Prolabo®, Leuven, Belgium) and ethanol (J32T04; Mallinckrodt Baker®, Phillipsburg, Malaysia) in a test tube, sonicated for 3 min to remove any fatty materials from their surfaces, and blot-dried on a piece of filter paper. The hair samples were then soaked with xylene (J41B16; J.T. Baker®, Charleroi, PA, USA) in a test tube, sonicated for 3 min, and blot-dried on another piece of filter paper. Each dried hair sample was examined grossly for its shape, color, curl, and length. Only hair portions at the proximal regions of each hair sample (≤ 0.5 cm from its cut end) were subsequently used to make permanent slides. The mounted hairs were examined and measured to determine the microscopic characteristics of their transverse sections.

The maximum hair diameter, minimum hair diameter, and medullary diameter of 10 random hair cross-sections from each hair sample were measured under a compound upright microscope (Labophot-2; Nikon®, Tokyo, Japan) equipped with NIS-Elements BR program version 3.0 (Nikon Instruments Inc., New York, USA) at a standard magnification of 40–400×. Only cuts with a complete medulla at the center of the hair section were examined. All hair strands were measured in microns (μm). The diameters of the hair shaft and medulla of each subject were the average of the hair shaft diameters and the medullary diameters, respectively, of 10 hair strands selectively chosen. At a particular region, HI values were calculated as a percentage ratio of the minimum hair shaft diameter to the maximum hair shaft diameter. MI values were calculated as a ratio of the maximum diameter of medulla to the maximum diameter of the hair shaft. HA values were calculated by multiplying half of the least diameter (minor diameter) by half of the greatest diameter (major diameter) and the product by pi (≈3.1416), as shown below, which is the formula for the area of an ellipse.

$$\mathrm{HA} = \frac{\text{minor diameter} \times \text{major diameter} \times \pi}{4}$$

2.3. Statistical analyses

All of the quantitative measurements were re-checked before analysis for possible typological errors. All statistical analyses in this study were performed using the Statistical Package for the Social Sciences (SPSS) software for Windows version 18.0 (PASW® Statistics 18, SPSS Inc., IBM Company, Chicago, Illinois, USA). Descriptive and inferential statistics were used to calculate percentages, means, standard deviations, and 95% confidence intervals. An independent sample *t*-test was used to evaluate the significance of sex differences in terms of the HI, HA, and MI. One-way analysis of variance with multiple comparisons (Scheffe's test), was used to evaluate the significance of each age group differences in terms of the HI, HA and MI. Pearson's correlation coefficient was used to establish the correlation between the means of the HI, HA, and MI with age. Linear regression was used to establish the prediction of age with the means of the HI, HA, and MI. A value of $p < 0.05$ was considered to indicate significance.

3. Results

A total of 3400 head hairs (10 from each subject) were evaluated to determine the HI, HA, and MI. The mean age of all 340 subjects was 43.02 ± 24.84 years (range 13 days to 97 years): males ($n = 170$) 43.17 ± 25.05 years (range 13 days to 91 years) and females ($n = 170$) 42.88 ± 24.71 years (range 7 months to 97 years). The HI, HA, and MI means of all subjects were, respectively, 79.58 ± 7.39 (range 54.63–94.05), 4766.41 ± 1622.89 μm^2 (range 857.10–9146.78 μm^2), and 0.16 ± 0.02 (range 0.10–0.23). The data are detailed in Table 1. The mean HIs were relatively constant among all ages ($r = 0.001$, $p = 0.98$), whereas the mean HAs were negatively correlated with age ($r = -0.50$, $p < 0.001$). The mean MIs were not different among the age groups ($r = 0.043$, $p = 0.43$).

The HI, HA, and MI means for the male subjects were 79.03 ± 7.51, 4571.85 ± 1728.66 μm^2, and 0.16 ± 0.02, respectively. The HI, HA, and MI means for the female subjects were 80.14 ± 7.25, 4960.97 ± 1489.55 μm^2, and 0.16 ± 0.02, respectively. The mean HIs in male subjects were in a range of 54.63–94.05 and in female subjects 57.32–92.56. Mean HA values in male subjects were in a range of 857.10–9146.78 and in female subjects 2107.34–8987.48. The mean MIs in male subjects were in a range of 0.10–0.23 and in females 0.10–0.20.

Neither HI nor MI was significantly different among the age groups ($p > 0.05$), as shown in Figs. 1 and 2, respectively. In contrast, the HA increased abruptly during the early twenties and then decreased gradually until ≥80 years, as shown in Fig. 3 ($p < 0.05$). Neither HI nor MI differed significantly ($p > 0.05$) between the male and female subjects, as shown in Figs. 4 and 5, respectively. The HA, however, was significantly different between the sexes in four age groups: 50–54, 55–59, 60–64 and 65–69 years ($p < 0.05$), with the female subjects showing a higher mean HA value than the male subjects (Fig. 6). The discriminant functions for determining age are shown in Table 2, with very low strength ($R^2 < 0.4$). The discriminant functions for determining sex are shown in Table 3, with the highest percent accuracy (93%) at the age range of