Thesis

Probability Prediction of Jumping Skills in Sport Horses

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Abstract

This thesis looks into the various factors which are considered when breeding horses for showjumping. Showjumping is a demanding equestrian sport requiring a high level of agility and skill in order to succeed. Therefore, the breeding of these horses is a large industry worth a high amount of money. Breeders are constantly striving to produce the best horse possible and the next star of the sport.

Therefore, this thesis seeks to look into the influential areas to consider when looking into breeding horses, such as their genetic health, temperament and conformation. As well as using a mathematical model to see whether it is possible to accurately predict if a horse has the potential to compete to a high level in the sport. This model uses information from the bloodlines and recorded level of competition of the relatives of 138 young showjumping horses included in this study.

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List of Abbreviations:

AI - Artificial Insemination

ET - Embryo Transfer

EBV - Estimated Breeding Value

QTL - Quantitative Trait Loci

mtDNA - mitochondrial DNA

SNP - Single Nucleotide Polymorphisms

BLUP - Best Linear Unbiased Prediction

OCD - Osteochondrosis Dissecans

KS - Kissing Spines

PSSM - Polysaccharide Storage Myopathy

UELN - Universal Equine Life Number

1. Introduction:

Since the domestication of horses 5500 thousand years ago [1], humans have been selecting equines for breeding, resulting in the hundreds of breeds we have today. Horses have been a massively influential animal in human history, from providing food from their meat to a form of transport, their use in warfare and agriculture, whilst now becoming an animal used for pleasure and sport. Horses have helped to shape human history by providing mobility and strength.

The breeding of horses is a centuries-old practice, with animals being selected for different roles, for example, the Thoroughbred for their speed or the Shire for its ability to pull a plough through a field. The first breed registries were created in the 18th and 19th centuries and have been essential in developing the modern horses we have today. Most of those registries, for example, for Thoroughbreds, Arabians and the American Quarter Horse, were set up to help these animals excel in their disciplines and are still in existence today, with many more being created since.

Nowadays, horses are predominantly used for pleasure and sport, with numerous equestrian sports being practised around the world. Showjumping, eventing and dressage are included in the Olympic games. The sport originated in Europe and has evolved over the centuries into what we know today. Initially, it began on the hunting field, with riders having to jump natural fences such as walls, ditches and hedges to follow a fox or stage. It then evolved over the years and gained popularity to ultimately become the modern sport we now have. First being included in the Olympic Games in Stockholm in 1912. Within the sport, horses and riders need to jump a track of fences without knocking them, ideally, in the fastest time possible. If they exceed the time allowed, knock down a pole or unsuccessfully clear a fence in any way, they will incur penalties.

The sport horse industry is a growing industry worldwide, creating large amounts of revenue. In Europe alone, it generates over €100 billion annually. The sport is fast growing and gathering more and more fans worldwide. This has caused a change in recent years, requiring

faster, more agile and more careful horses as the courses get more technical. Therefore, more thought must be put into producing the correct animal for the sport.

Breeding of horses is multifactorial and depends on several aspects. Hence, this project aims to identify influencing factors contributing to the success of a jumping horse to explore how different aspects related to the specific individual will affect a horse's career and ability, for example, their genetics, environment, anatomy, physiology and more. It is then the aim to develop mathematical models to express these so they can be used for other individuals. Ultimately producing a reliable resource for breeders to utilise to make more informed choices when breeding to maximise potential.

Thousands of foals are bred each year, with only a small percentage making it to the top of the sport. With rising costs for breeders, it is essential to try to avoid overbreeding. At the present moment, it is difficult to predict the success of a foal before it is born. The current model for breeding uses past results of the sire and dam as well as their respective conformations to decide what will be potentially the most successful mating. This model is not entirely accurate and has resulted in an overproduction of horses as well as a narrowing of the gene pool [2]. Recent advances in assisted reproduction techniques such as AI and embryo transfer have increased this bottleneck effect even more, allowing easier access to stallions which would otherwise not be available and allowing mares to have multiple foals a year whilst also being able to compete.

A more accurate model for predicting success would help to eliminate the overproduction of horses and also help reduce costs for the breeder. Raising a foal is an expensive process and can create a significant economic loss if it does not turn out to be as successful as hoped. Generally, there is a 10-year wait between making breeding decisions and seeing the result of those decisions reaching their peak performance [3]. Therefore, a breeder being able to more accurately predict and breed the type of foal they want is of significant benefit to the industry as a whole.

The objective is to look at the different factors that have an effect on a horse's jumping skills and how we can predict them. Past studies have already shown that genetics will play a

major role and jumping skills are a heritable trait. In fact, in eventers the show jumping phase showed the highest amount of heritability [4]. However other factors must also influence this too.

This study aims to explore, using available literature the different aspects influencing the chances of a horse being successful. Using a database of 138 foals from showjumping lines to determine if it is possible to accurately predict, using mathematical models, the ability of a jumping horse before breeding. This will be done by exploring how much of an effect the performance of an animal's relatives can influence their own probability of success.

