Hematological Parameters and Red Blood Cell Indices in Healthy Thai Children: A Revision for 2005

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In order to provide a reference range for hematological parameters and red blood cells indices in Thai children, we analyzed data from 395 healthy non-anemic Thai children age from 1-16 years old, who all had normal pattern of hemoglobin typing (Hb A and Hb A_2 less than 3.5%). Hematological analysis was performed using an automated cell counter and the hemoglobin studies were carried out by electrophoresis and liquid chromatography. Owing to a high frequency of a thalassemia in Thailand, cases with MCV < 75 fL has been excluded from the study since these cases were likely to be heterozygotes for α^0 thalassemia. These criterions were applied to select so-called 'normal' controls for our analysis. Relatively mild microcytosis and hypochromia were observed, in particular in the first three years of age, suggesting an intrinsic immature nature of erythropiesis in the children. Age-dependent differences in the reference values for white blood cell (WBC) count and differential and platelet count were observed. Herein the hematological data and red blood cell indices were summarized according to ages and these will be of clinically useful for the future reference.

Keywords: *Normal hematology, Complete blood count, Hemoglobin, Hematocrit, MCV, MCH, MCHC, α and β Thalassemia*

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The year 2005 has witnessed a cerebration for six decades of the establishment of the Department of Pediatrics, Siriraj Hospital, the first pediatric department in Thailand. Not long after the beginning of a new pediatric department, works on diagnosis and treatment for pediatric blood diseases including thalassemia and leukemia have flourished under the Division of Pediatric Hematology and Oncology. Indeed, the Hematology Division was also the first of its kinds in the Country. Although there was a serious lack of medical equipments and technology in Thailand during the Second World War, a manual blood cell counting, a basic coagulation test, and simple compatibility testing for blood transfusion were, soon all well, operated at the Department. These were also the days of the enumeration of red cells and white cells in counting chambers and of the estimation of hemoglobin concentration by calorimetric analysis. This was a time of simple and practical technical innovations in hematology. One of the most basic laboratory tests in hematology, dated back from that period, is the evaluation of the complete blood count (CBC) to determine leucocytes (WBC), red blood cells (RBC) and platelets, quantitatively and qualitatively. Several hematological parameters including; hemoglobin (Hb), hematocrit or packed cell volume (Hct or PCV), red blood cell count (RBC), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC) and red blood cell distribution width (RDW) have been extensively used as common determinators in clinical medicine. There is a wide range of clinical application of the complete blood count on the daily basis of medical practice; from detecting

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anemia and related hematological diseases, to predicting either bacterial or viral etiologies in patients with infectious diseases. However, interpretation of an isolated value of a laboratory test is not possible without comparing it with reference values and the reference distribution[1]. It has long been known that in establishing reference values in a population it should be taken into account of race, age, sex and genetic factors of the reference population[1,2]. There is widely acknowledged that in the children, variation between different ages of these hematological parameters is even greater due to developmental changes in hematopoiesis and immune system in the postnatal life[3].

To set up such a reference value in Thailand is rather not straightforward owing to a high prevalence of thalassemia and other hereditary hemoglobin disorders[4]. Nearly 30% of the population are carriers of either α or β thalassemia or abnormal hemoglobin, mainly Hb E disorder (due to the β globin codon 26; G to A substitution)[5]. Imbalances in the production of the α or β globin chains, which make up the hemoglobin tetramer, cause the clinical syndromes of α and β thalassaemia[4]. These result from many different natural mutations of the α and β globin genes, which are extremely common throughout all tropical and subtropical regions of the world. The majority of thalassemia carriers have abnormal red blood cell indices (low MCV, low MCH and higher RDW)[6, 7]. The presence of these carriers in a so-called 'healthy' control hampers a setting up of a 'normal' reference value. In the 1970s, two groups have determined the reference range for hematological parameters in Thai children, however these studies have analyzed data based on manual hematological evaluations including WBC counting and differentiation[8, 9]. However, they did not exclude possible individuals with thalassemia carriers by hemoglobin typing and this may affect, in particular red blood cell indices, the reference range reported. With the utilization of automated cell counter[10] and hemoglobin analyzer for more than 15 years in our Department, the examination for the basic hematological data has never been simpler. Nevertheless, there is no documented reference range based on this analytic platform in Thai children. Therefore, on commemorating the special sixty year-anniversary of the achievement in pediatrics in Thailand, it is of interest that we revisit the simple and basic question on what is the normal distribution of these common hematological and red blood cell parameters in our population. In addition, we propose a new reference range based on an automated system for future clinical and diagnostic application.

