Dependence of speed qualities and elemental status on the mercury level in the mane hair of purebred riding horses

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Abstract. To assess the influence of the level of mercury in the hair from the mane on athletic performance and elemental status of horses, a study was carried out on purebred horse breed stallions. Age at the time of sampling of hair 5-7 years. The elemental composition of biosubstrates was determined by 25 indicators, by atomic emission and mass spectrometry (AES-ICP and MS-ICP). The assessment of the speed qualities of stallions was carried out in sports competitions according to the time of passing a distance of 2400 meters. It was found that the effect of the level of mercury in the hair from the mane on the speed qualities of stallions (r = −0.57). Moreover, if stallions with a mercury concentration of less than 0.0018 mg/kg spent 158.6 ± 3.5 seconds to overcome the distance, at a level of 0.0767-0.304 mg/kg, on average 15 seconds longer. Comparison of the groups with the boundaries of the reference intervals of the concentrations of chemical elements in the mane showed that the high agility of the horses was associated with a relatively smaller number of elements exceeding the boundaries of the intervals, so if there were four of them in group I: K, Na, I, Sn, then in II and III groups of them were eight Ca, K, Na, I, Zn, Pb, Sn, Hg and Ca, Cu, Zn, B, Si, Li, Sn, Hg, respectively. It was revealed that the elemental composition of the hair of the mane is closely related to the sports results of thoroughbred riding horses, and for some of them the changes exceeded 250% (Si). It was concluded that it is necessary to study the concentrations of Hg and Si in the hair from the main during preparation for the competition, for their further correction.

1. Introduction
Minerals play an important role in biological processes in the body, as structural components of the body and macromolecules, they are involved in muscle contraction, nerve impulses, oxygen transport, activation of enzymes and hormones, immune functions, antioxidant activity and others [1].

Recent studies have shown a relationship between the level of provision with chemical elements and sports results in humans [2], horses [3, 4].

The importance of controlling the level of mineral nutrition of athletes is due to their professional activities associated with increased psychoemotional and physical loads, during the competitive periods the need for which increases several times [1,5]. Insufficient intake of chemical elements with the diet leads to a decrease not only in sports results, but also in a multifaceted palette of pathologies, which are based on violations of their balance [6,7].
Toxic chemical elements are one of the cofactors for the deterioration of human health, the development of pathologies and a decrease in the productive qualities of farm animals. This is determined by the versatile negative effects of these substances [8-10].

The scanty literature data on the elimination of toxic elements depending on physical activity [11,12] do not reveal their influence on sports results.

To control and optimize the intake of mineral substances in the diet, more and more resort to non-invasive methods for assessing metabolism in the body, including the determination of the multi-element composition of biosubstrates, among which hair is increasingly considered.

This is explained by the fact that the concentrations of many elements in biosubstrates correlate with important sports indicators, such as endurance [13], physical performance [14], stress resistance [15].

In this regard, it seems promising studies aimed at studying the speed qualities of horses and the level of concentrations of chemical elements in the hair of the mane.

**Purpose of the study.** Study of the speed qualities and elemental status of purebred riding horses from the level of mercury in the hair of the mane.

**2. Material and research methods**

The protocol of the present investigation was approved by the Local Ethics Committee of the Orenburg State University, Orenburg, Russia. All animal studies have been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

**2.1. Experiment scheme**

The studies were carried out on purebred horse breed stallions (n = 49, age 5-7 years), participating in a race at a distance of 2400 meters, bred in one of the regions of Russia - Stavropol Territory, which, based on the elemental analysis of hair, depending on the concentration of Hg divided into three groups:

- I - up to the 25th percentile,
- II - 25-75 percentiles,
- III - above the 75th percentile.

**2.2. Evaluation of speed qualities**

The study of speed qualities was carried out according to the results of the performances of stallions in competitions at a distance of 2400 meters.

**2.3. Hair sampling**

To study the elemental composition of hair, samples with a mass of at least 0.4 g were taken from the area of the mane in the projection area of the first cervical vertebra; the samples were taken immediately after the competitive process. For selection, stainless steel scissors were used, which were pretreated with ethyl alcohol. The sample was formed from the proximal part of the mane 15 mm long from the hair root.

**2.4. Elemental status assessment**

To study the elemental composition of hair, samples with a mass of at least 0.4 g were taken from the area of the mane in the projection area of the first cervical vertebra; the samples were taken immediately after the competitive process. For selection, stainless steel scissors were used, which were pretreated with ethyl alcohol. The sample was formed from the proximal part of the mane 15 mm long from the hair root.

**2.5. Statistical processing**

The Shapiro - Wilk test was used to test the hypothesis about the normal distribution of quantitative traits. Statistical comparison of the results was carried out using the Mann-Whitney U and Student's test. In all procedures of statistical analysis, the achieved level of significance (p) was calculated, while the critical level of significance in this study was taken to be less than or equal to 0.05. The data were
processed using the Statistica 10.0 software package (Stat Soft Inc., USA). The tables show the average values of indicators (M) and their standard deviations (± STD).

