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INVESTIGATING EVALUATOR BIAS WHEN ASSESSING POTENTIAL PERFORMANCE HORSES WITH RESPECT TO HORSE COAT COLOUR

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INVESTIGATING EVALUATOR BIAS WHEN ASSESSING POTENTIAL PERFORMANCE HORSES WITH RESPECT TO HORSE COAT COLOUR

by

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Abstract

Investigating Evaluator Bias When Assessing Potential Performance Horses With Respect To Horse Coat Colour

Anna Fisker Hansen

Colour bias in judging has been suggested in a variety of subjectively judged sports, but has not previously been examined in equine performance evaluations. Potential performance evaluations, such as the British Breeding Futurity (BBF), can increase the momentary value of a horse, as status is given to horses with a premium evaluation record. The existence of bias in scoring could have economic implications particularly because the numbers of low value equids have increased in Britain, leading to worrying numbers of equine welfare cases.

The potential occurrence of horse coat colour bias was investigated by 1) comparison of differences in BBF component and premium scores according to differently grouped horse colours (n=4001) using One-way ANOVA and Tukey HSD post hoc analysis, 2) analysis of the effect of different disciplines (dressage, eventing, show jumping and endurance), years (2008-2014) and regions on BBF scores according to horse colour, using permutation based analysis in PRIMER-E, 3) evaluation of the breed registrations of BBF horses and their genetic potential using the WBFSH top 100 stallion lists and 4) examination of British equestrians perception of horse colour bias using a questionnaire and subsequent analysis in SPSS (n=65).

A significant difference in mean BBF scores was found between block coloured and spotted horses (and grey horses in dressage and eventing) compared to all other horse coat colours ($p < 0.05$). The difference in scores between horse colours ($R = 0.094$) was greater than the difference over time ($R = 0.082$) and between regions ($R = 0.027$). Grey/block coloured dressage evaluated horses (2014) had significantly lower scores than bay horses with a similar genetic potential ($p = 0.012$). Spotted horses was the least favourite horse coat colour amongst survey participants ($p = 0.001$) and also the colour thought to be least favoured by BBF evaluators. However, the majority of survey participants (55%) did not believe horse coat colour bias exists in the BBF.

In conclusion, horse coat colour bias is suggested, proposed by the significantly lower scores of block coloured, spotted and, in part, grey horses in the BBF. This is attributed to the high visibility and possible motion camouflaging nature of these colours in addition to a historic negative bias amongst British equestrians.

Keywords: Judging bias, colour bias, equine coat colour, sports horse breeding, young horse evaluation, British Breeding Futurity, British equestrians.

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Abbreviations

APH: American Paint Horse

APHA: American Paint Horse Association

AQHA: American Quarter Horse Association

BBF: British Breeding Futurity

BCE: Before the Common Era

BD: British Dressage

BE: British Eventing

BEF: British Equestrian Federation

EGB: British Endurance

BHS: British Horse Society

BS: British Show Jumping Association

CE: Common Era

Def: definition

df: Degrees of Freedom

FEI: The Fédération Equestre Internationale

FM: Franches-Montagnes

OLWS: Overo Lethal White Syndrome

N= population size

sd: Standard Deviation

se: Standard Error

ICGR: The International Champagne Horse Registry

RHQT: Swedish Riding Horse Quality Test

WBFSH: The World Breeding Federation for Sport Horses

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Author's Declaration

At no time during the registration for the research degree has the author been registered by any other university award without prior agreement of the Graduate Committee.

Work submitted for this research degree at the Plymouth University has not formed part of any other degree either at Plymouth University or at another establishment

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2015 – delegate

1 Introduction and Literature Review

Judging and decision making has been studied since the late 1940's e.g. in the research areas of decision- and game-theory (i.e. evaluative logical decision making), social-psychology/sociology (i.e. social behaviour) and psychology (i.e. cause of the ideal versus the observed human decisions) (Bar-Eli and Raab, 2006). Multiple ways in which judging can be biased have been reported in social cognition literature (i.e. "general study of how people make sense of other people and themselves on the basis of an information processing framework") (Plessner and Haar, 2006). Bias in sport has also been investigated to improve the accuracy of sport performance judging in equine and non-equine sports (Plessner and Haar, 2006). Bias in judging (i.e. judging bias) as a result of uniform colour has been suggested in a variety of subjectively judged sports e.g. gymnastics, figure skating and rope skipping, but has never been examined in equine performance evaluations (Balmer *et al.*, 2003; Bar-Eli *et al.*, 2006; Findlay and Ste-marie, 2004; Ste-Marie and Lee, 1991). Potential performance evaluations, such as the British Breeding Futurity (BBF), can increase the momentary value of a horse, as status is given to horses with an evaluation record, especially if a high grade is received (BEF, 2013a; British Breeding, 2007). Furthermore, breeding of low value equines contributes to the greatest number of equine welfare cases in the UK (Rogers, 2015). It is therefore important to identify and understand evaluator biases in assessment of potential performance of young horses, as this could have positive effects by reducing the number of equine welfare cases and improving the potential economic-worth of horses, both of which would benefit the British equine industry.

1.1 Aims and Objectives

This project aims to investigate equine coat colour bias within the BBF evaluations, and to study the cause of potential bias via (a) analysis of objective data and (b) a survey of British equestrians.

The objectives of this programme of research are to:

1. Investigate if horse coat colour bias exists in the final premium scores awarded to potential performance horses, using 7 years of data (n=4001) from the British Breeding Futurity database.
2. Investigate which, if any, of the assessed components (veterinary mark, conformation, correctness of pace for walk, trot and canter, athleticism, jump) are subject to more coat colour bias.
3. Identify trends in colour bias with respect to year and geographical region of evaluations.
4. Determine whether particular genetics (bloodlines and breeds) contribute to perceived colour bias during the evaluations.
5. Ascertain whether a current fashion in horse coat colour exists.
6. Compare perceived horse colour bias in the BBF data to surveyed equestrians perception of horse colour bias, in order to investigate the potential cause of horse colour bias in Great Britain.