2. Literature Review:

This literature review will focus on existing evidence on what makes the ideal showjumping horse. Topics include what technologies are available to breeders, what genes are of particular importance or can hinder an animal, as well as what different physical attributes we can breed in that can aid in a horse's performance.

The following areas will be investigated:

1. Current breeding technologies
2. Systems for evaluation
3. Genetic Attributes
4. Physical Attributes
5. Inheritable diseases/problems
6. Rider Influence on Success

2.1 Current Breeding Technologies:

The first record of Artificial Insemination (AI) in animals was recorded in horses in 1322 [5] when an Arab chief stole semen from the stallion of a rival to put into one of his mares, and allegedly a foal was born the following year. However, it wasn't until the 1960s that the technology began to take shape [6]. Nowadays, within the sport horse industry at least, the use of AI is commonplace, and other technologies are beginning to grow in popularity. These practices remain banned within the Thoroughbred racing industry, with only live natural coverings being used. Due to the increase in these advancements, it has never been easier to access elite bloodlines enabling breeders to make use of the genetic potential of several top-level sport horses from around the world in order to create the best offspring possible.

Whilst the use of AI with fresh and frozen semen is now offered by most equine veterinarians, other technologies are being utilised also. Embryo Transfer (ET) is becoming more successful and widespread. Whilst the procedure has been utilised in cattle for many years, it is only a recent advancement in equine practice [6]. With the development of the correct procedures, success rates for a successful pregnancy are over 90%. Whilst still out of reach for the many breeders, due to costs, it is being utilised by more and more people, with the 5-year-old

winner, HHS Ocala, in the World Breeding Championships for Young Horses this year, 2023, being born by ET. The use of this also allows mares that are successful in competition to continue to compete, whilst also being able to make use of their genetic potential in breeding. It can also allow for multiple offspring out of a proven mare in the same year. Thus, expanding the possibilities of producing a more successful foal.

The use of technologies such as Intracytoplasmic Sperm Injection (ICSI) are also on the rise. This is useful in animals that have poor fertility [7], allowing us to make use of their genetics. It can also be utilised in the case of animals that have died, such as in a mare that has passed but the ovary has been recovered. As well as from deceased stallions whose frozen semen stock is running, to give the highest chance of a successful embryo being produced.

Cloning is also being utilised within breeding now. Whilst these horses can be used in competition, it is predominantly used for continuing lines of successful horses that for reasons, such as castration cannot breed themselves [7]. This allows for the preservation of important bloodlines.

These new technologies can also allow owners the chance to choose the gender of a foal, by deciding to delete embryos of a certain sex. Whilst it has been said that males are more successful [3] than females, an owner may want to breed a certain gender for various reasons. Such as personal preference, ease of handling or a female for breeding at the end of their career.

However, this trend is increasing the use of certain popular bloodlines more and more. In the racing industry, only live coverings can be used which limits the number of foals born by that stallion each year. For example, the horse Cornet Obolensky currently has sired over 4500 horses. This increased use of the same bloodlines is leading to a bottleneck effect, which “although the average inbreeding coefficient exhibited at an acceptable level (approx. 1.01%), the increasing percentage of inbred animals seems disturbing” (Próchniak et al., 2015). As the sport continues to grow and evolve, we must find the balance between preserving bloodlines and safeguarding the genetic health of these animals.

2.2 Evaluation Systems

There is no standard system between countries or studbooks as to how to evaluate show jumping horses. Eight studbooks currently run their own genetic evaluations [3], but they do not all follow the same system. Studbooks should have clear and concise breeding objectives that aim to better the animal for the breed's intended purpose. Unfortunately, many of the traits objectified within horses are quite general and difficult to quantify easily [8]. In other species, it is much easier due to the efficiency of production and economic value being less difficult to quantify. Discrepancies can also be found in wording or not all ideal traits are recorded in the objectives, making the task even more difficult.

Most sport horse studbooks include showjumping in their estimated breeding values (EBV), with some, such as the Irish Sport Horse studbook, the Hungarian Sport Horse and both of the Belgian studbooks, including showjumping as the single EBV. Breeding values are a numerical description of a prediction of what traits an animal can pass on to its offspring. When comparing how the EBV for showjumping is measured across the studbooks there are also discrepancies. Most focus solely on competition results, but others also review performance tests and/or studbook inspections. The Polish Horse Breeders Association takes it even further and carries out genetic evaluations, comparing 16 traits and assigning the animal a score for these [3]. Due to these differences, it is hard to accurately quantify what makes an animal successful within the sport, and what breeders need to be aiming for when making their breeding decisions.

2.3 Genetic Attributes

Since the complete sequencing of the equine genome [9] we now have a greater understanding of the equine species as a whole. This has led to more studies being carried out around equine genetics, such as the discovery of the ‘speed gene’ in thoroughbred racehorses [10]. These advancements have also extended into other areas of horse sport, including showjumping. It is important as understanding the genetics of what contributes to the animal's success can help us understand what attributes we should look for in breeding. Unlike in some other species, the use of genomics in sport horse breeding is massively underutilised [3].