Material and Method

Subjects

We retrospectively analyzed 450 healthy children who have been investigated at the Hematology/ Oncology, Department of Pediatrics, Faculty of Medicine Siriraj Hospital, Bangkok, Thailand from 1995-2005. Analysis was restricted to steady state data by excluding hematology associated with major clinical events. Their ages range from 1 to 16 year of age. These children were not in any acute health problems and had no medical history of chronic illness or conditions. They have been evaluated for their thalassemia carrier status by complete blood count and hemoglobin analyses since they were relatives or siblings to patients with β thalassemia major, Hb E/β thalassemia or Hb H disease diagnosed in our clinic. All of them had normal pattern of hemoglobin; Hb A and Hb A_2 (less than 3.5%). Cases with Hb E heterozygote (Hb AE), homozygous Hb E (Hb EE) and β thalassemia carriers (with Hb A_2 > 3.5%) were excluded from our study[6]. Considering the possibility of the α^0 thalassemia heterozygotes, individuals with MCV less than 75 fL were subsequently excluded[11]. In addition, individuals with incidental anemia, possibly due to nutritional causes or chronic blood loss, defined as a hemoglobin concentration < 11 g/dL for children age 1-6 years, < 11.5 g/dL for children aged 6-11 years and < 12 g/dL for those aged > 12 years according to the World Health Organization (WHO)[12], were also excluded in the final analysis.

Hematological studies

Routine haematological studies were carried out on peripheral blood samples collected using EDTA as anticoagulant. The detection of reticulocytes was preformed by staining peripheral blood with methylene blue. Red blood cell indices were analysed using an automatic red blood cell counter (Sysmex F280, Japan). Standard hemoglobin electrophoresis and chromatography were performed and quantified after cellulose acetate chromatography, iso-electric focusing (IEF) and the LPLC automated hemoglobin analyser (HB Gold; Drew Scientific Ltd., Cumbria, UK) according to the manufacturer's instruction. Starch gel electrophoresis was additionally performed and stained with orthodianisidine to detect any abnormal hemoglobin bands running anodic to Hb A_2 and resembling the position of Hb CS. Hb F was assessed by alkali denaturation.

Statistical Analysis

For each hematological parameter studied the mean, standard deviation (SD), maximum value,

minimum value, coefficient of variation (CV) and mean standard variation (MSD) were calculated and presented using the Microsoft-Excel programme (Window version 2000). All variances (mean ± SD) were compared using a two-tailed Student's t-test to identify group differences. A p value <0.05 has considered to be statistically significant.

Results

From the total four hundred and fifty individuals with normal hemoglobin profile, 55 cases were excluded due to anemia or microcytosis. The demographic data of 395 individuals is shown in Table 1. The male to female ratio is 1.1:1 and nearly 40% of cases were under 6 year old. Hematological data including hemoglobin (Hb), hematocrit (Hct), red blood cell count (RBC), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), red cell distribution width (RDW), platelet count and mean platelet volume (MPV), in different age groups, are presented in Table 2. It appeared that the levels of average Hb, Hct, MCV and MCH were increasing with age while the platelet count gradually decreased in older age groups. The RBC, RDW and MPV remained constant in all age populations, in both males and females. The numbers of white blood cell (WBC), differential counts and absolute neutrophil counts (ANC) are presented in Table 3. Total WBC was highest at the first two years of life and appeared to gradually declined in older ages. This dynamic change accompanied an inverse correlation between the proportion of lymphocytes (Lym) and polymorphonuclear (PMN) cells in their peripheral blood; the percentages of lymphocytes declined while that of polymorphonuclear cells increased during the same period (Figure 1). The percentages of eosinophil, monocytes and absolute white blood cells were very stable for all ages (Table 2). Average percentages of Hb A_2 and Hb F from hemoglobin analysis are shown in Table 4 demonstrating that there was no difference between the levels of Hb A_2 in different ages. However, it appeared that fetal hemoglobin (Hb F) fell from 1 to 3 years and then the levels maintained at approximately 1% from three year of age (Figure 2). The reticulocyte (Retic) count numbers were in the range of 1.5-2% throughout the childhood (Table 4).

