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FREQUENCIES OF THE POLYMORPHIC TYPES OF RED CELL ACID PHOSPHATASE IN ZAIRIANS AND IN BELGIANS. RELATION BETWEEN PHENOTYPES AND ENZYMATIC ACTIVITIES

by

T. VERVOORT, M. DE VLIEGER-BENSEL & G. VAN ROS

Summary — Red cell acid phosphatase phenotypes of 228 Zaïrians and of 559 Belgians were determined; the following gene frequencies were drawn out of the results : Zaïrians : $p^a = 0.164$, $p^b = 0.797$, $p^c = 0.006$, $p^r = 0.033$; Belgians : $p^a = 0.327$, $p^b = 0.630$, $p^r = 0.043$. In both statistical samples, the relative enzymatic activities linked to the p^a, p^b and p^c alleles were found to be respectively 1.0, 1.6 and 2.1; furthermore the ratio $p^a : p^r$ was 1.2 in Zaïrians.

KEYWORDS : Belgium; Enzymatic activities; Phenotypes; Red cell acid phosphatase; Zaïre.

The red cell acid phosphatase polymorphism was described by Hopkinson *et al.* (1963), who found five electrophoretic patterns of the enzyme and predicted a sixth one, later detected by Lai *et al.* (1964). Family studies were carried out and the results indicated that the electrophoretic phenotypes were controlled by three codominant autosomal allelic genes, subsequently denoted P^a, P^b and P^c (Spencer *et al.*, 1964; Giblett and Scott, 1965; Fuhrmann and Lichte, 1966; Speiser and Pausch, 1967; Lamm, 1970). Another allele, P^r, was first reported in American Negroes (Giblett and Scott, 1965) and found later in other Negro populations (Kirk *et al.*, 1971; Jenkins and Corfield, 1972). The existence of two rare variant genes P^d and P^o was demonstrated by Karp and Sutton (1967) and by Herbich *et al.* (1970). and recently a new phenotype called EB was described by Sørensen (1975).

The different electrophoretic forms of the enzyme were found by Spencer *et al.* (1964) to differ quantitatively in enzyme activity and their data strongly supported the hypothesis that the quantitative effects of the three genes were additive in a single way.

This paper reports the study of the red cell acid phosphatase phenotypes, the gene frequencies and the activity of the enzyme in the different phenotypes in Belgians and in Zaïrians.

Materials and methods

Blood samples of 559 Belgians and 228 Zaïrians living in Belgium were taken at random among those examined in our laboratory for clinical purposes; both groups consisted of unrelated adult persons.

The acid phosphatase electrophoretic phenotype was determined using two different buffer systems, the tris-succinate-citrate system of Hopkinson *et al.* (1964) and the phosphate buffer (Giblett, 1969). Both electrophoresis were followed by staining according to Hopkinson *et al.* (1964). An example of the results obtained is given in figure 1.

The method of Valentine *et al.* (1961), was used for the quantification of the phosphatase activity. The hemoglobin concentration in the hemolysates was 2 g/100 ml and the activity was expressed as micromols of p.-nitrophenol liberated during 30 min at 37 °C per gram of hemoglobin.

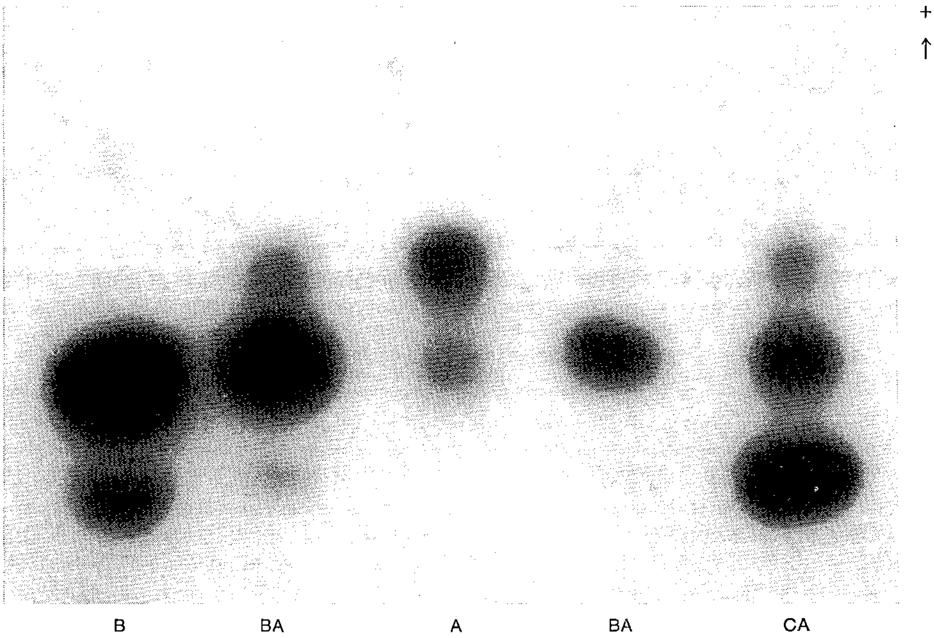

Figure 1

Starch gel electrophoresis of red cell hemolysates showing different acid phosphatase phenotypes (Tris-succinate-citrate buffer system, pH 6.0).