1.2 Equine Domestication and Coat Colour Selection

1.2.1 Pre-Domestication

Human selection of horse coat colour phenotypes is thought to have started from the beginning of domestication (Linderholm and Larson, 2013; Rieder *et al.*, 2008). A recent archaeological find of horse bones showed the most recent common ancestor of the genus *Equus* being twice as old as previously thought i.e. 4-4.5 million years old (Orlando *et al.*, 2013). However, the precise start of equine domestication is more difficult to determine; as archaeological specimens do not always reveal any signs of the horse being used by man e.g. marks on molars from the use of bits. Nevertheless, the time of domestication is thought to be 5000-6000 years ago (Cai *et al.*, 2009; Ludwig *et al.*, 2009).



Figure 1 a) “The Chinese Horse”, Lascaux Cave Painting 15,000-17,000 BCE (Pruvost *et al.*, 2011) b) Two wild Przewalski horses, their coat colour (bay) dun is believed to be that of pre-domestic horses (Beliczay, 2013).

In early horse breeding, traits such as meat, milk and tameness were thought to be initially selected for, and novel coat colours were a by-product of this breeding

selection (Linderholm and Larson, 2013; Cieslak *et al.*, 2011). Camouflage from predators and heat regulation are thought to be the main biological purposes of equine coat colour (Linderholm and Larson, 2013). The colour dun (see appendix 1.3.1) is thought to be the colour of pre-domesticated horses (*Equus ferus caballus*) as it is of the last remaining wild horses (*Equus ferus przewalski* see Figure 1) (Orlando *et al.*, 2013; Pruvost *et al.*, 2011). This colour would have been useful in providing camouflage and efficient sun reflection on open plains. However, the genetic makeup of the dun mutation has only recently been identified (Animal Genetics, 2014), and it has therefore not been possible to previously distinguish in archaeological finds (Ludwig *et al.*, 2012; Pruvost *et al.*, 2011). However, the genes for bay (see appendix 1.1.1) have been discovered in the oldest remains, suggesting that pre-domesticated horses were genotypic bay with the dun dilution i.e. yellow dun (see Figure 1) (Kathman, 2012).

Bay and black alleles (see appendix 1.1.1) have been found in east European horses 7000-6000 years ago (Ludwig *et al.*, 2009). Pre-domesticated horses are thought to have this phenotype, because darker coat colours are assumed to have provided better camouflage in forested areas (Ludwig *et al.*, 2012; Ludwig *et al.*, 2009). All other horse coat colours are thought to have developed much later in time. The chestnut allele (see appendix 1.1.1) was identified with DNA sequencing in an archaeological find of a wild Romanian horse from the Copper Age (Kathman, 2012). However, the colour was not displayed phenotypically until the Bronze age, as suggested by DNA from a Siberian archaeological find (Ludwig *et al.*, 2009). The occurrence of this colour continued to increase rapidly with domestication, attributed to human selection based on a belief that chestnut

horses were calmer than other horses (Viegas, 2012; Ludwig *et al.*, 2009). Interestingly, nowadays a popular belief is to the contrary; that chestnut horses, especially mares, are hot-tempered (Finn *et al.*, 2016). However, no scientific evidence has directly linked temperament with coat colour in animals (Cieslak *et al.*, 2011; Albert *et al.*, 2009).

Chestnut, black and bay are naturally occurring coat colours in the pre-domesticated equine gene pool, but selective breeding seems to have resulted in more domesticated horses with these phenotypes. It is thought that selective breeding, through domestication, also resulted in the mutations responsible for coat colour dilutions and spotting patterns (Cieslak *et al.*, 2011). However, seemingly spotted horses are seen in cave paintings dating back 25000 years e.g. the Dappled Horses of Pech-Merle (see Figure 2) (Pruvost *et al.*, 2011).



Figure 2 a) “Dappled Horses of Pech-Merle”, Cave Painting c.25,000 BCE (Pruvost *et al.*, 2011) b) Leopard spotted Knabstrup stallion (Knabstrupperforeningen for Danmark, 2015).

The Dappled Horses of Pech-Merle portray spotted horses with markings very similar to the modern equine coat colour pattern leopard spotting (see Figure 2 and appendix 1.4.5) (Pruvost *et al.*, 2011). Furthermore DNA analysis has shown that pre-domestic horses in Europe had the leopard spotting allele (Pruvost *et al.*, 2011).

Mutations responsible for cream dilutions (see appendix 1.3.2) did not appear until 2800-2600 years ago in Siberia. During the fifth millennium, the spotting pattern sabino appeared (see appendix 1.4.3), and the tobiano pattern (see appendix 1.4.4) followed 3500-3000 years ago. However, these mutations were not recorded in Spain until medieval times (Ludwig *et al.*, 2009). Since only three coat colour phenotypes have been found prior to the believed domestication of the horse, in contrast to 11 in early domesticated horses, it seems reasonable to conclude that selective breeding during domestication resulted in the variability seen in present day horse coat colours (Pruvost *et al.*, 2011).

1.2.2 Post-Domestication

White coat colour has been documented as sacred, as early as 485 to 465 BCE (Linderholm and Larson, 2013; Rosengren Pielberg *et al.*, 2008; Haase *et al.*, 2007). Cream diluted horses appear throughout art and literature (see Figure 3), and were especially popular in the seventeenth and eighteenth centuries in a number of studs e.g. Oldenburg and Berberbeck in Germany (Kathman, 2012). However, during the twentieth century creams were lost in European studbooks, which is attributed to the increasing influence of English Thoroughbreds and

Arabian horses. Similarly, horses with tobiano markings were portrayed in numerous paintings during the Baroque period, illustrating their popularity at the time (see Figure 3). However, in America during 1881, spotted horses had reportedly 'gone out of fashion' (Kathman, 2012).