However, there are more aspects to consider in a show jumping horse's success than in a racehorse. It has been found that high-level performers in the show jumping ring have a much more variable phenotype than their racing counterparts [11], which makes it more difficult to pin it down to just one gene responsible for success. Racehorses are selected for speed and endurance; however, in the show jumping ring, on top of those, muscle contraction force, amongst other things, may have more of an impact.

Certain areas on the genome are still thought to contribute to jumping performance. Six quantitative trait loci (QTL) have been found as possible genes that could influence an animal's success as a sports horse. This means that the utilisation of genetic markers could offer an advantage in selecting horses for use in showjumping. The study also promoted selecting genes that are beneficial to limb health, to avoid horses missing training due to problems associated with this. Further studies still need to be done in this area to find out more specific areas of the genome that could contribute to an animal's performance. EBVs are difficult to quantify in horses and the use of genomics to identify these QTLs could have a massive impact on identifying if a horse has a chance at success from a young age.

Another area thought to influence performance in the showjumping ring is the mitochondrial DNA (mtDNA) [12]. It has been observed that multiple EBVs associated with jumping are associated with mitochondrial single nucleotide polymorphisms (SNPs). mtDNA is solely inherited from the maternal line so therefore it is easy to trace back to that line and is mainly responsible for energy metabolism and protein synthesis. Both of these processes have a major effect on how the body performs and therefore performance ability. Hence, it is noteworthy that the maternal line plays an important role.

Personality is another trait which can be considered when breeding, although it is mainly a secondary trait for selection, it is a factor people consider when buying a horse. Temperament refers to the animal's innate ability to react to the world and its various stimuli. It is, however, shown to have a limited effect on performance [13], and is mostly independent of it. The only personality trait shown to correlate is the level of fearfulness an animal shows. A fearful animal is much less safe for the rider, whilst also hindering performance. There is no evidence to suggest that increased fearfulness will create increased tactile sensitivity and a more careful jump.

Therefore, we do not need to massively factor in an animal's personality when it comes to breeding for performance.

2.4 Physical Attributes

There does not seem to be much correlation between genetics and the longevity of an animal's career. A previous study found no major QTLs to suggest the length of an animal's career is influenced by genetics [14] unless health traits are involved, however, these would normally appear early in life. This being said the same article found a positive correlation between gaits and longevity. Particularly desirable was lateral and dorsoventral activity at the trot and a low stride frequency at the canter. Gait unfortunately is subject to the examiner and therefore may not be useful, it was noted that maybe accelerometers could be used to help avoid this. Height was also said to not affect the horse's longevity.

Another study backs up this theory that low stride frequency at canter may aid a horse's jumping career, as well as adding that low longitudinal activity may be beneficial to jumping ability. It is also said that although gait characteristics may impact the longevity of a jumping horse, it does not seem to help their jumping performance massively [15]. The analysis of gait is multifactorial and dependent on many things. Whilst judges are subjective, their background knowledge of a horse's pedigree amongst other factors may be more beneficial than relying solely on accelerometry, which is purely objective.

As discussed earlier, gait is an important aspect to consider when predicting a horse's future success, as having a correct gait and suppleness should have a positive effect on showjumping performance. Correct confirmation will also aid in this. It has been found that a strongly muscled neck and haunches, as well as a sloping croup, have a moderately favourable genetic correlation with show jumping [16]. These characteristics will help a horse maintain enough balance to get around the technical turns in the jumping ring. As well as enough power and muscle in the hind end to push off of the ground high and wide enough to clear the fences without knocking poles.

When breeding, we want to produce foals with ideal limb conformation to decrease their chances of lameness and poor performance. We want an animal with straight, well-aligned limbs,

good bone density, correct joint angles and hooves. This should allow the horse to move as it should, in a balanced manner, and to achieve adequate propulsion to clear the obstacles and avoid issues such as uneven feet, which are proven to have a genetic link [17]. The horse's conformation likely has an influence on their risk of injury, with an animal having poor conformation being at higher risk of incurring an injury [18]. An interesting finding is that conformation had a limited effect on the performance of the animal [19], however, I do not think this is the basis to disregard conformation, considering its association with injury risk [18].

Analysing an animal's jump could be useful in determining breeding value and whether the offspring will be successful. Elements of the jump are heritable, such as their technique over a fence which has been said to be moderately heritable [19]. Hence, it may have a good prognosis for effective use in breeding. Other elements of the jump have also been proven to be heritable traits, such as free jumping and duration of the jump. These both are related to performance in competition as well [20].

2.5 Inheritable Diseases

The process of domestication is known to reduce the fitness of a species [21], as gene pools narrow whilst breeding for certain traits. Due to this, the presence of diseases with a genetic origin are becoming more prevalent. These problems are important to avoid as they will have a negative effect on an animal's future performance and career.