Results

The phenotypes detected in the population samples and the gene frequencies are shown in tables 1 and 2. No significant difference has been found between the observed and the expected phenotypes on the basis of the Hardy-Weinberg equilibrium.

TABLE 1

Distribution of red cell acid phosphatase phenotypes and gene frequencies in a sample of 559 Belgians

Phenotypes	Numbers observed	Numbers expected	χ^2
A	67	59.8	0.867
BA	216	230.3	0.888
B	229	221.9	0.227
CA	16	15.7	0.006
CB	30	30.2	0.001
C	1	1.1	0.009
Totals	559	559	1.998

$\chi^2 = 1.998$, df. $= 3$, $0.50 < P < 0.90$

Gene frequencies : $P^a = 0.327$, $P^b = 0.630$, $P^c = 0.043$

TABLE 2

Distribution of red cell acid phosphatase phenotypes and gene frequencies in a sample of 228 Zaïrians

Phenotypes	Numbers observed	Numbers expected	χ^2
A	7	6.2	0.103
BA	58	59.6	0.043
B	146	145.5	0.004
CA	1	0.5	0.500
CB	2	2.7	0.181
C	0	0	0
BR	12	11.4	0.032
AR	2	2.2	0.018
CR	0	0	0
R	0	0.2	0.200
Totals	228	228	1.081

$\chi^2 = 1.081$, df $= 6$, $P > 0.90$

Gene frequencies : $P^a = 0.164$, $P^b = 0.798$, $P^c = 0.006$, $P^r = 0.031$

Acid phosphatase activity was determined in 173 samples of the Belgians and in 145 samples of the Zaïrians. The results are given in tables 3 and 4. The figures 2 and 3 show the enzyme activities found in the samples of each of the various phenotypic groups.

TABLE 3

Mean, standard deviation and standard error of mean of red cell acid phosphatase activity in the different phenotypes of the Belgian population sample

Phenotype	Number of subjects	Mean	S. D.	S. E. M.
A	28	93	13.4	2.5
BA	79	121	14.4	1.6
B	52	154	17.1	2.4
CA	3	146	11.8	6.8
CB	10	176	13.2	4.2
C	1	197	—	—

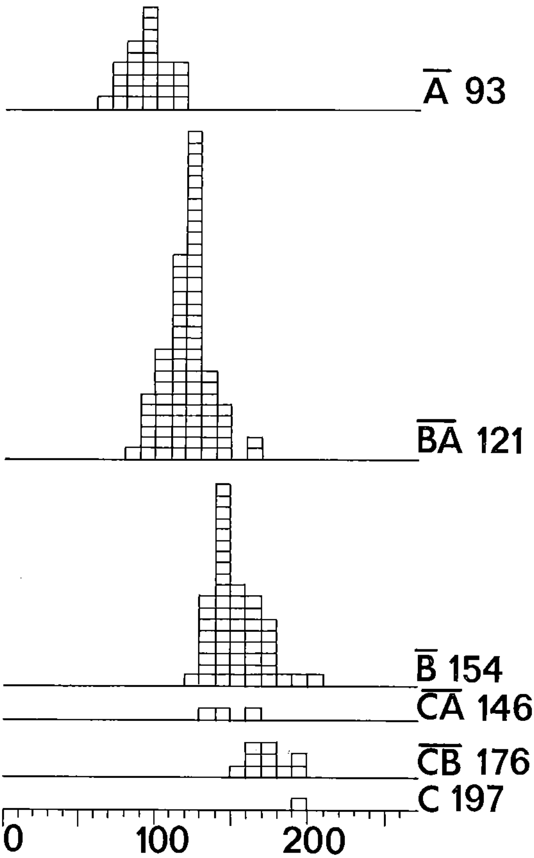

Figure 2

Histogram of the acid phosphatase activity in 173 Belgians according to the different phenotypes. The mean activity for each phenotype is shown on the right. Each square represents one individual. Enzyme activity expressed as μmoles p-nitrophenol liberated in 30 min at 37° C per g Hb.

