most resistant line was CBA and the most sensitive was C57Bl/6. The practical use of animals of these two lines, opposite as regards their sensitivity to the pathogenic action of living EV microbes, and differing from one another in their levels of corticosteroids, activity of nonspecific defense factors, and mobility of phagocytes [3, 4, 6], can be recommended for the study of the mechanisms of natural and acquired resistance to plague infection, and also for the study of residual virulence of strains of *Y. pestis* proposed for use as vaccine strains.

LITERATURE CITED

1. V. I. Zhabin, Problems in Microbiology and Laboratory Diagnosis of Especially Dangerous Infections [in Russian], Saratov (1965), pp. 261-265.
2. O. R. Kuznetsova, E. M. Svintsova, and T. I. Anisimova, Problems with Especially Dangerous Infections [in Russian], No. 2, Saratov (1969), pp. 159-161.
3. Lines of Laboratory Animals for Medico-Biological Research [in Russian], Moscow (1983).
4. R. V. Petrov, R. M. Khaitov, V. M. Man'ko, and A. A. Mikhailova, Control and Regulation of the Immune Responses [in Russian], Leningrad (1981).
5. V. E. Pigarevskii, Arkh. Patol., No. 9, 3 (1975).
6. V. A. Taranov, Zh. Mikrobiol., No. 2, 57 (1985).
7. I. S. Freidlin, The System of Mononuclear Phagocytes [in Russian], Moscow (1984).

ANALYSIS OF THE COMPOSITION OF SKELETAL MUSCLE FIBERS IN SKATERS' MUSCLES

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The present view is that the relative percentage of slow type I muscle fibers (MF) in human muscles is genetically determined and remains unchanged during training [1-4]. Hence it follows that the best opportunities for the achievement of good results during endurance training, other conditions being the same, will be a feature of persons whose skeletal muscles contain many MF of this type, and that successful performance in speed and strength training will correlate with a large number of intermediate type IIa MF and of fast type IIb MF. Racing skaters compete over distances ranging from 500 to 10,000 m. The skaters prefer to compete over distances at which they have exhibited their best results. That is why this type of sport is a good model with which to study the relationship between athletic results and the composition of MF in the skeletal muscles. No research devoted to the study of the composition of MF in skaters' muscles and its correlation with the chosen distance and athletic achievement could be found in the accessible literature.

EXPERIMENTAL METHODS

Fragments of the vastus lateralis muscle at the boundary between its middle and lower thirds were obtained by punch biopsy from 103 volunteer skaters aged 18-25 years, of whom 27 specialized in short and 76 in long distances. The muscle fragments were frozen in cold (−78°C) petroleum benzin and serial sections 12 μ thick were cut in a cryostat, and used to determine myosin ATPase activity after preincubation at pH 4.6 and 10.4 [5]. The relative percentages of MF of different types were determined by comparing the results of the reaction for ATPase after the two different preincubations. Sections containing fewer than a total of 100 muscle fibers were not investigated. The results were subjected to statistical analysis by the usual methods.

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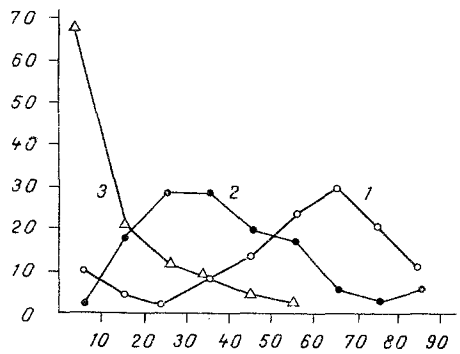

Fig. 1. Distribution of MF of different types in muscles of skaters (n = 103). Abscissa, number of MF, %; ordinate, number (in %) of athletes with a particular percentage of MF.