3. Results
Actual intergroup differences in hair Hg concentration in purebred stallions are shown in figure 1.

**Figure 1.** Hg content (mg / kg) in mane hair of purebred riding stallions by group (Note: *** - P<0.001 compared with I group).

The hair of stallions of group II contained 15 (P≤0.001) times, and III - 87 (P≤0.001) times more mercury, compared with group I.

Evaluation of sports results depending on the level of mercury in the hair showed their decrease with an increase in its concentration (figure 2).

**Figure 2.** The agility of purebred riding stallions at a distance of 2400 m (s) (Note: *** - P<0.001 compared with I group).
Stallions of the III group spent more time on passing the distance in comparison with the I group by 9.67 and II - 8.83%.

The elemental composition of the hair of the compared groups differed in the content of a number of chemical elements (Table 1).

**Table 1.** Concentration and percentile values of chemical elements in the mane hair of purebred riding horses depending on the Hg percentile interval, mg/kg.

| Element     | Reference interval (25-75 percentile)1 | Group |
|-------------|----------------------------------------|-------|
|             |                                       | I     | II     | III    |
| **Macronutrients** |                                      |  | | |
| Ca          | 872-1369                               | 1184±317 | 1441±399 | 1405±444 |
| K           | 566-1307                               | 1376±1220 | 1947±1392 | 826±458 |
| Mg          | 362-618                                | 537±221 | 593±200 | 515±306 |
| Na          | 207-1177                               | 1738±2057 | 2011±1941 | 668±595 |
| P           | 418-534                                | 422±81 | 457±63 | 530±84** |
| **Essential trace elements** |                                  |  | | |
| Co          | 0.01-0.022                             | 0.011±0.003 | 0.012±0.004 | 0.013±0.005 |
| Cr          | 0.06-0.14                              | 0.091±0.042 | 0.125±0.088 | 0.141±0.064* |
| Cu          | 5.09-6.04                              | 5.55±0.48 | 5.84±0.53 | 7.96±2.22*** |
| Fe          | 14.94-37.61                            | 20.2±9.8 | 21.0±10.7 | 24.0±8.7 |
| I           | 0.094-0.72                             | 1.27±1.02 | 0.77±0.88 | 0.59±0.32* |
| Mn          | 0.93-2.08                              | 1.26±0.64 | 1.59±0.67 | 1.69±1.07 |
| Se          | 0.36-0.53                              | 0.46±0.11 | 0.48±0.10 | 0.49±0.14 |
| Zn          | 121-141                                | 129.6±13.5 | 142.2±44.8 | 147.5±19.9** |
| **Conditionally essential trace elements** |                      |  | | |
| B           | 1.44-3.16                              | 2.23±1.28 | 2.01±1.02 | 1.36±0.45* |
| Si          | 4.95-16.47                             | 9.73±6.33 | 7.34±8.10 | 2.70±0.84*** |
| Li          | 0.026-0.103                            | 0.056±0.068 | 0.096±0.080 | 0.326±0.154*** |
| Ni          | 0.093-0.175                            | 0.132±0.044 | 0.157±0.245 | 0.140±0.177 |
| V           | 0.013-0.058                            | 0.022±0.015 | 0.039±0.044 | 0.039±0.014** |
| As          | 0.011-0.025                            | 0.014±0.006 | 0.017±0.010 | 0.014±0.007 |
| **Toxic trace elements** |                         |  | | |
| Al          | 4.49-18.89                             | 7.73±6.46 | 5.38±4.23 | 10.19±10.82 |
| Sr          | 1.89-3.89                              | 2.77±1.32 | 2.53±1.04 | 2.31±0.83 |
| Pb          | 0.035-0.181                            | 0.060±0.040 | 0.126±0.248 | 0.055±0.043 |
| Sn          | 0.007-0.028                            | 0.061±0.170 | 0.043±0.100 | 0.029±0.034 |
| Cd          | 0.003-0.01                             | 0.008±0.007 | 0.009±0.008 | 0.005±0.005 |
| Hg          | 0.002-0.004                            | 0.002±0.001 | 0.023±0.020*** | 0.138±0.061*** |

* P≤0.05; ** P≤0.01; *** P≤0.001 compared to group 1

1 – the boundaries of the 25-75 percentile interval are presented according to previously published data [16]

If the differences in the concentrations of chemical elements in the hair between groups I and II were obtained only for one element: Hg, then between groups I and III there are already ten of them: P, Cr, Cu, I, Zn, B, Si, Li, V, Hg, there are six between groups II and III: K, Na, P, Cu, Li, Hg. Moreover, the differences for individual elements exceeded 200%.