The most common reason for a sport horse's end of career due to veterinary reasons are orthopaedic issues, which account for 63.7% of career-ending injuries [22]. A number of these disorders can be inheritable, such as Osteochondrosis Dissecans (OCD) and Kissing spines, to name a few. Therefore, if we can avoid breeding from horses known to have these issues, we stand a higher chance of creating more successful offspring. Parental injuries and their cause is one element which should be considered when choosing to breed from particular animals.

Certain genes can predispose these horses to defects that can have a significant effect on their career. Hence, efforts should be made to avoid breeding these genes into a population. OCD is often seen in horses. Whilst at times it goes unnoticed, causing no problems, it can also have a detrimental effect on performance. In some cases, it causes lameness that can result in the end of

an animal's career. OCD is a developmental orthopaedic disorder characterised by the formation of cartilage lesions in the joints. The hocks in particular are most affected and have the highest heritability [23]. The hocks are pivotal in the career of a showjumping horse as they provide the hind limb propulsion for them to clear the obstacles in the ring. Taller horses are predisposed to the disease [24], with environmental factors playing a role in its development. Height is a highly heritable trait [21]. Therefore, extra caution must be paid to these animals to ensure their success or avoid any future problems.

Fig 1 : OCD, tarsocrural joint, horse, radiograph[32]

Back pain is another issue for performance horses that can be detrimental to their careers. This can be due to several reasons, but one disease which has been linked to genetics is equine overriding spinous processes, commonly known as kissing spines [25]. Kissing spines is a condition where adjacent vertebrae in the horse's spine have abnormal contact or impingement due to the proximity of their spinous processes. Typically, these processes should have sufficient

space between them to allow for unrestricted movement of the back. When they come into contact, it can lead to pain, inflammation, and a range of clinical signs that affect the horse's well-being and performance. This pain can cause reduced athleticism, behavioural changes and a change in the horse's jumping technique, all of which will affect their results in the ring. Warmbloods, which are a popular choice of breed for jumping, are "at an increased risk for developing clinical signs" (Patterson Rosa et al., 2022).

Polysaccharide storage myopathy (PSSM) is another disease of genetic origin that is known to affect Warmbloods and can hinder their performance[26]. The disease is associated with the abnormal accumulation of glycogen in the muscles, which leads to muscle pain and stiffness in the animal. It is an inherited disease, possibly an autosomal recessive trait, and therefore can be avoided with correct testing and breeding.

Since the sequencing of the equine genome [9], genetic testing has become more freely available. Studbooks should be using technologies such as these to help improve bloodlines and lessen the risk of these genetic diseases affecting performance. A study done on the Selle Francais breed proved its usefulness in this regard [27]. By utilising these technologies available, it is possible to reduce the risk of losses due to genetic diseases whilst also locating areas on the genome proven to aid in success.

These are just a small selection of the many issues that can affect the athletic abilities of horses within showjumping. It is of utmost importance that we take note of these issues in breeding programmes to avoid future problems that can affect the health of these animals and their performance. Breeders must thoroughly research the lineage and genetic history of potential animals and make use of the genetic testing available to avoid mating carriers of specific detrimental alleles. By avoiding the use of breeding animals that could predispose their offspring to inheritable diseases, we can increase the likelihood of offspring being more successful.

2.6 Rider Influence on Success

Another variable one would assume to have an effect on an animal's performance is the riders themselves. It is the job of the rider to set their horse up for success by providing the correct conditioning training, and communication to allow the horse to perform to the best of its

ability. They must guide the animal around the course of fences in the ring, keeping them balanced and concentrated to set them up correctly for the jump.

Surprisingly, few studies have been done to look into this area and just how much it affects performance. This is probably due to the difficulty of analysing the number of variables present. However, the rider has been shown to influence the genetic potential of an animal. The amount it affected the animal depended on the animal itself and the age, with it seemingly having a more significant effect on older animals than on younger horses [28]. Therefore, more consideration should be made to ensure a rider and horse are compatible for better results.

Riders often describe their relationships with their horses, and this is obviously a contributing factor to success. Each animal is very different, and it is up to the rider to learn these differences so that they can develop a riding style suited to that animal. Also, it has been shown that horses will behave differently with people that they know rather than with strangers. With them behaving more positively around people with whom they already have a relationship with, regardless of age [29]. However, this could be attributed to humans being more relaxed around an animal that they know and can predict the behaviour of more easily.

The experience level and style of a rider also affect a horse's performance. A rider with more experience will know how to guide and communicate with the animal more effectively, which will, in turn, lead to better results. More advanced riders tend to have a different posture and move more consistently in the saddle than less experienced riders do. Professional riders have a more significant degree of tilt in their pelvis, allowing them to sit straighter in the saddle and, therefore, are more balanced on the horse. It has also been found that to control the horse more effectively, a swinging pelvis and a well-adjusted seat are desirable [30].