TABLE 4

Mean, standard deviation and standard error of mean of red cell acid phosphatase activity in the different phenotypes of the Zaïrian population sample

Phenotype	Number of subjects	Mean	S. D.	S. E. M.
A	3	91	4.6	2.6
BA	43	119	26.8	4.1
B	87	153	33.7	3.6
CA	1	151	—	—
CB	1	180	—	—
BR	10	105	27.6	8.7

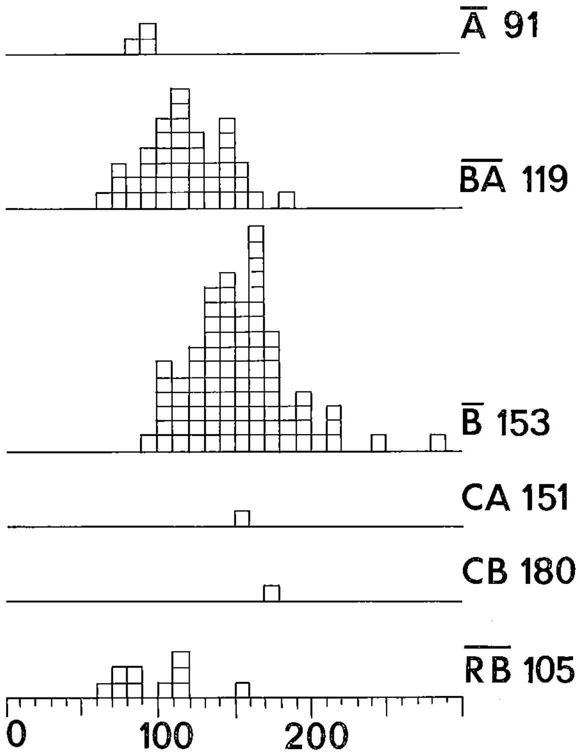

Figure 3

Histogram of the acid phosphatase activity in 146 samples of the Zaïrian Negro population according to the different phenotypes. The mean activity for each phenotype is shown on the right. Each square represents one individual. Enzyme activity expressed as μmoles p-nitrophenol liberated in 30 min at 37° C per g Hb.

Discussion

1. *Acid phosphatase phenotypes in Caucasian populations*

The frequencies observed in Belgians are in agreement with those reported for most European populations (table 5).

TABLE 5

Population	Number of subjects examined	Gene frequency P^a	P^b	P^c	Reference
Germany (Hamburg)	681	0.38	0.56	0.06	Goedde *et al.* (1970)
Norway	210	0.38	0.55	0.07	Heiberg and Amundsen (1973)
Sweden	517	0.37	0.56	0.07	Braman *et al.* (1971)
Czechoslovakia	307	0.36	0.58	0.06	Herzog and Bohatovia (1969)
England	367	0.36	0.60	0.04	Hopkinson *et al.* (1964)
Germany (Berlin)	1,188	0.36	0.58	0.06	Radam *et al.* (1966)
Belgium (Liège)	500	0.35	0.59	0.06	Brocteur *et al.* (1970)
Austria	406	0.35	0.59	0.06	Herbich and Kahlich (1968)
Denmark	679	0.35	0.59	0.06	Lamm (1970)
Swiss	1,365	0.34	0.61	0.05	Pflugshaupt *et al.* (1970)
Belgium	559	0.33	0.63	0.04	Present study
France	487	0.32	0.64	0.04	Van Cong and Moullec (1967)
Poland	1,064	0.32	0.59	0.10	Wysbouchowa (1970)
Italy	782	0.27	0.65	0.08	Modiano *et al.* (1967)

The results of table 5 show that the frequency of the P^a gene found in Italians by Modiano (1967) is distinctly lower than the frequencies found in other European populations; his sample consisted of 417 Romans and 365 Sardinians; also Bottini *et al.* (1971) found a low frequency of the P^a gene in a Sardinian population sample ($P^a = 0.210$). In our laboratory we had the occasion to determine the acid phosphatase phenotypes in 38 Spaniards; we found the following gene frequencies : $P^a = 0.197$, $P^b = 0.750$, $P^c = 0.053$. It seems therefore that the frequency of the P^a gene is smaller in Southern Europe than in Central and Northern Europe; the opposite is true for the P^b gene. A similar conclusion was made by Ananthakrishnan *et al.* (1972) in their study of the world distribution of the red cell acid phosphatase phenotypes.

2. *Acid phosphatase phenotypes in African Negro people*

Studies made among Negro populations are scarce. Table 6 shows the gene frequency in some Negro Populations of South and Central Africa.