Discussion

The past 60 years have seen both technical progress and remarkable scientific advances in the discipline of pediatrics hematology. Due to simple accessibility of the system, scientific progress has gained enormously in our understanding of the nature of both inherited and acquired blood disorders, in particular, in the fields of hemoglobin genes and their disorders. At now, nearly all laboratory tests preoccupying our foregenerations have become much more accurate and more precise due to the automated and standardized system[10]. Several hematological parameters can now be, more speedily performed, and thus far, with a much higher accuracy than hitherto. Thus, absolute values, in comparison with the reference range described here, can attain an importance in diagnosis. Moreover, the use of electronic counter can reduce the analytic coefficient of variation to 2.5% in case of white blood count and differentiation[10,13]. This suggests that there is an increasing awareness of possible clinical significance in relatively small fluctuations and deviation of the

Table 1. Demography data on the healthy control children analyzed in this study

Age group	Total cases	Male	%	Female	%
1	54	29	53.70	25	46.30
2	29	13	44.82	16	55.18
3	16	9	56.25	7	43.75
4-6	52	29	55.76	23	44.23
6-8	80	43	53.75	37	46.25
8-10	46	28	60.86	18	39.14
10-12	41	20	48.78	21	51.22
12-14	39	19	48.71	20	51.29
>14	38	17	44.73	21	55.27
Total	**395**	**207**	**53.4**	**188**	**47.6**

Table 2. Hematological parameters and red blood cell indices in healthy Thai children (NA, not available)

Age-years	Parameters	Hb (g/dL)	Hct (%)	RBC ($x10^6/mm^3$)	MCV (fL)	MCH (pg)	MCHC (pg/dL)	RDW (%)	Plt. Count ($x10^6/mm^3$)	MPV (%)
1 yrs	mean ± SD	12.50±0.93	37.68±3.22	4.73±0.41	80.10±3.91	26.58±1.99	33.15±1.83	14.67±1.53	335.96±118	8.48±1.5
	median	12.4	37.65	4.72	79.6	26.45	33	14.7	332	8.1
	range	10.3-15	30.4-46	3.96-5.77	75.2-93.2	23.1-33.5	29.1-37.2	10.4-17.6	118-607	5.4-12.2
2 yrs	mean ± SD	13.12±1.10	39.56±2.94	4.88±0.35	81.11±3.73	26.78±1.35	33.06±1.42	14.25±1.22	337.67±127	8.22±0.71
	median	12.9	39.3	4.93	80.9	26.7	33.2	14.35	290.5	7.9
	range	10.8-15.9	32.9-45.1	4.02-5.53	75.2-90.9	24.6-29.3	30-35.3	11.5-15.6	201-579	7.2-9.3
3 yrs	mean ± SD	12.58±0.73	38.97±3.14	4.78±0.36	81.45±3.27	26.27±1.32	32.25±1.47	15.08±1.36	323.25±90.3	NA
	median	12.5	38.05	4.76	81	26.25	32.4	15.5	345	NA
	range	11-13.6	34.4-46.3	4.22-5.46	75-87.2	24.9-29.5	29.4-34.6	13-17.5	178-436	NA
4-6 yrs	mean ± SD	12.77±0.99	38.50±3.52	5.47±5.35	81.74±4.94	27.17±2.06	33.37±2.02	14.13±1.12	338.88±108.3	8.57±1.14
	median	12.8	38.5	4.755	80.4	27	33.2	14.15	313	8.55
	range	11-16.4	31.9-48.9	3.78-43.2	75.4-103	23.8-33.9	29.6-38.9	12.2-16.9	164-665	7-10.9
6-8 yrs	mean ± SD	12.87±1.08	38.66±3.22	4.72±0.37	82.09±3.98	27.28±1.57	33.27±2.64	14.31±1.36	310.72±95.7	8.91±1.36
	median	12.9	38.5	4.69	81.9	27.4	33.3	14.05	302	8.7
	range	10.2-16.4	30.4-48.5	3.92-5.81	75.1-96.5	23.8-32	30.6-36.1	11.7-18.3	181-670	6.5-13
8-10 yrs	mean ± SD	12.87±0.80	38.98±2.95	4.62±0.39	84.04±5.27	27.73±1.70	33.04±1.74	13.9±1.09	304.45±84.1	8.9±1.31
	median	12.9	38.8	4.685	83	27.8	33.15	13.85	301	8.45
	range	11.1-14.7	31.8-46.4	3.59-5.35	75-103.4	24.5-31.2	29.4-37.4	12.2-16.2	121-467	7.2-11.5
10-12 yrs	mean ± SD	12.96±0.94	39.51±3.42	4.75±0.49	83.33±4.54	27.39±2.01	32.78±1.64	14.1±1.72	284.80±84.3	9.13±1.25
	median	13	39.4	4.86	82.6	27.6	32.75	13.9	302	9.2
	range	11-16	31.5-46.9	3.32-5.8	75.1-94.9	23.1-32.8	28.9-35.5	10.8-19.6	120-422	7.4-11.9
12-14 yrs	mean ± SD	13.43±1.23	40.58±3.95	4.81±0.49	84.41±5.64	28.97±6.06	33.06±1.79	14.2±1.79	274.13±67.7	8.54±0.91
	median	13.4	41	4.86	83	27.65	32.7	13.7	267	8.7
	range	11-16.2	31.3-49.1	3.38-5.49	76.3-108.4	24.9-62.1	29.1-36.7	12.3-20.5	186-428	6.7-9.7
> 14 yrs	mean ± SD	13.70±1.47	41.5±4.82	4.9±0.49	86.1±6.0	28.50±2.19	33.0±1.59	14.1±1.91	272.8±70.8	8.9±1.18
	median	13.5	41.9	4.9	85.6	28.6	33.2	13.7	263.0	9.1
	range	11.0-16.3	34.6-49.8	3.9-5.5	76.3-106.3	24.9-34.7	29.1-36.7	12.3-20.5	152-428	6.5-11.3