Horse sport is one of the only sports in the world where men and women compete against each other. At the lower levels of showjumping, it is mainly female dominated. However, this changes at the top end of the sport. The leaderboards are primarily filled with male riders. Whilst it has not been looked into massively in showjumping, there has been more research into gender bias in horse sport within the racing industry. Previously, female jockeys have had little success, but that has changed in recent years, with more female jockeys winning large races, such as Rachel Blackmore winning the Grand National in 2021, for example. It has been shown that the

sex of the rider does not affect the speed or stride length of a racehorse [31], and therefore, both males and females have an equal chance of performing as well as each other in horse sport.

3. Method:

3.1 Data Collection:

The first step in the project was the data collection. A selection of around 100 horses were initially bought from various auctions in 2022, and most were taken to a stable in the Netherlands for studies to be carried out. Passports were used to gather the details of these horses and entered into Excel to create a worksheet containing their information. The HorseTelex database was used for supplementary data. The numbers changed from the original 109 animals purchased due to a variety of reasons; some were deemed unsuitable due to lameness, injury, or poor quality, and a few horses passed away. More animals were purchased because of this, which brought the final number of animals up to 138.

The animals purchased for this study came from a variety of elite sport horse auctions in the Netherlands and Sweden. They were mainly purchased at 1 or 2 years of age, and most were brought to a stable in the Netherlands. Most came from elite bloodlines within the sport, with many famous sires, such as Chacco-Blue and Diamant De Semilly, appearing repeatedly.

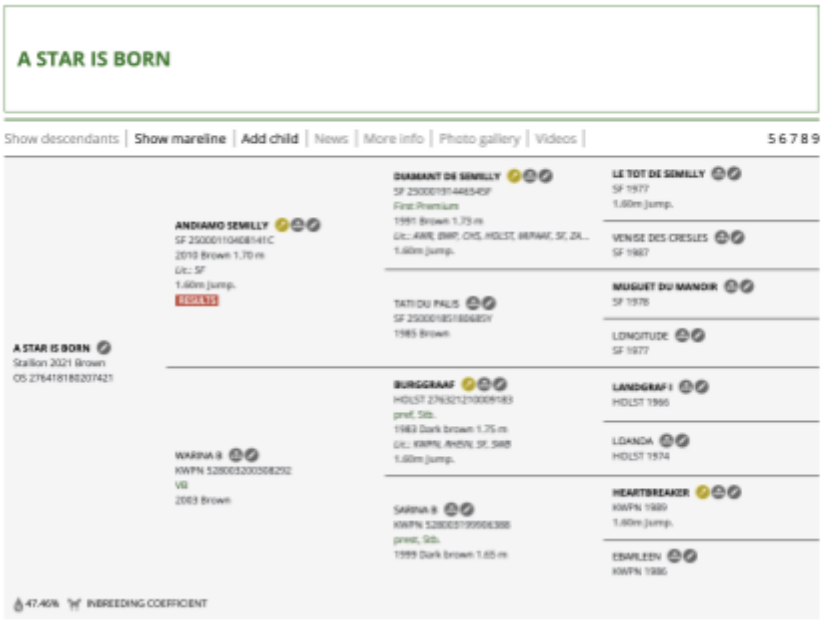

Fig. 2 : example of a bloodline on the HorseTelex website(https://www.horsetelex.com/home)

The HorseTelex website is a popular website designed to provide information for the equestrian community. The page includes information on horses such as a pedigree database, stallion directory, auction information, and rankings, as well as providing a community including forums, articles, news and a marketplace to trade animals and equipment. Information about an animal, such as name, studbook, and parent information, can be entered on the site to bring up a horse's full pedigree, including descendants and siblings. From there, a database could be compiled containing as much information as possible about these animals' genealogical backgrounds. This was done to see if any link could be found between their pedigree and its effect on the horse's future success as showjumpers.

The information from the animal's passports was entered first. This contained their name, sex, date of birth, the studbook they were registered to, microchip number and their Universal Equine Life Number (UELN). Where they were stabled at the time was also entered.

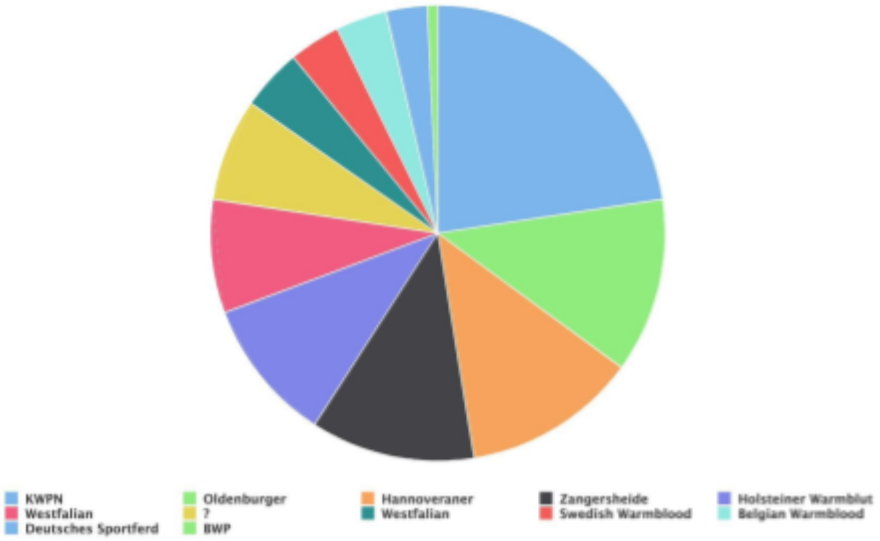

Fig. 3: breeds included, from data

Information regarding each horse's family tree was then gathered from their parents back until their great grandparents, as well as the level, if any, that each horse had competed to. Most were from showjumping lines with family members competing up to 1.60m, but a few animals