Figure 3 a) "Cerbero", tobiano horse painting by Johann Georg von Hamilton, 1725 (Kathman, 2011) b) "Adonis" by James Ward, 1826, painting of the "Royal Cream" stallion owned by King George III (Kathman, 2011)

In the Victorian ages, the British were fascinated by novel animal colours, and often selectively bred for these e.g. uniquely coloured birds were highly fashionable in Poultry Shows (Sheppy, 2011). In contrast, British literature from the very beginning of the Victorian era suggested that more common horse coat colours were those that were considered 'appropriate' for young female equestrians (Anonymous, 1838). Bright bay horses were preferred, followed by chestnut and greys. Silver grey horses with black mane and tail were particularly preferred, which might equate to the early stages of the greying process of a black/bay horse (see appendix 1.4.1). Jet-black horses were described as

‘elegant’ but were not as desired for a lady, whilst a brown coat colour was acceptable, but considered dull (Anonymous, 1838). This is an example of how “washy” colours have been historically biased against, although horses, unlike dogs, have not traditionally been selected in breeding for the intensity of a colour (Kathman, 2014b). Horses with large white markings on the head and legs, piebalds (see appendix 1.4.4), roans (see appendix 1.4.2), sorrels (light coloured chestnut), mouse coloured (see appendix 1.3.1), dun (see appendix 1.3.1), and cream coloured horses (see appendix 1.3.2) (although a cream horse was considered appropriate for carriages) were advised to be avoided by the young Victorian age ladies (Anonymous, 1838). It is interesting how these ‘preferences’ do not follow the evolution of coat colour mutations seen through domestication. The pre-domestication colour dun was, according to the literature, not favoured. Bay, another pre-domestication coat colour was highly desired, but without the newer mutation of white leg markings i.e. black legs only. The early post-domestication colour chestnut was desired, but later dilution mutations i.e. cream were unwanted. It is possible that such literature is based upon personal opinion rather than widespread occurrence, or that the coat colour preferences were a decade early for the Victorian fashion of selective breeding for colour. However, it could also suggest a fashion emerging regarding preferred equine coat colours, which contrary to previous selection for novel coat colours, follows a trend of classic, but not ‘dull’, horse coat colours.

Thoroughbred horses were considered to be the most suitable breed for young equestrian ladies (Anonymous, 1838). The first modern stud book was the English Thoroughbred which was established in 1793. Breed standards, including

specific coat colours, were selectively bred for in the English thoroughbred which could have significantly influenced colour preferences during this period (Cieslak *et al.*, 2011). The bay colour was at the time associated with the high quality and speed of the Thoroughbred (Ridgeway, 1905). Consequently, many breeds established during the late nineteen and early twenty century, especially the ones influenced by Thoroughbreds and Arabians, were selectively breed for the bay colour (Kathman, 2012). However, white horses were seen as a kind of novelty, and have consistently been documented in Thoroughbreds, through the late nineteenth century (Kathman, 2014b). Nevertheless sabino¹ (see appendix 1.4.3) and appaloosa (see appendix 1.4.5) coloured horses, had gone out of favour following their fashion amongst nobility during the Baroque period, and as a result eliminated from breeding programmes (Kathman, 2014b). Furthermore, tobiano patterned horses have been excluded from many breeds with closed stud books (e.g. the Arabian), due to this change in horse colour fashion in the early twentieth century (Kathman, 2014b).

1.2.3 Modern Day

The Thoroughbred breed societies of modern day retain the traditions of coat colour; despite the fact that horse coat colour has shown not to be correlated with performance or speed (Stachurska and Ussing, 2007; Stachurska *et al.*, 2007). In Australia, only the colours black, bay, brown, chestnut, grey and white are allowed for registered Thoroughbreds (Autralian Stud Book, 2008). The American Jockey Club additionally allow palomino and roan horses (The Jockey Club, 2014). However, roan has to be categorised with grey as “Grey/Roan” in the stud

book records, a category made “in order to reduce the number of corrections involving the colors” The Jockey Club (2014). Weatherbys, the British Thoroughbred association, state that bay, dark bay, black, chestnut, grey and roan are the most common colours amongst Thoroughbreds, but they have more recently revised the colour classification, and now permit the colours piebald and skewbald (Weatherbys, 2014, 2008). This rule change has happened as a result of research in equine coat colour genetics, making it apparent that even in breeds like the Thoroughbred, where specific rules on coat colour have been put in place for generations, new colour mutations can spontaneously occur (Kathman, 2014b). These mutations create phenotypes that do not fit the criteria for ordinary registration, which is especially the case with the white spotting colour mutations located on the unstable KIT locus (see appendix 1.4) (Kathman, 2014; Hauswirth *et al.*, 2013).

Horses with coat colour phenotypes unfit for registration with the parentage studbook would as a result be devalued. In the past, breed associations e.g. The American Paint Horse Association (APHA), have arisen to accommodate these horses. The American Quarter Horse Association (AQHA) has, like the Thoroughbred studbooks, strict registration regulations only allowing horses of ‘solid’ colours (Bowling, 1994). However, phenotypes with minimal marking exists within the breed (see appendix 1.4.6), creating horses with large amount of white when homozygous or in combination with other patterns (Hauswirth *et al.*, 2012). These foals would be referred to as ‘crop outs’, and would not be acceptable for registration with AQHA (Bowling, 1994). Consequently, APHA was founded as a breed register for these horses (APHA, 2014). Today APHA has its own

regulations on which horse colours are fit for registration e.g. a certain amount of white spotting has to be present (Bowling, 1994). However, some white spotting mutations only cause minimal white markings, and horses with a minimal white phenotype, but registered APHA parentage, can therefore only be registered with APHA in a sub category for solid breeding stock (APHA, 2007). Horses registered as solid breeding stock are often of lower value than those registered in the regular APHA studbook (APHA, 2007). This suggests that horse colour has a correlation to financial value of a horse, although this has not been proven.

