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Behavioral Peculiarities of the *Equidae* Family in the Conditions of the Moscow Zoo Stud Farm

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Abstract

For a comparative analysis of the behavior of wild and domestic equids (Perissodactyla) of the equine (Equidae) family in the stud farm of the Moscow Zoo, the ratios of different forms of behavior in the following species have been studied: the domestic horse (Equus caballus), Przewalski's horse (Equus Przewalskii), kiang (Equus kiang) and an ethological assessment of the level of animal welfare is given. It was found that in the behavioral repertoires of Przewalski's horses and domestic horses there was a significant similarity in the duration of such forms of active behavior as food and water intake, auto-grooming, allogrooming, urination, and defecation. However, Przewalski's horses showed higher physical activity, moving around the enclosure and exploring the environment, by 10% and 2%, respectively, and also showed aggression much less frequently. It was found that the absence of a male in the group of domestic horses increased the frequency of aggression by 1.8 times as compared with the group of Przewalski's horses. The ratio of behavioral patterns in kiang horses has a different structure, except for such metabolic manifestations as water intake and urination. Representatives of this species spent 1.4 times less time on food intake, while simultaneously increasing the time for defecation by 1.8 times, showed low motor activity, exploratory activity, and a high level of aggression, and also spent more time on allogrooming. The noted features in the behavior of the kiangs indicate the stressful state of animals, and, as a consequence, the low level of their welfare.

Keywords: Przewalski's horse, Domestic horse, Kiang, Stress

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Introduction

The behavior of animals is important in the process of their evolutionary development and domestication. Animals adapt to changes in the environment primarily by changing the reaction of their behavior. In the modern world, thanks to nature conservation, research, and recreational activities, zoos make a significant contribution to maintaining biodiversity on the planet, contributing to the conservation of endangered animal species and their natural habitats (de Graaff *et al.*, 2015). Even in the recent past, zoos were only a place for the demonstration of animals, and now they serve as a scientific platform for educational activities in the field of nature conservation (Hemsworth *et al.*, 2015). In recent years, there has been significant progress in the knowledge of the biology of animals of different species, and the results of scientific research, applied in practice, make it possible to create optimal conditions for their existence in captivity, thereby achieving high standards of welfare (de Graaff *et al.*, 2015). Leading zoos view animal welfare as a paramount factor in keeping and breeding wild animals in their collections (Rose, 2018). Assessing animal welfare is the key factor to improve the quality of animal life (Coe & Hoy, 2020). One can speak of a high level of animal welfare if the animals are healthy, eat well, can exhibit the behavior characteristic of their species, and do not experience any discomfort (fear, pain, suffering, etc.) (Maple & Bocian, 2013). Accumulating more and more information intended for further understanding the welfare of different species of animals, it became obvious that a high standard of welfare presupposed the satisfaction of not only physical but also psychological needs of animals (Watters, 2014; Ksenofontova *et al.*, 2020).

The domestication process introduced significant changes in the behavior of animals, but the vital and zoosocial needs of domestic animals and their wild ancestors do not differ significantly (Vonk, 2021). On the one hand, knowledge of the behavior of closely related wild species helps to create the most favorable living conditions for the domestic species, in particular domestic horses (Davies *et al.*, 2020). On the other hand, it allows organizing the maintenance of the wild species in captivity in such a way as to maintain their mental and physical health at a high level (Tadich, 2020).

However, captive animals often have problems that they do not encounter in nature. Living in a zoo or stud farm, they do not look for food, they do not need to hide or run away from enemies, there is no need to show observation, ingenuity, and knowledge of the situation to survive. Much of what makes up the life of most animals in nature, to which species have adapted over many centuries of evolution, is simply absent in captivity. Animals become bored if they do not have the opportunity to demonstrate their unique species abilities while experiencing a state of stress (Fischer & Romero, 2019).