Table 3. White blood cell and differential counts in healthy Thai children by an automated counter

Age -year	Parameters	Total WBC ($x10^6/mm^3$)	Lym (%)	PMN (%)	Eo (%)	Mo (%)	ANC ($x10^6/mm^3$)
1 yrs	mean ± SD	11.46 ± 3.9	60.58 ± 14.6	29.14 ± 11.3	5 ± 3.5	6.72 ± 2.8	3295.2 ± 1805.2
	median	11.3	61	12	4	7	3634
	range	4.6-20.2	12.8-86	9-50	1-13	3-12	560-6292
2 yrs	mean ± SD	10.58 ± 2.8	60.08 ± 9.8	29.25 ± 9.7	3.9 ± 3.8	8.7 ± 6.9	3137.2 ± 1564.2
	median	10.8	59.5	31.5	2.5	7	2620.5
	range	6.7 - 17	39-74	12 - 44	1 - 13	1 - 25	1480 - 6800
3 yrs	mean ± SD	7.36 ± 0.9	45.33 ± 10.1	46.6 ± 8.8	4 ± 4.08	4.16 ± 2.5	3347 ± 617.5
	median	7.5	40	52	2.5	4	3400.5
	range	5.7 -8.6	34 -62	33 - 57	1-10	2 - 9	2625 - 4004
4 - 6yrs	mean ± SD	8.33 ± 2.5	49.76 ± 12.7	43.3 ± 13.1	4.13 ± 5.7	5.23 ± 3.4	3859.5 ± 1949.5
	median	8.2	47.5	45	2	4	3427
	range	3-14.1	23 - 76	16 - 67	1 - 20	1 -16	1168 - 8170
6 - 8 yrs	mean ± SD	8.73 ± 2.87	44.31 ± 13.3	45.6 ± 11.7	5.13 ± 5.4	5.0 ± 2.8	3445.0 ± 1463.4
	median	7.6	43	43	3.5	5	3517.5
	range	5.5-20	5 - 71	17 - 69	1 - 22	1- 11	568 - 6468
8 -10 yrs	mean ± SD	8.19 ± 2.53	48.41 ± 11.7	42.7 ± 12.8	2.68 ± 2.5	6.37 ± 3.5	3299.5 ± 1496.7
	median	8.3	51	41.5	2	6	3065.5
	range	3.5 -15.6	26 - 81	11 - 64	0 -9	0 - 14	565 - 5974
10 -12 yrs	mean ± SD	8.04 ± 2.71	46.41 ± 13.7	44.86 ± 14.7	4.4 ± 3.5	6.25 ± 4.28	3222.6 ± 1563.7
	median	7.6	47	44	4	6.5	3150
	range	4.2-15.5	17 - 71	19 - 79	1 - 13	1 - 18	798 - 7521
12 - 14 yrs	mean ± SD	7.54 - 1.87	41.06 - 11.5	49.33	4	6.25 ± 4.5	3888.7 ± 1616.1
	median	7.15	40	51	4	6	3618
	range	4.9-11.4	25 - 63	25 - 70	2 - 9	1 - 14	1274 - 7350
> 14 yrs	mean ± SD	7.1 ± 1.98	44.2 ±10.3	45.7 ± 11.5	2.6 ± 1.4	7.4 ± 5	3184.5 ± 1188.3
	median	7.2	44	48	2	6.0	3148
	range	4.5-11.4	28 - 66	15 - 67	1 - 5	1 - 18	675 - 5244