TABLE 6

Population	Number of subjects examined	P^a	Gene frequency P^b	P^c	P^r	Reference
Mozambique	317	0.16	0.81	0.001	0.003	Giblett (1969)
S. Africa (Durban)	304	0.14	0.83	0	0.037	Kirk *et al.* (1971)
S. Africa (Cape Town)	198	0.14	0.84	0	0.02	Hopkinson (1968)
Zaïre	228	0.16	0.80	0.006	0.034	Present study

These results show that the P^a gene is significantly less frequent in Negroes than in Europeans and that the inverse is found for the P^b gene. The P^c gene is rare or absent. The most remarkable fact is the presence of the P^r gene in all the African populations examined so far, whereas it is not found in Europeans.

3. *Geographical distribution of the acid phosphatase alleles*

In all populations studied the P^a and P^b genes are present; the frequency of the P^b allele is always higher than of the P^a allele except in Alaskan Eskimos and Indians (Scott *et al.*, 1966).

The frequency of the P^c gene varies between 0.04 and 0.10 in Caucasian people; in Negroes it is very rare as shown in table 6.

So far P^r is only found in Negroid populations with very high frequency of 0.23 in Khoisan people of South Africa (Jenkins and Corfield, 1972). In Negro people the frequencies range from 0.03 in Central Africa (present study) to 0.10 in South Africa; this difference might be due to gene flow from the Khoisans into the South African Bantus (Jenkins and Corfield, 1972).

4. *Interpretation of the quantitative data*

Spencer *et al.* (1964) postulated that the quantitative effects of the acid phosphatase genes were additive in a single way. Meanwhile this theory has been confirmed by various other investigators (Giblett and Scott, 1965; Modiano *et al.*, 1967; Jenkins and Corfield, 1972; Eze *et al.*, 1974).

The data found in the Belgian sample do not differ significantly from those reported for other Caucasian populations (table 3). As the different methodologies used in the various laboratories give different absolute results, we made a ratio between the enzyme activity per gene, putting the value of the P^a gene at 1.0 (table 7).

TABLE 7

Acid phosphatase activity per gene in different Caucasoid populations

Population	Activity per gene P^a	P^b	P^c	Reference
England	1.0	1.5	1.9	Spencer *et al.* (1964)
Italy	1.0	1.3	1.8	Modiano *et al.* (1967)
England	1.0	1.5	2.0	Eze *et al.* (1974)
Belgium	1.0	1.6	2.1	Present study

Using the data of table 4, the same calculation was made for the Negro sample (table 8).

TABLE 8

Acid phosphatase activity per gene in two African populations

	Activity per gene				
Population	P^a	P^b	P^c	P^r	Reference
S. Africa	1.0	1.5	—	1.0	Jenkins and Corfield (1972)
Zaïre	1.0	1.6	2.1	1.2	Present study

Examination of tables 3, 4, 7 and 8 shows that the enzyme activity per gene in Negro and Caucasian populations is generally the same; only in the Italian sample the P^b allele seemed to produce less enzyme than it did in the other populations; however more extensive studies on enzyme levels in identical phenotypes in different population groups are needed before any definite conclusion can be made.

Résumé — **Les fréquences des types polymorphiques de la phosphatase acide érythrocytaire chez les Zaïrois et les Belges. Relation entre phénotypes et activités enzymatiques.**

Les phénotypes de la phosphatase acide érythrocytaire de 228 Zaïrois et de 559 Belges ont été déterminés; les fréquences géniques suivantes ont été déduites des résultats : Zaïrois : p^a = 0,164, p^b = 0,797, p^c = 0,006, p^r = 0,033; Belges : p^a = 0,327, p^b = 0,630, p^c = 0,043. Dans les deux échantillons statistiques, les activités enzymatiques relatives liées aux allèles p^a, p^b et p^c furent respectivement 1,0, 1,6 et 2,1; de plus chez les Zaïrois le rapport p^a : p^r fut de 1,2.

Samenvatting — **De frekwenties der polymorfe typen van de zure fosfatasen der rode bloedcellen bij Zaïrezen en Belgen. Verhouding tussen fenotypen en enzymatische aktiviteiten.**

Bij 228 Zaïrezen en 559 Belgen werden de fenotypen van de zure fosfatasen der rode bloedcellen bepaald; volgende genen frekwenties werden van deze resultaten afgeleid : Zaïrezen : p^a = 0,164, p^b = 0,797, p^c = 0,006, p^r = 0,033; Belgen : p^a = 0,327, p^b = 0,630, p^c = 0,043. In de twee statistische stalen bedroegen de relatieve enzymatische aktiviteiten gebonden aan de p^a, p^b en p^c allelen respectievelijk 1,0, 1,6 en 2,1; daarenboven was de verhouding p^a : p^r bij de Zaïrezen 1.2.

Department of Tropical Hematology (Prof. G. Van Ros),
Institute of Tropical Medicine, Nationalestraat 155, B-2000
Antwerpen, Belgium.
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