In a study of breeding values for coat colour phenotypes in the Swiss Franches-Montagnes Horse breed, it was suggested that there was increased demand for certain horse colours e.g. “painted” horses were easy to sell, and solid coloured horses were selected for dressage (Rieder *et al.*, 2008). Rieder *et al.* (2008) investigated the Swiss Franches-Montagnes Horse breed as white marking had more than doubled in the horse population during 30 years, despite the phenotype exclusion from the breed standards, and this caused concerns because of pathological consequences of excessive depigmentation. e.g. LWOS, malignant melanomas in greys and blindness in appaloosas (see appendix 1.4.) (Fritz *et al.*, 2014; Sponenberg, 2009; Rosengren Pielberg *et al.*, 2008).

Additionally, concerns about breeding exclusively for coat colour, could be to the detriment of performance. The Palomino Breed Society are an example of a breed register where only a specific colour, no performance or conformation traits, are considered for registration (Billington and McEwan, 2009). On the other hand, breeding solely for performance can also have negative consequences e.g. the poor reproductive conformation of many Thoroughbreds (Sharma *et al.*, 2010;

Allen *et al.*, 2007). Today, the disorders associated with certain horse coat colours are mostly detectable by DNA analysis (Kathman, 2014b). However, it is not yet common practice for studbooks to register horse colours based on genotype. The International Champagne Horse Registry (ICGR), formed in 2000, was the first equine breed organisation to register horses based on the presence of one specific genetic coat colour mutation, i.e. champagne (see appendix 1.3.3) (Shepard, 2014). However, identification of the champagne colour is only performed visually by the ICGR, who do not require genetic testing or verification. The potential problem with this subjective assessment is that the champagne phenotypes are similar to other dilution mutations (see Figure 4), consequently non-champagne diluted horses have often been incorrectly termed champagne (Kathman, 2012; Cook *et al.*, 2008).



Figure 4 a) A genotypic gold champagne (Cook *et al.*, 2008) b) a genotypic palomino Quarter Horse (Simonsen, 2015) c) b as foal (Simonsen, 2015). Problems arise when identifying horse colour by phenotype as different genotypes can look the same, and phenotype can change as the horse ages.

Therefore, the risk of human error in determining the horses' colour genotype, based solely on the subjective assessment of phenotype, is as likely in the new

ICGR as in the older breed societies. It is hereby apparent that although equine coat colour genetics have progressed, the equine breeding industry has not fully incorporated such advances into studbook regulations. Furthermore, historic evidence suggest that horse colour fashion changes with time (Kathman, 2014b). However, the current relationship between studbook regulations on coat colour registration and equestrians' horse colour preferences are not clear. Moreover, horse colour preferences can have financial implications for the equine industry, and therefore associated research is needed.

1.3 British Sport Horse Breeding

The equine sector is a highly profitable industry in the British economy, worth £3.8 billion per year (BETA, 2014). However, Great Britain is struggling to make breeding of top performing sports horses profitable (Crossman, 2006). British breeding is renowned for the Thoroughbred horses (typically used for racing and eventing). However, due to a change in the Olympic rules for eventing, implemented in 2005 (i.e. shorter cross country courses) horses of the warmblood type, which are relatively more successful in dressage and show jumping, are now also being successfully competed internationally in eventing (USEA, 2010; The Henley Centre, 2004). Therefore, the need for British Thoroughbreds have declined.

1.3.1 The British Breeding Futurity

The BBF run under the British Equestrian Federation (BEF) annually assesses over 400 horses during the summer months at multiple venues throughout the United Kingdom (BEF, 2013a). The BBF aims to (1) identify talented young sport horses and ponies, and (2) collect data that can be used to inform future breeding decisions and also to provide feedback to participants (BEF, 2013a). Studies have shown that traits evaluated in young sports horses are well suited to describe genetic properties that are important for future results in sport, therefore young horse evaluations like the BBF are considered a good indicator of potential performance (Olsson *et al.* 2008; Ducro *et al.* 2007; Thorén Hellsten *et al.* 2006; Wallin *et al.* 2003). By evaluating horses at a young age (foals to 3 years old) the BEF Futurity aims to improve future breeding decisions helping to ensure the production of top performance horses, making breeding profitable in Britain, and at the same time ensure that future British medal winners ride British bred horses (BEF, 2013a; BEF, 2013b).

1.3.1.1 Rules and Regulations of the British Breeding Futurity

The BBF evaluates the potential of individual horses and ponies to succeed in the future according to their intended sports discipline i.e. dressage, show jumping, eventing or endurance (BEF, 2013a). In order to be eligible to enter, the young horses must be British bred i.e. the horse was either foaled in Great Britain or foaled abroad to a dam normally living in Great Britain. The country of origin of the dam and sire is not important, and neither is the issuing country of the evaluated horses' passport. Registration with British stud books is however preferred (BEF Futurity, 2014). The sire of the evaluated horse needs to meet a

number of criteria relating to their studbook (BEF, 2014). However, to date, there is no required criteria for the evaluated horses' dam. It is common practice to give emphasis to the breeding stallions, as a stallion, unlike the dam, can sire several offspring in one breeding season, despite the fact the dam contributes half of the genetic material of the offspring. The criteria of eligibility and general rules and regulations of the BBF are regularly revised, and the dam criteria is currently under review i.e. to include a grading scheme of successful competition dams (BEF, 2014).