EXPERIMENTAL RESULTS

The composition of MF for all groups of skaters was characterized by the following parameters: type I 54 ± 2%, type IIA) 35 ± 1%, and type IIB) 11 ± 1%. This composition also is characteristic of nonathletes [1]. On the variance curve (Fig. 1) two maxima can be clearly distinguished for MF of type I (0-10 and 60-75%), for MF of type IIA, besides the principal maximum (about 30%) an additional unresolved maximum (about 50%) also can be detected, whereas the curve reflecting the distribution of type II MF rises to a very sharp maximum and is shifted considerably to the left. In other words, in all cases the existence of significant deviations from the normal distribution can be deduced, and in the case of MF of types I and IIB this is confirmed analytically also and is due to the heterogeneity of the population. The probable cause of this heterogeneity may be the different specialization of the athletes studied. In sprinters (n = 27) the muscles contain 37 ± 5% of type I MF, 43.4% of type IIA MF, and 20 ± 4% of type IIB MF. In long-distance runners (n = 76) the number of type I MF was 59 ± 2%, of type IIA MF 33 ± 2%, and of type IIB MF 8 ± 1% of all MF. The difference between the relative proportion of MF of all types in muscles of long- and short-distance skaters was significant ($p < 0.001$). In the group of short-distance skaters there was considerable scatter of the data: type I from 2 to 84% (V = 78%), type IIA from 14 to 85% (V = 43%), and type IIB from 0 to 58% (V = 96%). The group of skaters was subdivided by a statistical method, depending on the content of type I MF, into two subgroups, differing significantly also in their content of MF of other types (in all cases $p < 0.001$). In the first subgroup the number of type I MF was 9 ± 2%, of type IIA MF 57 ± 4%, and of type IIB MF 34 ± 5%; the corresponding numbers in the second subgroup were 62 ± 3, 30 ± 3, and 8 ± 2%. It was found that the subgroups of skaters differed in the qualifications of the athletes included in them. Whereas in the first subgroup 54% of the skaters had high and 31% had average qualifications, in the second subgroup the corresponding figures were 7 and 50%. On the basis of the coefficient of association (K) of qualitative features, correlation between the subgroup in which the short-distance skaters was placed and their level of qualification was significant (K = 0.42, $p < 0.05$). Whereas the 10 best athletes for a distance of 500 m included eight (62%) from the first subgroup of athletes, and one (7%) from the second, for a distance of 1000 m the corresponding figures were five (38%) and one (7%).

Comparison of the percentages of MF in the muscles of short-distance skaters with different levels of qualification yielded the following data: in muscles of highly trained athletes (n = 8) there were 13 ± 8% of type I MF, 56 ± 6% of type IIA MF, and 31 ± 7% of type IIB MF; in muscles of athletes with an average level of training (n = 11) there were 44 ± 8, 40 ± 6, and 16 ± 7% respectively, and in the muscles of athletes with a low standard of training (n = 8) there were 51 ± 10, 34 ± 5, and 15 ± 6%. Differences in percentages of MF of types I and IIA in the muscles of highly trained athletes, on the one hand, and of athletes with average and low levels of training, on the other hand, are statistically significant ($p < 0.01$ and < 0.05 respectively).

It follows from the facts described above that the muscles of highly trained short-distance skaters are characterized by a low percentage of type I MF and a higher percentage of types IIA and IIB. Thus the best results over short distances can be expected from athletes whose muscles contain not more than 25-30% of type I MF.

The composition of MF in the muscles of the long-distance skaters was more homogeneous: of 76 skaters, a low percentage of type I MF was observed in only two individuals with a low standard of training. If the figures for these two skaters who, in our opinion, had been incorrectly directed by the trainers for specialization, were disregarded in the calculations, the distribution of MF in the muscles of the long-distance skaters did not differ significantly from normal. Their division into subgroups based on percentage of MF cannot therefore be justified. Comparison of the composition of MF in the muscles of long-distance skaters with different levels of training showed that muscles of skaters with a high (n = 15), average (n = 38), and low level of training (n = 21) do not differ in their percentage of MF of type I (60 ± 4, 62 ± 2, and 61 ± 3% respectively) and type IIA (33 ± 4, 32 ± 2, and 28 ± 2%). With respect to the percentage of type IIB MF, muscles of athletes with high (7 ± 2%) and average (6 ± 1%) levels of training differed from muscles of long-distance skaters with a low standard of training (11 ± 2%; $p < 0.001$); however, these differences can hardly be taken as the basis for practical conclusions, more especially because under the influence of endurance training, type IIB MF can acquire certain properties of type IIA MF [2]. It will be evident that if the content of type I MF in the muscles is about 60% or more it will guarantee successful performance at long distances, and athletic performance in this case is linked with other factors such as, for example, better training techniques.

Thus the percentage of type I MF in muscles determines successful performance of physical work of a definite relative power and duration. For short distances (speed and strength activity) it is recommended that athletes whose muscles contain not more than 30% of type I MF be recommended for specialization, whereas for longer distances (endurance work) athletes whose muscles contain 60% or more MF of this type should be recommended.

LITERATURE CITED

1. Yu. A. Afanas'ev, S. L. Kuznetsov, T. G. Kutuzova, et al., Teor. Prakt. Fiz. Kul't, No. 12, 41 (1986).
2. E. F. Coyle, W. H. Hartin, S. A. Boomfield, et al., J. Appl. Physiol., 59, 853 (1985).
3. V. Klissouras, Sport Wyczinowy, No. 8-9, 200 (1981).
4. P. V. Komi and J. Karlsson, Acta Physiol. Scand., Suppl. 462, 1 (1979).
5. H. A. Padikula and E. Herman, J. Histochem. Cytochem., 3, 161 (1955).