One of the domesticated species of animals is the domestic horse, which, having existed next to humans for many centuries, has recently been increasingly used not for the military, economic, and food purposes, but as a sports partner and the scope of its use by humans is constantly expanding. Although horses were domesticated by the beginning of the 4th millennium BC, their behavior does not differ significantly from that of their wild relatives. Before domestication, individual horse populations were subjected to long-term geographic isolation from each other, which led to the emergence of separate species that still exist today (Freymond *et al.*, 2020). At present, the structure and color of the domestic horse have little resemblance to their wild ancestors, but at the same time, one can find many similarities in them. The behavioral and physiological parameters of horses did not undergo significant changes in the process of domestication; therefore, domestic horses easily adapt to the wild lifestyle, while demonstrating the high survival rate characteristic of animals that have not undergone domestication (Janczarek *et al.*, 2020). Of all the currently existing species of the equine family, the domestic horse bears the greatest resemblance to the Przewalski's horse. Although genetic studies confirm this, there are differences in the set of chromosomes in these species. The domestic horse has 64 diploid chromosomes, while the Przewalski's horse has 66. Such differences may indicate that these subspecies are distinct, but at the same time, they may be part of the same species exhibiting chromosomal polymorphism. Hybrids obtained by crossing a Przewalski's horse with a domestic horse give fertile offspring that has a set of 65 diploid chromosomes. The similarity between these species is confirmed by studies of blood group and whey protein (Freymond *et al.*, 2020).

The last representative of living wild horses, which have disappeared in nature and survived on our planet thanks to the activities of zoos and stud farms, is the Przewalski's horse. This subspecies is included in the Red Book of the Russian Federation, the International Union for Conservation of Nature (IUCN) Red List as extinct in the wild, and Appendix 1 of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). From 1992 to the present, work has been going on for the reintroduction of this subspecies into nature, in particular in Mongolia and Russia (Klimov, 2018). Another representative of wild equids is the kiang, which belongs to the equine (Equidae) family and forms a separate species in the horse genus. The habitat of this species is Tibet and the surrounding regions.

The behavior of animals is of great importance in the process of their evolutionary development and domestication. Animals adapt to changes in the environment primarily by changing the reaction of their behavior. Cognition of the historical ways of forming the patterns of animal behavior and the factors determining them is of great theoretical value and practical importance for solving economic issues of keeping wild and domestic animals. Assessment of the behavioral repertoire of wild and domestic equids in a zoo plays an important role in further characterizing the level of their welfare (Maple & Segura, 2015). A parallel study of the behavioral mechanisms of adaptation of wild and domestic ungulates as zoological objects increases the practical value of the work and contributes to the preservation of endangered species, and also makes it possible to effectively manage populations of domestic animals (Rankins & Wickens, 2020).

In this regard, the topic of this work is relevant and consists of the comparative characteristics of the behavior of wild and domestic equines, as well as the ethological assessment of the level of their welfare in the conditions of the stud farm at the Moscow Zoo.

Materials and Methods

The study was carried out in the summer of 2019 based on the reproduction center of rare species of animals of the Moscow Zoo, which contains 3 groups of different representatives of the equine family: 3 heads of Przewalski's horse *(Equus Przewalskii)* (1 male and 2 females), 3 heads of kiang (*Equus kiang)* (all females) and 5 heads of the domestic horse *(Equus caballus)* (all females). The animals at the time of observation were kept in groups in separate enclosures. To obtain comparable quantitative descriptions of the whole behavior of animals, one of the observation methods was used, namely the "time sample" method, the essence of which is the fixation of the behavioral patterns of the studied object at a certain point of time carried out at regular intervals (Jayne & See, 2019). A general measure for assessing the behavior of animals is the level of their activity. Both decreased and excessive mobility indicates that the conditions of keeping, feeding, and veterinary services do not meet the welfare standards for these species of animals. All forms of animal behavior can be divided into two categories: inactive, which includes sleep, napping, and rest; and active, including forms of behavior with movement in space, such as food intake, water, grooming, exploratory behavior, playing behavior, maternal behavior, etc.

Inactive forms of behavior are characterized by the following features: the animal adopts a comfortable posture to maximize muscle relaxation and reduce the level of excitation. At the same time, the activity of sensory systems is reduced, and, consequently, the reaction to stimuli is weakly expressed.