Any changes in BBF rules are formulated and implemented in accordance with the aims of the BEF to improve British Horse breeding. The initial Futurity evaluation design was based on the Swedish Young Horse Evaluations and piloted in 2005 (Ironside, 2009). Changes to the format have since been implemented based on feedback from participants, and the outcomes of postgraduate research (Ironside, 2009; Kearsley, 2008). These changes included the rule implemented in 2012 to only allow one Futurity entry per horse per year, in order to encourage breeders to more consciously breed horses for a desired discipline (BEF, 2013b).

1.3.1.2 The British Breeding Futurity Evaluation Process

The Swedish Young Horse Evaluations, was partially developed by a veterinarian (Ironside, 2009). Studies have shown that higher veterinary marks in the Swedish Riding Horse Quality Test (RHQT) correlate with future performance and length of life of the evaluated horses (Wallin *et al.*, 2001). The emphasis on a veterinarian evaluation phase has been included in BBF evaluations. The evaluations begin with a veterinarian assessment based on the quality of the

horse at the present time, and the horse's predicted ability to perform when it reaches competitive maturity, if any veterinarian advice is followed (BEF, 2013b). The two veterinarian scores are averaged to a final veterinarian mark out of ten. If the horse is regarded sound and healthy by the veterinarian, a panel of three evaluators then assess the individual horses' suitability for the chosen equestrian discipline. Horses are presented in hand around a triangle and then loose (BEF, 2014). Horses are assessed on their 'frame and build' (scored out of ten and averaged between judges), 'correctness of paces' (i.e. walk, trot and canter, each scored out of ten and averaged between judges), 'athleticism' (scored out of 20 and averaged between judges) and 'jump' if appropriate (scored out of ten and averaged between judges) (see appendix ii).

Conformation scores have been shown to influence the performance lifetime of sport horse, with musculoskeletal disorders resulting in euthanasia of 50-70% of riding horses (Jönsson *et al.*, 2014; Wallin *et al.*, 2001). Horses which score 7 or higher in the RHQT evaluations have been shown to have the greatest life endurance (Wallin *et al.*, 2001). In the gait evaluations, only canter scores have shown to significantly influence life expectancy. Horses with higher walk and trot scores show a trend of living longer, and movements in trot have shown to be associated with overall health status (Jönsson *et al.*, 2014; Wallin *et al.*, 2001). Jumping scores in the RHQT evaluations have furthermore been shown to significantly correlate with horses' longevity (Wallin *et al.*, 2001). In the BBF jumping ability is only evaluated for show jumping and eventing horses, and for welfare reasons only implemented for three year olds.

All averaged component scores are combined and the total divided by seven, to award a premium score from 0-10, rounded up to a 2 decimal placing (see Table 1) (British Equestrian Federation, 2013a).

Table 1: BBF premium awards, definitions and criteria

Premium	Description
Elite (9.00 or above)	A horse or pony that has an average of scores over 9 which means that it has the potential and the outlook to perform well at international level, if veterinary guidance is followed and the horse or pony is appropriately cared-for, produced and ridden.
Higher First (8.50 - 8.99)	A horse or pony that has an average of scores over 8.5 which means that it has the potential and outlook to perform well at national level, if veterinary guidance is followed and the horse or pony is appropriately cared-for, produced and ridden. The main difference between a higher first and a first is that the evaluators believe it shows greater athleticism and a greater potential to obtain a higher number of points/prize money and/or be in the placings so as to set it apart from a First premium.
First (8.00 – 8.49)	A horse or pony that has an average of scores over 8 which means that it has the potential and outlook to perform well at national/affiliated sport level, if veterinary guidance is followed and the horse or pony is appropriately cared-for, produced and ridden.
Second (7.50 – 7.99)	A horse or pony that has an average of scores over 7.5 which means that it has the potential and outlook suited to performing consistently within affiliated and riding club competition, if veterinary guidance is followed and the horse or pony is appropriately cared-for, produced and ridden.
Third (7.00 – 7.49)	A horse or pony that has an average of scores over 7 which means that it has the potential and outlook suited to performing up to a certain level in affiliated and unaffiliated competition if veterinary guidance is followed and the horse or pony is appropriately cared-for, produced and ridden.
No premium (<7.00)	4-6 some compromising features Below 4 seriously compromising features Seek veterinary guidance.

The 0-10 scoring system has been adopted from British Dressage (British Dressage, 2014). Similar systems are used in judging of various other non-equine sport disciplines e.g. figure skating, diving and trampolining (FINA 2013; Federation Internationale de Gymnastique 2013; International Skating Union

2003). Scoring in this way has been found to be superior to scoring systems with less variability (e.g. using a 1-6 scale) in terms of differentiating between individuals performance. To allow further differentiation in scores Futurity judges are allowed to use increments of 0.25 in all component scores.

1.3.1.3 Implications of the British Breeding Futurity Results

The BBF evaluates and predicts the health and career prospects of young horses. The awarded premium scores can (a) influence the monetary value of the horses and (b) inform on future training and breeding decisions (BEF, 2013a). Consequently, the equine sector (i.e. horse breeders, owners, riders, trainers, horse practitioners and in turn, the equine affiliated bodies such as British Dressage (BD), British Show Jumping Association (BS), British Eventing (BE) and British Endurance (EGB) can be financially influenced by this first step in the career of a performance horse. However, anecdotal feedback from Futurity exhibitors has suggested that a bias with respect to the coat colour of the horse may exist within evaluations (Dixon, pers. com, Rogers, pers. Com, 2013). Therefore, any subsequent bias in the Futurity scoring could have financial implications for the British equine sector. Conversely, the possibility of recognising and understanding of such bias could lead to improvements in the evaluating processes.