(Note; WBC, white blood count; Lym, lymphocyte; PMN, polymorphonuclear cells; Eo, eosinophil; Mo, mononuclear cells; ANC, absolute neutrophil counts)

count from the reference values.

Thalassemia and hemoglobinopathy are highly prevalent in all parts of Thailand. The allele frequencies differ from region to region and vary among different ethnic origins. The prevalence of a thalassemia carriers, combining all genotypes, is approximately 20-30%[11] while that of β thalassemia vary between 3-9%[5]. The average number of Hb E heterozygotes in Thai population is around 13%, however in the northeastern part of the Country the prevalence is even higher reaching 53% in Surin province[5]. Due to the enormous amount of this genetic background affecting hematological parameters and red blood cell indices, it is of important that we have to exclude individuals with thalassemia disease or carriers from further study for 'normal reference value' in Thai children. However such strategy has not been performed in the first two studies for 'normal' hematology in Thai children[7, 8] due to limiting resources and technical difficulties in the past. Therefore our study presented here provides, for the first time, a reference range for hematological parameters in Thai children who should be free from thalassemic diseases and major thalassemia carriers including β thalassemia and α^0 thalassemia traits.

Our findings also confirmed previous observations[2,14,15] in children who have normal hemoglobin A_2 and F levels that they were more microcytic and hypochromic with lower levels of hemoglobin in the younger age since the total hemoglobin fell rapidly after birth and rose steadily from 18 months[3]. Since the majority of α^0 thalassemia carrier caused by two a gene deletions (- -/αα) from four normal α genes (αα/αα), have a marked microcytosis (MCV < 75 fL,

Table 4. Hemoglobin profiles and reticulocyte percentages in the healthy controls Thai children

Age-years	Parameters	Hb typing		Retic. (%)
		A_2 (%)	F (%)	
1 yrs	mean ± SD	2.83 ± 0.5	1.87 ± 0.3	2.06 ± 1.6
	median	2.8	1.4	1.25
	range	1.9-3.5	0.3-8.7	0.4-6
2 yrs	mean ± SD	2.87 ± 0.35	1.38 ± 0.6	1.37 ± 0.5
	median	2.9	1.2	1
	range	2.1-3.5	0.4-3.4	1-2
3 yrs	mean ± SD	3.01 ± 0.4	1.01 ± 0.4	1.53 ± 0.5
	median	3	1	1.5
	range	2.1-3.5	0.3-1.7	1-2.2
4-6 yrs	mean ± SD	2.81 ± 0.5	1.1 ± 0.7	1.93 ± 2.6
	median	2.85	1	1
	range	1.3- 3.5	0.4-4.7	0.1 - 13
6-8 yrs	mean ± SD	2.92 ± 0.47	1.0 ± 0.6	2.19 ± 2.1
	median	3	1	2
	range	1.3 - 3.5	0.1 - 3.2	1- 11
8-10 yrs	mean ± SD	2.82 ± 0.4	1.02 ± 0.7	1.92 ± 1.2
	median	2.75	1	1.75
	range	2 -3.6	0.2 - 3.2	0.2 - 5
10-12 yrs	mean ± SD	2.89 ± 0.5	1.0 ± 0.7	1.37 ± 0.7
	median	3	0.85	1
	range	1.5 - 3.5	0.2 - 4.2	1 - 3
12-14 yrs	mean ± SD	2.76 ± 0.4	0.89 ± 0.5	1.52 ± 0.8
	median	2.7	0.7	1
	range	1.9 -3.5	0.2 - 2.7	0.7 - 3.3
> 14 yrs	mean ± SD	2.7 ± 0.38	1.1 ± 0.6	1.6 ± 0.8
	median	2.7	1.0	1.2
	range	1.9 - 3.5	0.2 - 2.9	1.0 -3.3