Active forms of behavior are accompanied by motoric activity, which is the main form of the external manifestation of an individual behavioral act in animals. No ethological manifestation can occur without the participation of the musculoskeletal system. The variety of manifestations of the motoric activity of animals in nature is due to the lifestyle of animals, the nature of reproduction, the way of obtaining food, and protection from enemies (Ivanov *et al.*, 2016). Based on the data obtained during observation, the percentage ratio of active and inactive forms of behavior was

calculated, as well as the percentage ratio of different forms of behavior in the studied animals.

To calculate the statistical significance of the results obtained, the Shorygin similarity factor was calculated (it is used to compare the relative frequencies of occurrence of individual acts in animals). During the calculation of this factor, a series of minimum occurrence values for each form of behavior in the compared animal species was compiled and the members of this series were summed up. The formula for calculating the Shorygin similarity factor is as follows:

$$\sum_{i=1}^{n} \min(a_i b_i) \quad (1)$$

Where a_i is the occurrence of animal behavior in a group of animals of one species, and b_i is the occurrence of animal behavior in a group of animals of another species.

The values of the Shorygin similarity factor vary from 0 (in the absence of common elements in behavior) to 100% (with complete similarity of behavior) (Jayne & See, 2019).

Another method of statistical processing that allows obtaining data for comparison of quantitative characteristics of behavior is the calculation of the Shannon diversity index, the value of which is determined by the formula:

$$H = \sum [p_i \times \log(1/p_i)] \quad (2)$$

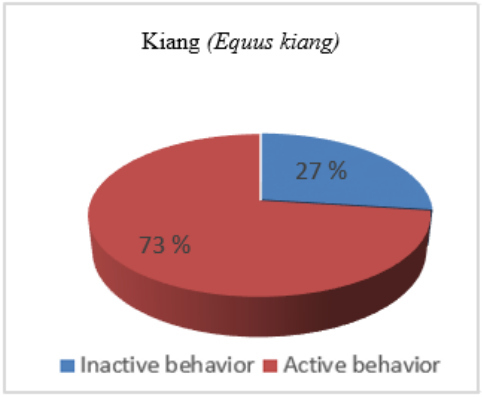
where pi is the fraction of time spent on the i-th form of behavior. The value of the index depends both on the number of registered forms of behavior and on the uniformity of the distribution of time spent on each form of behavior. The higher the value of H, the more varied the behavior (Jayne & See, 2019).

Results and Discussion

Behavior is a complex activity of an animal aimed at satisfying its needs, providing adaptation to environmental conditions, which plays an important role in preserving the life of both an individual and the species as a whole. The results of our studies showed that active forms of behavior prevailed in all species of the studied animals since the observations were carried out in the daytime. In the behavioral repertoire of the kiang, the proportion of active forms was 70%, in Przewalski's horses it was 83%, and in domestic horses, it was 79% **(Figure 1)**. The ratio of periods of wakefulness and sleep is an indicator of the body's adaptive capabilities (Berihulay *et al.*, 2019).

Inactive forms of behavior in both wild and domestic equines were represented by rest. Sleep and napping were not observed for the entire observation period, except for kiang, where napping accounted for only 1%. Rest plays an important role in the life of horses. Horses usually rest while standing, because they inhabit open spaces and are a target for predators, and therefore, their activity during the day repeatedly alternates with phases of rest (Auer *et al.*, 2021). Biological rhythms, in particular circadian rhythms, are congenital, and the duration of individual body cycles is a constant which is inherited.

The highest level of activity was recorded in Przewalski's horses, which may be due to the presence of a male in the group. In the group of kiang and domestic horses, represented only by females, the activity of animals was lower by 9% and 10%, respectively **(Figure 1)**.



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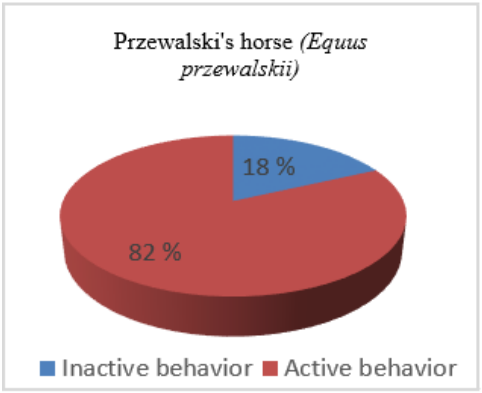