1.4 Judging Bias

Bar-Eli and Raab (2006, p 519) defines judgement and decision making as:

“a set of evaluative and inferential processes that people have at their disposal and can draw on in the process of making decisions”.

Bias is used to describe the deviation from the norm, or a point of view which can be positive or negative, it does not in itself indicate an error of judgement, but a subjective opinion on how the outcome should be (Keren and Teigen, 2004). It is defined by Keren and Teigen (2004, p 92) as:

“the result of cognitive limitations, processing strategies, perceptual organizing principles, an egocentric perspective, specific motivations (e.g. “self-serving biases” in social psychology), affects, and cognitive styles”.

1.4.1 Judging Bias in Sport

Thirty-nine different biases have been reported in social cognition literature (Plessner and Haar, 2006). Sport performance judging follows the general principles of social judgement and, is as a result, inevitably prone to bias (Plessner and Haar, 2006). Studying bias and its underlying processes is, therefore necessary to improve the accuracy of sport performance judging.

There are different dimensions upon which a sporting performance can be judged. The BBF evaluations are evaluative judgments, where performance is judged on a good-bad scale. In contrast, judgment of identification is where a certain rule has to be identified (e.g. recognising foul play). Bias has been identified in sports in the judgment of identification dimension e.g. in judging football, rugby and table tennis (Krenn, 2014; Plessner and Haar, 2006; Greenlees et al., 2005). However, the possibility of bias is increased when judging is reliant on the subjective opinion of the performance viewed, as seen in gymnastics, figure skating and rope skipping (Balmer *et al.*, 2003; Bar-Eli *et al.*, 2006; Findlay and Ste-marie, 2004; Ste-Marie and Lee, 1991). Subjective judging relies heavily on abilities of decision making and memory recall, and the

limitations of the human brain in these processes is what ultimately produces bias (Keren and Teigen, 2004). In a sporting performance, where the judging decision is also time limited, mental short-cuts are made by generalizing the performance, the athletes, and the situation, according to previous memory (Plessner and Haar, 2006). This is not to be confused with the self-serving biases defined as a specific motivation for bias. Many negative consequences can result from a judge having bias e.g. hostility from exhibitors (Keren and Teigen, 2004). Therefore, most people involved in sport aim to make accurate judgments, and judging bias in sport is typically out of the conscious control (Plessner and Haar, 2006).

Mental short-cuts happens even in simple social interactions when a lot of information has to be processed, as a way of simplifying cognitive processes, and can serve very well in everyday life (Bless *et al.*, 2004). The sequence of information processes introduced by Bless *et al.* (2004) and applied to sport judging by Plessner and Haar (2006), describes the different steps of information processing from observation to behavioural response. The different steps i.e. stimulus events, perception, categorization of event, related memory and organized knowledge, judgment/decision and behavioural response, makes it apparent that small errors in one or more of these steps can easily result in faulty judgement. Furthermore, a two system of the mind has been proposed in judgement and decision making, where system 1 makes quick reactions to challenges, short term predictions and models to familiar situations, and system 2 takes over to make more calculated decisions (Kahneman, 2012). Where system 1 is generally accurate in decisions, it is biased by not using logic and statistics and cannot be turned off. System 2 can be trained e.g. to think

statistically, but few people receive the necessary training and when information is especially complex (e.g. judgement of horses' gait/build/movement) and/or there is a time pressure (e.g. competition/evaluation) and/or pressure to make correct decision (from organisation/horse owners), processing information logically simply exceeds the human capability, and system 1 takes over by using the mental short-cuts (Kahneman, 2012; Wolframm, 2010). The short-cuts may arise in the 'related memory' step of information processing and be influenced by preconception of the athlete or situation resulting in a biased judgement/decision (Wolframm, 2010; Plessner and Haar, 2006). Table 2 displays examples of forms of biases suggested in sports performance judging.

Table 2: Examples of judging biases in sport

Type of Bias	Definition and Source
Nationalistic	The athletes nationality biases the scoring according to the nationality of the judges (Emerson, Seltzer and Lin, 2009).
Location	Scoring is effected on what angle the sport performance is viewed e.g. judge position in dressage (Hawson et al., 2010).
Rank Order	Several performances in a row result in a comparison to the previous performances resulting in a low-high biased scoring (Wolframm, 2010).
Reputation	Using knowledge of previous titles, performances or warmup performance (Findlay and Ste-marie, 2004).
Conformity	A desire for individual scoring to conform and follow any group decision (Boen et al., 2008)
Home Advantage	The audience reaction/perceived advantage of players influencing the judging (Boyko et al., 2007; Balmer et al., 2003).

1.4.2 Colour Bias in Sporting Events

Colour bias has been suggested in various subjectively judged sports. For example, Frank and Gilovich (1988) investigated football and ice hockey players and found that teams wearing black uniforms received more penalties than teams wearing uniforms that were not black. When teams switched from non-black to black uniforms a significant increase in penalties awarded was evident. This was attributed to cultural perception i.e. black is typically associated with evil and villains, psychologically influencing both the teams' self-image and the judging (Frank and Gilovich, 1988). However, a similar study by Tiryaki (2005) in the Turkish Premier Soccer League, found that the number of penalty kicks was not correlated with teams wearing black uniform. The difference between the studies was thought to be due to cultural differences i.e. Turkish referees' not perceiving black as a colour of villains. The different result could also be due to other mechanisms being behind the colour bias. A study comparing Chinese and British people showed a stronger preference for reddish colours amongst the Chinese participants, which further supports a cultural difference in colour preference i.e. red being the colour associated with good luck in China (Hurlbert and Ling, 2007).