In general, the elemental status of horses, established by the composition of the hair, with a low mercury content (group I) corresponded to the reference interval for the largest number of elements (25-75 percentile), except for 4 elements: K, Na, I, Sn. As the concentration of Hg in the hair increases, the number of elements outside the 25-75 percentile increases. So, for purebred horse breed stallions of the II group, differences are characteristic with reference intervals for 8 elements: Ca, K, Na, I, Zn, Pb, Sn, Hg; III group of 8 elements: Ca, Cu, Zn, B, Si, Li, Sn, Hg.
Individual assessment of the elemental status of the horses with the highest and lowest athletic performance also demonstrated the importance of assessing the level of mercury in the hair from the mane. As an example, we present the elemental profile of the stallions of the record holders Conard Lord and Mr. Chucky (figures 3 and 4).

**Figure 3.** Multiplicity of differences in the elemental composition in mane hair of the record holder Conard Lord (born in 2012, agility at 2400 m - 154.3 seconds) of a purebred riding stallion from the reference intervals (25-75 percentile) of chemical elements content in the hair (given by Skalny's method).

**Figure 4.** Multiplicity of differences in the elemental composition in mane hair of the record holder Mister Chucky (born in 2013, agility at 2400 m - 154.9 seconds) of a purebred riding stallion from the reference intervals (25-75 percentile) of chemical elements content in the hair (given by Skalny's method).
And also the elemental profile of the slowest stallions at a distance of 2400 meters Sandora and Sidi Zhmur (figures 5 and 6).

**Figure 5.** Multiplicity of differences in the elemental composition in mane hair of the record holder Sandor (born in 2015, speed at 2400 m - 184.9 seconds) of a purebred riding stallion from the reference intervals (25-75 percentile) of chemical elements content in the hair (given by Skalny's method).

**Figure 6.** Multiplicity of differences in the elemental composition in mane hair of the record holder Sidi Zhmur (born in 2014, agility at 2400 m - 178.9 seconds) of a purebred riding stallion from the reference intervals (25-75 percentile) of chemical elements content in the hair (given by Skalny's method).
4. Discussion
The mineral metabolism of athletes is characterized by high intensity and speed of processes [17, 18]. Chemical elements are necessary for a wide range of metabolic and physiological processes in the body of athletes; their participation in muscle contraction, oxygen transport, conduction of nerve impulses, immune functions and others has been proven [1].

The increased toxic load is one of the factors of health deterioration, decrease in sports results, development of pathologies [8,9]. Mercury belongs to a number of highly toxic chemical elements, an increase in the level of which causes DNA damage, lipid peroxidation, oxidation and deactivation of proteins, and is also associated with cardiovascular diseases [19,20].

In this regard, the main purpose of these studies was to assess the level of mercury in the hair and its effect on the speed performance of thoroughbred riding horses. The choice of the concentration of mercury as a criterion for assessing sports results was due to the performed correlation analysis, which showed a significant relationship with speed qualities (r = −0.57). This was confirmed in the future, as a group of stallions with a mercury concentration in the hair of 0.0767-0.304 mg/kg walked the distance of 2400 meters on average 15 seconds slower than animals with a level of less than 0.0018 mg/kg.

Comparison of the groups with the reference intervals of the concentrations of chemical elements in the mane showed that the high agility of horses was associated with a relatively smaller number of elements going beyond the boundaries of the intervals, so if there were four of them in group I, then in groups II and III there were eight of them, such the pattern was earlier obtained by us on trotting horses [4].

One of the evidence of antagonistic interactions of toxic and essential elements in our case was the level of iodine in the hair of horses. So in the group of record-breaking stallions, its level was 1.27 mg/kg, which is higher than in the group of animals of group II by 64.9%, in group III - by 115.2% (P≤0.05). A decrease in the level of iodine was noted against the background of an increase in the concentration of mercury in the hair, this pattern was also manifested in studies obtained on children when assessing Kashin-Beck diseases [21] and autism [22].

It should be noted that a decrease in speed qualities in this study was associated with a 3.6-fold decrease in the level of silicon in the hair between groups I and III, which is known to play an important role in neutralizing heavy metals and radionuclides, maintaining immunity, vascular elasticity, and hormone synthesis. and others [23,24].

The construction of elemental profiles of stallions of record-holders Conard Lord, Mister Chucky with a reduced level of toxic elements and slow Sandora and Sidi Zhmur, who exceeded the reference intervals for 2 and 3 toxic elements, was indicative.

5. Conclusion
The elemental composition of mane hair is closely related to the athletic performance of thoroughbred riding horses.

In order to increase athletic performance in equestrian sports during the preparation for a competition, it is necessary to assess the Hg and Si concentrations in the hair from the mane. Further research is needed to expand the sample of animals and include different distances.

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