Vip Viprakasit, unpublished data), therefore our criteria should have excluded such heterozygotes from subsequent analysis. Although in this study, we could not identify cases with α^+ thalassemia due to single gene deletions ($-\alpha^{3.7}$ or $-\alpha^{4.2}$) or point mutations, namely non-deletional a thalassemia ($\alpha^T\alpha$ or $\alpha\alpha^T$) because of limitation on molecular analysis. The presence of these α^+ thalassemia carriers should have minimal effects on our analysis since most carriers have almost normal levels of hemoglobin and mean cell volume (MCV).[4,14] These findings suggest that microcytosis observed in early childhood is an intrinsic feature of developmental erythropoiesis and that in most instances this feature cannot be attributed to iron deficiency or α or β-thalassemia syndromes.

In addition, our study demonstrated that the WBC fell steadily from 1 to 3 year with a relative increased proportion of the polymorphonuclear cells (PMN). At the same period, the lymphocyte percentages went down progressively. This age dependent differences in the clinical reference values for white blood cell (WBC) count and differential, observed in this study, is similar to those found from previous studies in other populations[2,13,15]. Therefore, a normal range of WBC count and differentiation described here is of useful for the future reference in Thai children.

In the near future, hematology, as a rapidly evolving field, will become increasingly molecular oriented, both in its diagnostic and in its therapeutic approach. Management of patients will be based on a much more precise understanding of the nature of the disorders that we are treating and will become much more individualized. Soon, effective blood substitutes will certainly be developed and recombinant proteins and gene therapy will improve our management of inherited disorders. One facet that will not change is the irreplaceable value of complete blood count and basic hematological parameters as a basic tool to unravel

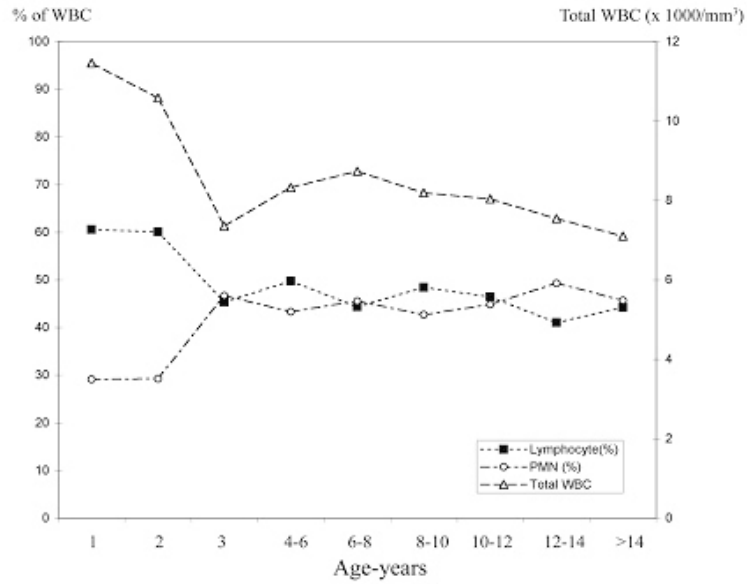

Fig. 1 Variations in total leukocyte count and differential count in the first 14 year of life