had members competing in eventing or dressage also. Some horses were flagged to appear multiple times in an animal's genealogical tree; this was also noted on the spreadsheet, as well as the inbreeding coefficient of each horse.

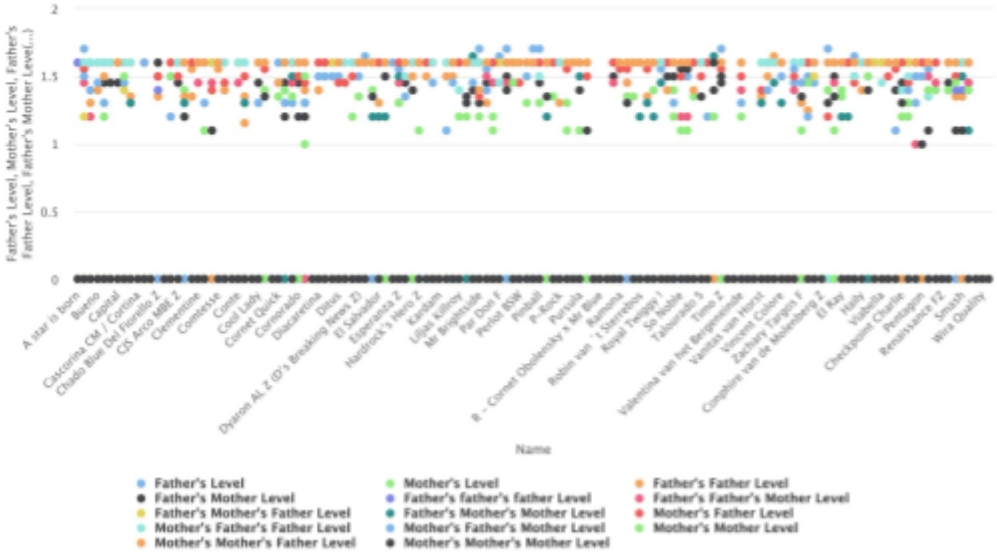

Fig. 4 : Ancestors level of jumping for each animal, from data

The maternal and parental lines for siblings of the animals included in this project were then traced. The HorseTelex database also contains all the information for this. The dam lines of each animal were investigated first. Here, information could be gathered on each foal born to the dam, as well as each foal born on the dam lineup to the animal's great-great-great-grandmother. This list also included the year of birth of each of their foals, the sire, sex, studbook and the level that they competed at, if any. It was done as it could be helpful to judge whether any animal from a similar bloodline has also been successful in the sport.

Fig. 5: section of the datasheet

This then led to compiling information on each horse's paternal line. Stallions normally produce more offspring than mares, meaning their lists were considerably longer. A list for each foal's sire was created and contained its siblings from that line, similarly to the dam lines. This information included the dam of the foal, the dam's sire, sex, year of birth, studbook and their level of competition.

Some sires came up repeatedly and had several foals within the study or had a large number of offspring registered. For the common sires or animals having sired more than 1000 foals. A separate list with more detailed information was created. There were 22 stallions included in this list, some having up to and over 4,000 offspring. The information gathered included their complete bloodlines, the same as was compiled for the young horses incorporated in the study, a picture of their bloodline, and their list of descendants, which contained all their information.

3.2 Data analysis:

The data was analysed using a software called “Rapidminer”. This utilises data analysis and machine learning to help process the data that was collected. The data was uploaded to the

software so that a process could be created to develop a regression model. Regression models are mathematical equations that allow us to use certain numerical variables to help predict another variable. In this case, the level of competition of family members was the variable analysed to predict an animal's future success. The regression model could find us the linear regression value, t-statistic value, as well as the p-value. All of these values could then be looked at to show us the probability of being able to predict the success of an animal just by looking at its family tree and its relative's previous level of competition.