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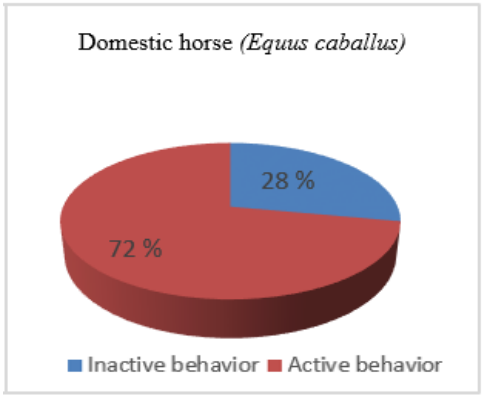

c)

Figure 1. The Ratio of Active and Inactive Forms of Behavior in Representatives of the Equine (*Equidae*) Family

It was found that the ratio of different forms of behavior in Przewalski's horses and domestic horses had a significant similarity, which is also evidenced by the value of the Shorygin similarity factor, which was 86%. This is probably since for more than 150 years, Przewalski's horse, a species on the verge of extinction, has been living under the care of humans. Besides, one of the reasons for this may be that when keeping domestic horses in conditions close to natural conditions (group keeping in an enclosed pasture), lost stereotypes of behavior can be restored, since it is believed that ethological losses as a result of domestication are not absolute (Vonk, 2021). Thus, in animals of these species during the observation period, there were no significant differences in the duration of such forms of active behavior as food and water intake, auto-grooming, allogrooming, urination, and defecation.

At the same time, Przewalski's horses spend much more time on moving around the enclosure and exploring behavior, by 10% and 2%, respectively, which, most likely, is due to the peculiarities of the natural habitat of the species (the steppes of Asia) and the way of life of wild horses in nature.

Exploratory behavior helps horses gain personal experience, thanks to which animals, when faced with new objects and unfamiliar situations, can subsequently avoid negative environmental influences and receive important information. Through exploratory behavior, horses learn about danger, food, and water sources, social companions, resting places, convenient routes, etc. (Sheffer, 2014).

The result of domestication is that some forms of animal behavior have degenerated, since, living in artificial conditions for several millennia under the care of humans, animals do not waste time looking for food, they have become less careful, since there is no threat from natural enemies, etc. The lower motor and exploratory activity of domestic horses, most likely, is the result of their domestication, during which the ratio of some components of the behavioral repertoire inherent in wild ancestors was redistributed in animals.

We also found that aggression in the group of domestic horses occurred 1.8 times more often than in Przewalski's horses, which may be due to the absence of a male in this group.

Group organization and socialization of animals are often based on mating and family relations. In communities of the harem type, the male plays a protective role, smoothing out conflicts that arise between individual members of the group. As a result, in his presence, the females are calmer and feel more comfortable. Violation of the gender ratio in the community leads to the development of stress in animals (Ivanov *et al.*, 2016).

When assessing the adaptive capabilities of animals, identifying stereotypical forms of behavior and the presence of frustration states, it is necessary to fix the behavioral patterns in animals, then calculating their significance in the balance of the behavioral repertoire. This makes it possible to assess the degree of satisfaction of vital and social needs, thereby identifying and eliminating the factors of destabilization of homeostasis in animals (Appleby & Mench, 2011).

In kiangs, the ratio of different forms of behavior differs from similar indicators in the other two studied species. Shorygin similarity factor, when comparing the relative frequencies of occurrence of individual behavioral acts in the kiang with the Przewalski's horse and the domestic horse, was 71% and 80%, respectively. The exception is the frequency of occurrence of such behavioral patterns as water intake and urination, which reflect the metabolic processes occurring in the body and are associated with the maintenance of homeostasis constants, in particular with the osmotic of its internal environment. Besides, no differences were recorded in the duration of auto-grooming, which is an element of comfortable behavior, thanks to which horses maintain healthy skin, which is the largest organ in the body of animals and performs such functions as the protective, excretory, receptor, thermoregulatory functions, etc. (Sheffer, 2014).