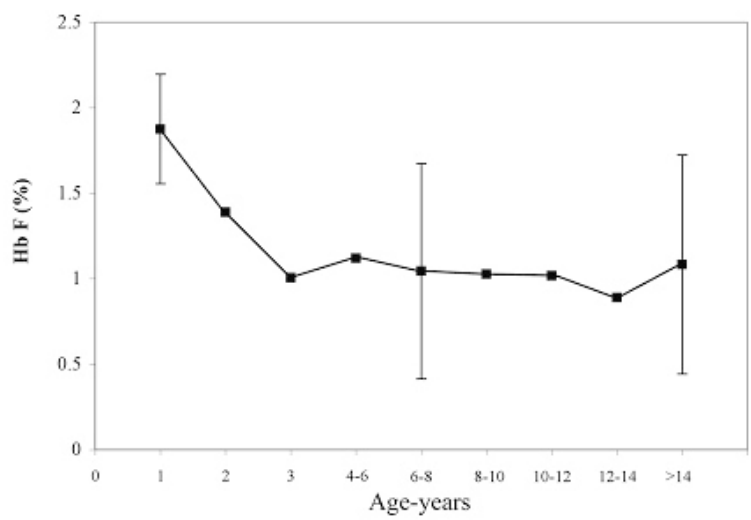

Fig. 2 Age variation in Hb F percentage identified during the childhood period

abnormalities by which differ from the 'normal' references.

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การศึกษาค่าปกติทางโลหิตวิทยาในเด็กไทยซึ่งมีสุขภาพดี เพื่อใช้เป็นค่ามาตรฐานในปัจจุบัน: ฉบับปรับปรุง ปี พ.ศ. 2548

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คณะผู้วิจัยได้ทำการศึกษาย้อนหลังถึงผลการตรวจวิเคราะห์ทางโลหิตวิทยาและค่าดัชนีเม็ดเลือดแดงในเด็กไทยสุขภาพดี จำนวน 395 รายซึ่งมีอายุตั้งแต่ 1 ปี จนถึง 16 ปี ผู้ที่ถูกคัดเลือกในการศึกษาดังกล่าวมีผลการตรวจชนิดของฮีโมโกลบินที่เป็นปกติ คือ ตรวจพบ ฮีโมโกลบินชนิดเอ (Hemoglobin A; Hb A) เป็นหลักและพบฮีโมโกลบินชนิดเอสอง (Hb A_2) น้อยกว่า 3.5% การตรวจทางโลหิตวิทยาในการศึกษานี้ใช้เครื่องตรวจนับเม็ดเลือดชนิดอัตโนมัติซึ่งสามารถตรวจนับจำนวนและจำแนกชนิดของเม็ดเลือดชนิดต่างๆได้ ส่วนการวิเคราะห์ทางฮีโมโกลบินนั้นใช้วิธีการตรวจด้วยแผ่นเซลลูโลสและเครื่องตรวจแยกชนิดฮีโมโกลบินอัตโนมัติด้วยวีธีโครมาโตกราฟฟี่ เนื่องจากภาวะโลหิตจางธาลัสซีเมียชนิดอัลฟ่า พบได้บ่อยในประชากรชาวไทย กลุ่มศึกษาซึ่งมีขนาดเม็ดเลือดแดงเล็กกว่า 75 เฟนโตลิตร จึงถูกคัดออกเพื่อทำให้กลุ่มประชากรที่ศึกษาใกล้เคียงกับภาวะปกติมากที่สุดโดยปราศจากภาวะอัลฟ่าศูนย์ธาลัสซีเมียและเบต้าธาลัสซีเมียแฝง

ผลการศึกษาพบว่าในช่วงอายุ 1- 3 ปีแรกขนาดเม็ดเลือดแดงจะเล็กและปริมาณฮีโมโกลบินในเม็ดเลือดแดงน้อยกว่าเมื่อเทียบกับช่วงอายุอื่นๆ บ่งชี้ถึงการเจริญของการสร้างเม็ดเลือดที่ยังไม่สมบูรณ์นอกจากนี้ยังพบว่าระดับของเม็ดเลือดขาวประเภทของเม็ดเลือดขาวและปริมาณของเกล็ดเลือดเฉลี่ยยังแตกต่างกันไปในแต่ละกลุ่มอายุ ซึ่งรายงานฉบับนี้ได้สรุปค่าปกติ ประเภทต่างของเม็ดเลือดแดงเม็ดเลือดขาวและเกล็ดเลือดเพื่อใช้เป็นค่ามาตรฐานในการอ้างอิงสำหรับประชากรเด็กไทยต่อไปในอนาคต