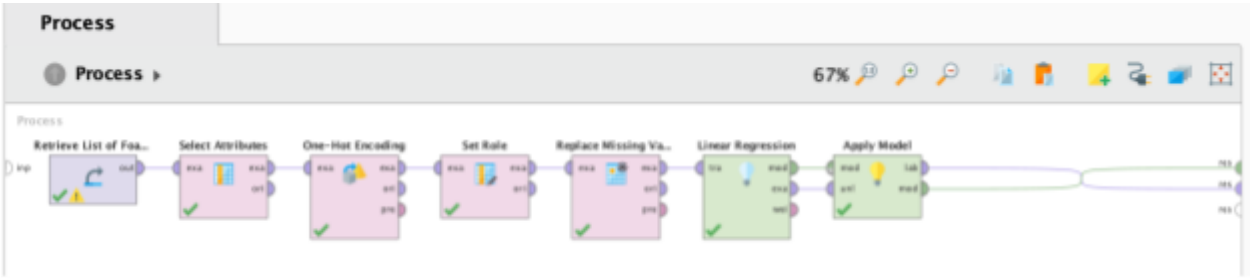

Fig. 6: the process created within the Rapidminer software

4. Results:

A process was created with this data within the Rapidminer software, which gave the following results:

- Linear Regression = 0.007
- T-stat =
- P-value = 0.319

LinearRegression (Linear Regression)

Attribute	Coefficient	Std. Error	Std. Coefficient	Tolerance	t-Stat	p-Value	Code
(Intercept)	0.007	0.007	?	?	1.000	0.319	

Fig. 8: Rapidminer results of the linear regression model

The linear regression value of 0.007 suggests a positive relation between the jumping performance of a horse's relatives and their own performance in the jumping ring. For each unit increase in a horse's relative's performance, the horse's performance should increase by 0.007 units.

The t-statistic is a measure of how many standard errors the coefficient is away from zero. A value of 1 is relatively small, showing us that the linear regression value of 0.007 is not that far from zero. The farther from zero that this value is, the stronger the correlation would be. This means that the positive relationship shown by the linear regression value may not be the most reliable.

Associated with this t-statistic is the p-value. Our p-value of 0.319 means that there is a 31.9% chance that the correlation between a relative's success and an animal's success is due to random variables rather than being directly correlated. This means that just because horses in their family perform well does not guarantee that they will also perform well in showjumping.

These results show us that whilst there is more than likely a slight positive relationship between a horse's own success and the success of their relatives, it is not statistically significant.

Other variables may play a more prominent role in influencing success, and it can never be guaranteed due to the nature of the population.

A prediction average of 0.007 +/- 0.082 was also found within the regression model. This means there could be a range in variation of 0.082 above or below the linear regression value of 0.007. This suggests that the margin for error in the prediction is quite large. This shows us that the model's predictions have a high degree of uncertainty, and that the horse's actual performance could deviate quite significantly from the predicted average.

5. Discussion:

The breeding of horses is a multifactorial process which is influenced by a large number of variables. The characteristics and abilities of the resulting foal are determined by many factors. As many of these as possible must be considered when trying to produce a successful animal for the show jumping ring.

Showjumping horses are typically selected for breeding due to their success in competition. These horses tend to show a great deal of athleticism, agility and ability to clear challenging obstacles. With advancing technologies such as ET and ICSI, even mares can continue to compete whilst also producing the next generation of horses destined for the ring. These technologies allow for the collection and fertilisation of eggs and for them to be placed into another recipient mare so as not to interrupt training and competition schedules. The use of frozen semen allows for desirable stallions to be used whenever it is necessary, and even very successful horses that have been castrated can be cloned to allow the use of their genetic potential. However, as the mathematical model has shown, the level of competition alone is not a reliable source to guarantee an animal will become a successful showjumping horse. Whilst I believe that a horse's relative's competition success can be an excellent baseline to decide if an animal has the possibility of producing a successful foal, we must also pay close attention to the other factors that play a role, some of which may not be possible to define mathematically.

Another aspect which should be considered is temperament. There is little point in breeding animals that do not have the correct temperament for the job and risking them passing it on to their offspring. Whilst at the top level of the sport, these animals are handled mainly by professionals; it is unsafe for them to be around a horse whose behaviour could be dangerous. Welfare must also be considered, it is hardly fair for a highly anxious animal to be exposed to the stress of travelling and shows on a regular basis, even if they can perform well, medical issues such as gastric ulcers can develop.

Riders also play a role in the success of a horse and, therefore, must be well-suited to each other to form an effective partnership. Little research has been done in this area, however. Precaution must be taken to ensure that the personalities of both the rider and horse are suited; for example, a nervous rider with a skittish horse would not be an ideal pairing and perhaps would not perform as well. Rider skill level also has an influence on the success of a horse in the ring, with a more experienced rider better able to guide the animal around the course effectively. They can also provide the best training to enhance the horse's natural ability.

Technique is another influencing factor in success. To jump well, a horse should be balanced and in rhythm, engage its hindquarters, produce a rounded bascule shape over the fence and tuck its knees and feet up neatly to its chest going over a fence. Some horses can use unusual techniques over a fence and still be very successful; however, it may not be advisable to breed

from these animals, as a unique technique may be less likely to be successful and could lead to a higher risk of injury, potentially ending their careers early.