The representatives of this group spent 1.4 times less time on food intake **(Figure 2)**, which is possibly due to the peculiarities of the feeding behavior of the species, whose habitat is the Tibetan mountain range, represented by mountain ranges and plateaus with sparse vegetation. The volume of food required for an animal can be compensated for by a higher rate of its consumption or lower metabolic processes. Besides, hypophagia is one of the symptoms of anxiety, the development of which is based on the influence of various stress factors (Kleinhappel *et al.*, 2019).

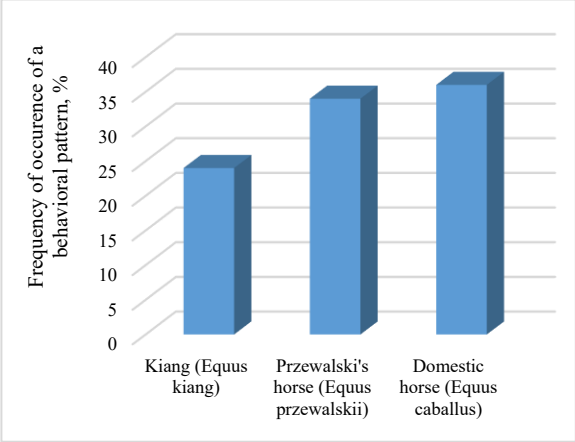

Figure 2. Eating Activity (%) in Different Representatives of the Equine (*Equidae*) Family

During the observation period, the kiangs did not demonstrate such a form of behavior as moving around the enclosure, which is not typical for representatives of this species, since, living in areas with a poor food base, they have to travel considerable distances in search of food **(Figure 2)**. Among specialists in the field of physiology and ethology, there is an opinion that physical activity is not only an external manifestation of most forms of behavior but the movement itself can be an important biological need (Wolter *et al.*, 2018).

Reduced physical activity or physical inactivity can be a manifestation of apathy, which is often interpreted as a passive stress management strategy. For quite a long time (26%) the animals stood, sheltering from the sun, resting under a canopy. Direct sunlight and high ambient temperatures (about 300°C) during the observation period caused discomfort in the representatives of this species since such high air temperatures are not typical for the highlands of Tibet, where the kiangs live.

Kiangs, like domestic horses, demonstrated a fairly high level of aggression in the group (7%), but unlike domestic horses, the reason for such aggressiveness in these animals was not the absence of a male in their community. In the wild, kiangs live in groups of mares, foals, and adolescents of both sexes, led by mature females, and the absence of adult males in the community is natural for this species of animals. Aggression caused by emotional stress manifests itself in conflict situations when animals cannot satisfy their biological or social needs for a long time (Takahashi *et al.*, 2018). An increase in aggressiveness is observed under stress, which is due to the excitation of the limbic system and the sympathetic nervous system, which causes the activation of the adrenal medulla and, as a result, the release of catecholamines into the blood.

Przewalski's horses proved to be more peaceful animals, and aggression in their group was much less common (4%) due to the presence of a stallion **(Figure 3)**. The harem type of community, as a natural social organization, serves as the main tool for horses to adapt and survive. In such groups, males are most often dominant and play the role of key figures maintaining stable intragroup relationships (Hester, 2014).

Kiangs demonstrated defecation, one of the forms of excretory behavior, 1.8 times more often than Przewalski's horses and domestic horses. The number of acts of defecation is used to assess the emotional reactivity of animals, and emotions are the most important ethological response to stimuli (Mellor, 2015; Queiroz & Young, 2018). In the studies of many authors, as in this work, this indicator negatively correlates with exploratory activities. The exploratory behavior of the kiang is 1.8 and 1.2 lower than that of the Przewalski and domestic horses, respectively.