Furthermore, red has shown to be central in colour bias of sport competitions e.g. in combat sports during the 2004 Olympic games, more winners wore red compared to blue (Hill and Barton, 2005a). In this study, it was suggested that red had a psychological effect on the opponent. The colour red can be associated with increased blood flow as a result of aggression, and compared to the correlation of male dominance and intensity of red in animals, red bias was in this men's Olympic competitions associated with male dominance (Hill and Barton,

2005a). This was in comparison to blue which was related to paler complexions possibly more associated with fear (Wiedemann *et al.*, 2015; Hill and Barton, 2005a). However, Rowe *et al.* (2005) also analysed Judo competition data from the 2004 Olympics, and found more winners wearing blue than white. They suggested bias was due to visibility mechanisms i.e. white is brighter and easier to see for the opponent, as they could not think of any plausible evolutionary explanation for blue winning bias (Rowe *et al.*, 2005). In contrast Hill and Barton (2005b) suggested that visibility was not considered a factor influencing close combat sports. What these two studies fail to consider was that the apparent colour winning bias could lay with the judge and not be between the opponents.

Hagemann *et al.* (2008) showed that the effect of colour on performance could also be due to perceptual bias of the referee. In their study the colour of sport uniforms were digitally changed (between red and blue) in video clips of Taekwondo competitors. Despite identical performances, red wearing competitors were still positively biased towards, hereby making it clear that differences in winning were influenced by colour attributed to difficulty in making objective judgements of the sport performance.

Similarly, in English football, red uniforms were associated with significantly more points and a higher position in the league. Over a 55-year period teams wearing red were compared with other colours across all divisions in English cities and showed a significantly higher performance i.e. best home record (Attrill *et al.*, 2008). This suggests that a preference for red is exclusively due to bias. The study also demonstrated that teams wearing white performed better than teams in yellow suggesting there is an order of colour bias (Attrill *et al.*, 2008). Similarly,

LeMaire and Short (2007) found a colour bias order in softball. Players in teams wearing red were perceived as 'strongest', 'intimidating', 'winning' and having higher confidence than teams wearing yellow, which were associated with more negative attributes i.e. 'bad', 'non-focussed', 'weakest', 'scruffy', 'least impressive' and 'least intimidating' (LeMaire and Short, 2007). Teams wearing black were also rated to be the 'meanest' compared to other uniform colours, which is comparable to the results of Frank and Gilovich (1988).

Research in football by Krenn (2014) also supports a hierarchy of uniform colours, suggesting blue is associated with peace, and athletes wearing blue, compared to green and yellow, receive less penalties. In contrast, athletes wearing red received the highest penalties; therefore, red uniforms were related with danger. This supports Hill and Barton's (2005a) conclusion that red winning bias is associated with male dominance, which is beneficial in combat sports, but seems to contradict the winning bias of red uniforms in football (Attrill *et al.*, 2008).

Although these studies give evidence to suggest that athlete's uniform colour can bias performance judging, the mechanisms behind the bias has not been fully explained.

1.4.3 Colour and Memory

Outside sport competition, colour has been studied as a non-conscious method of shortening the decision process i.e. colour can aid memory (Kawasaki and Yamaguchi, 2012; Fecteau *et al.*, 2009; Cornelissen and Greenlee, 2000). Colour was found to aid recollection through association, and additionally to create

involuntary attention to non-relevant events which shared the same colour as previously targeted events (Fecteau *et al.*, 2009). Patterns (form in combination with colour) have also been shown to aid memory. Information about colour and pattern are stored separately within the brain and can therefore be used independently in memory recall (Cornelissen and Greenlee, 2000). Combined with the fact that bias is a result of the human brains' limitation in memory recall and decision-making, judging bias according to colour can therefore be a result of colour affecting memory (Keren and Teigen, 2004). It can therefore be argued that memory of previous sporting events of similar (uniform) colour could be expected to bias a new sport performance evaluation, with pattern and colour in combination even likelier to be biased.

1.4.4 Equine Coat Colour Bias

Primary colours such as blue and green cannot be directly applied to horse coat colours. However, colours such as red, yellow, black and white can be compared to horse colours i.e. chestnut appears red, dun/palomino appears yellow, black in various shades, and grey, which can vary from dark to a pure white in horses (see appendix 1). White spotting patterns and face/leg markings of the horse can also be compared to the studies of patterns and colours (Cornelissen and Greenlee, 2000). Consequently, patterns and markings of the horse could theoretically be remembered differently, but also in combination with the base coat colour e.g. chestnut, bay and black. Accordingly, patterned horses are likely to be easier to remember and more likely to suffer bias. Furthermore, lesser memory of black and white block patterns compared to coloured, could suggest

black and white patterned marked horses (e.g. Piebald) are less likely to be remembered and therefore not so easily biased for/against compared to coloured and white patterns (e.g. skewbald) (Cornelissen and Greenlee, 2000).

Contrary, animal colour with interrupted patterns has been suggested to camouflage by masking the body of the animal (Cott, 1966). High-contrast conspicuous black and white patterns, such as zigzags, has been found to “dazzle”, making the estimation of speed and direction of the patterned object difficult, proposed as anti-predator markings (Stevens, Yule and Ruxton, 2008). Similarly, greyscale pictures of zebras, compared to ‘solid’ coloured horses, were found to generate much stronger motion signals (How and Zanker, 2014). These were corresponding to visual illusions causing a form of motion camouflage (How and Zanker, 2014).

It is not known if piebald horses would create a similar motion camouflage, due to the same high contrast of the black and white markings as zebras. Stevens *et al.* (2008) found that a pure white image was easier to catch by the human ‘predators’ in their study, compared to other conspicuous patterns. This could suggest that large amounts of white, such as in the piebald or skewbald horse patterns (see appendix 1.4.4), does not create motion camouflage, but increases visual attention. This is supported by Scofield *et al.* (2014) study on decreased road accidents of block coloured horses. However, the white object used in the Stevens *et al.* (2008) study was pattern-free, and no other solid colours were used for comparison. Nevertheless, these studies suggest visual attention is affected by patterned coat colours compared to solid, whether it improves or obscures the observers’ vision is currently unknown.