Due to the increase in the use of these new breeding technologies, we must be careful not to narrow the gene pool too much. It is not more accessible than ever to make use of high genetic value animals, and everyone wants to breed the best from the best. The risk of creating a bottleneck effect arises from the overuse of the same animals with high genetic potential in breeding. We must take precautions to avoid this to preserve the genetic health of future foals. Worryingly, from the data collected, it was not unusual to see the same animal appearing repeatedly in one horse's family tree. These increasing levels of inbreeding can lead to a whole host of genetic conditions and ailments, ultimately decreasing the chances of success for an animal. We must begin to make an effort to avoid this and increase the use of genetic screening technologies so as not to cause an inbreeding depression, where offspring inherit two identical copies of harmful recessive genes. By varying the gene pool, we can ensure the breeding of animals of better health and quality, which in turn should lead to higher chances of breeding animals that can perform to a high level.

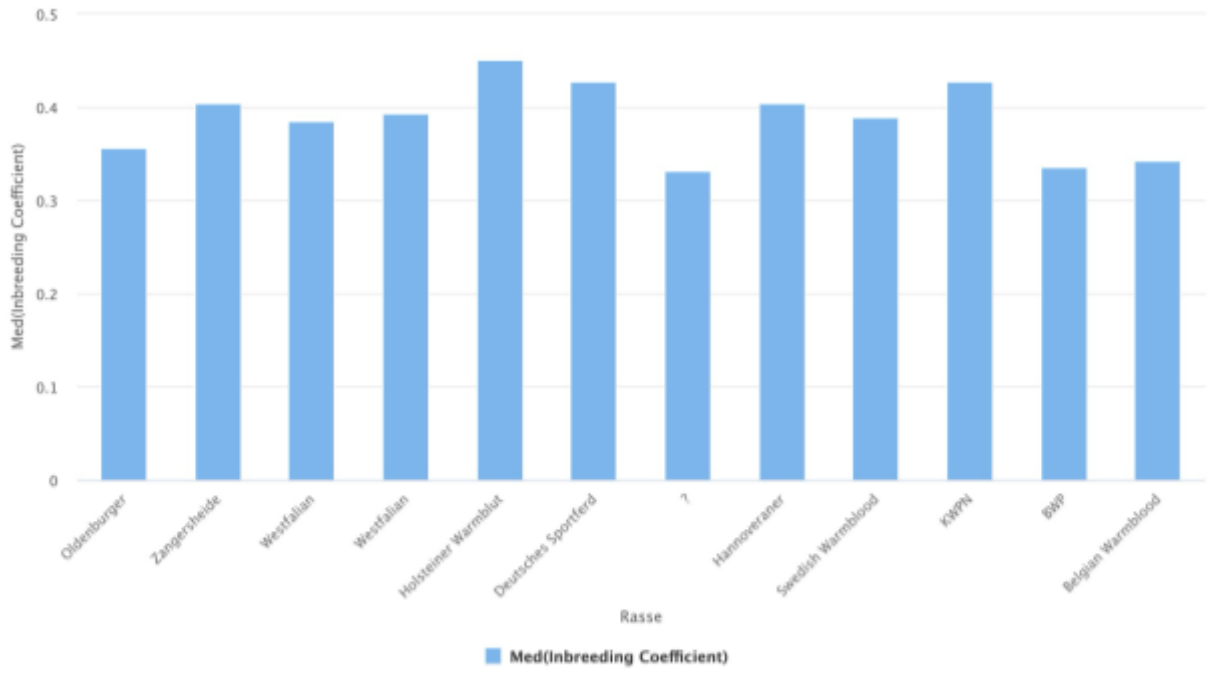

Fig. 8: Average inbreeding coefficient of breeds amongst the horses included in this study

Inbreeding can also lead to the poor conformation of a horse, which is vital to success, some issues can be resolved with correct veterinary and farriery care, and others can be more serious. This can lead to increased injury levels and prematurely end the animal's jumping career. Diseases such as OCD and KS can be inherited and cause lameness, which can massively affect an animal's performance. Pain can also cause many behavioural issues, leading to increased danger to the rider and changing an animal's technique so as to reduce their skill level.

6. Conclusion:

The aim of this thesis was to explore if it is possible to accurately predict the future jumping skills of a sport horse, determining whether or not they will go on to be successful in the sport of showjumping. Horse breeding is an ancient art and science that has been used for centuries to ultimately produce the performance animals we have today.

Whilst I do not believe it is possible to produce a 100% accurate model to perfectly predict if an animal will have suitable skills to compete at a high level of the sport, I think it is possible to increase our chances with correct breeding. However, we cannot solely rely on one variable alone, and it is a multifactorial process in which many variables must be considered. These variables include genetics, conformation, temperament, environment, and rider influence to name but a few.

Even considering all of these many variables there is random chance to consider as well. Horses are living, breathing creatures and can injure themselves very easily in everyday life. This can result in the end of their careers and even death. Which is why it is impossible to 100% guarantee their success, even with all of the technologies we have today.

Various areas, such as the influence of the horse-rider relationship, are still lacking in research. More work must be done into these areas and also into identifying other factors at play that can be of influence so that more accurate models can be developed and to increase our chances of being able to predict the jumping skills in sport horses accurately.

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