Kiangs devoted 13% and 14% more time to allogrooming (mutual social grooming) than Przewalski's horses and domestic horses **(Figure 3)**. In nature, grooming is an extremely common form of behavior that performs several important functions, such as skin and coat care, thermoregulation, distribution of chemicals, etc. (Wubs *et al.*, 2018; Sherwen & Hemsworth, 2019). At the same time, grooming, as well as acts of defecation, are activated in animals during the development of stress, being considered one of its behavioral markers and being the only behavioral manifestations of sympathoadrenal tension in the body (Brando & Buchanan-Smith, 2018; Fischer *et al.*, 2018; Miller *et al.*, 2020). As a result of stress, animals develop frustration, which is expressed in the characteristic manifestations of the mental state and behavior of the individual, due to the impossibility of satisfying certain needs (Finkemeier *et al.*, 2018). Excessive grooming inhibits other behaviors due to increased anxiety and uncertainty (Browning & Veit, 2021). At the same time, grooming is a stress-protective shifted activity that reduces the mental stress of an individual, due to an increase in the concentration of endorphins (hormones that reduce the level of anxiety) in the blood. The behavior of the kiangs in captivity indicates the stressful state of animals, probably caused by the conditions of keeping that do not allow the animals to fully realize the behavioral repertoire characteristic of this species and satisfy their needs (Rose *et al.*, 2019).

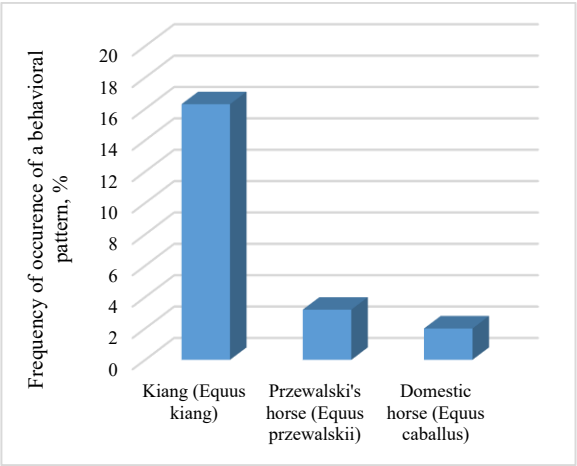

Figure 3. Frequency of Manifestation (%) of Allogrooming in Different Species of the Equine (*Equidae*) Family

It was found that in the wild representatives of the equine family, the Przewalski's horses, and the Kiang, the behavioral repertoire was more diverse, as evidenced by the value of the Shannon diversity index, which was 0.851 and 0.819, respectively. In domestic horses, this indicator turned out to be lower and amounted to 0.743, which, is the result of domestication as a result of which many behavioral adaptations are lost since for many generations they remain unclaimed when keeping animals in captivity.

Thus, to achieve a high level of welfare of animals kept in captivity, it is important to bring their conditions as close as possible to natural conditions. In the process of domestication, horses have undergone some changes, but there are no significant differences between domestic horses and their wild ancestors. Knowledge of the behavioral features of wild animals will allow creating the most comfortable conditions for them, and comparing their natural behavior with the behavior of domestic horses will make it possible to find flaws in the established rules and norms of keeping this species, organizing them in such a way as to maintain the welfare of animals at a high level.

Conclusion

In the process of domestication, the behavior of horses underwent a significant correction in the interests of humans; nevertheless, it is still based on the innate forms of behavior of their ancestors, as evidenced by the significant similarity in the ratio of different forms of behavior in Przewalski's horses and domestic horses. At

the same time, domestication made some adjustments in the ratio of different forms of behavior of domestic horses, compared with their wild ancestors. Domestic horses are 3.5 and 1.3 times less likely than Przewalski's horses to demonstrate such forms of behavior as moving around the enclosure and exploratory behavior. The ratio of behavioral patterns in wild equines such as the kiang is significantly different from that of domestic horses and their wild ancestors, the Przewalski's horses. Kiangs demonstrated behaviors that are generally accepted markers of stress, such as excessive allogrooming, defecation, and aggression, with a simultaneous low level of exploratory activity, as well as hypodynamia and hypophagia. When keeping domestic horses, it is necessary to take into account the natural behavior of their wild relatives, since the ethological changes observed as a result of domestication are not absolute and are easily restored when the conditions of their keeping approach natural, indicating that innate forms of behavior form the basis of the behavioral repertoire of animals.

An analysis of the behavioral repertoire of the studied equine species shows that keeping Przewalski's horses and domestic horses meets their welfare standards. At the same time, the living conditions of the kiangs do not correspond to their specific needs and do not allow avoiding the impact of stress factors, thereby reducing the level of their welfare.

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