1.5 Conclusion

No prior research of judging bias according to horse colour has been published. However, judging bias according to athletes' uniform colour and research in colours effect on memory recall has been previously suggested. Furthermore, history shows how horse colour has been a subject of changing fashion, which has been significantly influenced by domestication, and the development horse breed registers. Moreover, equine coat colour genetics has advanced greatly in the last 20 years. It has shown how breeding for specific colour genotypes can have ethical implications, and how selective breeding for horse colour phenotypes can have financial consequences. Together these findings support the theory that horse coat colour bias can exist, as suggested by participants of the BBF.

The British equine industry is struggling to make breeding of top performing sports horses profitable. Initiatives from the BEF, such as the BBF evaluations, wishes to improve this with the principal aim to have British medals being won on British bred horses. Investigating this perceived horse colour bias within the BBF evaluations can help develop ideas on how to improve equine potential performance judging. This could also benefit horse welfare by discouraging the overbreeding of unwanted low quality equines and improve the potential economic-worth of British horses.

2 Investigating Horse Coat Colour Bias in the British Breeding Futurity

To investigate horse coat colour bias in the BBF, data from previous evaluations (2007-2014) was received directly from the BEF and analysed for significant differences in scores according to the colour of the evaluated horses. The aims were to: (1) investigate the possible existence of horse colour bias in the final premium scores, similar to the historic preference for horse colour in Great Britain and comparable to bias of athletes uniform colour in sport competitions, (2) investigate if any difference in potential horse colour bias arose in the assessed components of the BBF evaluation, related to the arguably difference in subjectivity in component judging, and (3) identify trends in the potential horse coat colour bias according to year and geographical region of the BBF evaluations, to detect any change in colour bias over time, pinpoint potential areas i.e. evaluator teams with more/less bias, and evaluate the strength of the theorised bias compared to other occurring changes in BBF scores.

2.1 Method

2.1.1 Data Collection

Data from the BBF evaluations from 2007-2014 were provided from the BEF in Microsoft Excel spreadsheets. The data included: horse name, coat colour, year of birth, sex, breed registration, year of evaluation, venue, discipline, premium

score, veterinarian score, frame and build, walk, trot, canter, athleticism, jump, sire name, sire breed registration, dam name, dam breed registration, dam sire name and dam sire breed registration. Horse owners provided the details of horse name, sex, age, breed registration, parental details and coat colour. Therefore, horse coat colour was considered phenotypical and lacked details of shading and markings. Complete datasets were not available for all individual horses due to; change in BFF regulations (e.g. canter scores not introduced until 2012), different evaluation disciplines (e.g. jump evaluations only for three year old eventing and show jumping evaluated horses) and general typographical errors or missing data (e.g. horse colour not recorded in 2007). A description of the final data available according to year and evaluation discipline can be seen in Table 3. A Microsoft Excel master document was produced with BFF data from 4001 horses overall.

Table 3: Data missing/analysed

Year of Evaluation	Data Missing/Analysed (n)
2007 (n=286)	No horse coat colour or component score data: whole year excluded from analysis (n=0)
2008 (n=418)	No component scores. Analysis on: Horse colour and premium scores (n=418)
2009 (n=599)	No canter or jump component scores. Analysis on: Horse colour and premium scores (n=599), veterinarian (n=595), frame and build (n=595), walk (n=595), trot (n=595) and athleticism (n=595) component scores.
2010 (n=628)	No canter or jump component scores. Analysis on: Horse colour and premium scores (n=628), veterinarian (n=576), frame and build (n=576), walk (n=576), trot (n=576) and athleticism (n=576) component scores.

Table 3 continued: data missing/analysed

2011 (n=864)	No canter or jump component scores. Analysis on: Horse colour and premium scores (n=864), veterinarian (n=862), frame and build (n=862), walk (n=861), trot (n=862) and athleticism (n=862) component scores.
2012 (n=590)	Analysis on: Horse colour and premium scores (n=590), veterinarian (n=559), frame and build (n=559), walk (n=559), trot (n=559), canter (n=559), jump (n=47), and athleticism component scores (n=559).
2013 (n=485)	Analysis on: Horse colour and premium scores (n=485), veterinarian (n=480), frame and build (n=480), walk (n=480), trot (n=480), canter (n=479), jump (n=49), and athleticism component scores (n=480).
2014 (n=417)	Analysis on: Horse colour premium scores (n=417), veterinarian (n=411), frame and build (n=411), walk (n=411), trot (n=411), canter (n=411), jump (n=48), and athleticism component scores (n=411).

2.1.2 Initial Data Handling

2.1.2.1 Horse Coat Colours

Horse colours of similar phenotypes were combined in various groups as shown in Table 4. These groupings were used to try to safeguard against human error in assigning colour based on visual owner opinion only, the possibility of unknown mutations being responsible for the phenotype, the lack of specification of colour categories by the breed societies, and the possible combination of genes creating similar phenotypes (see appendix 1). Grouping also helped to create more equal sample sizes e.g. for statistical analysis. The owner prescribed horse coat colours were also retained for analysis i.e. bay (n=1650), light bay (n=75), dark bay (n=493), chestnut (n=700), dark chestnut (n=73), black (n=345), grey (n=237), roan (n=17), buckskin (n=25), palomino (n=56), dun (n=45), piebald (n=45), skewbald (n=196), appaloosa (n=28) and spotted (n=16).

Table 4: BBF horse coat colour groups

Horse Coat Colour Code/Group Description	Horse Coat Colour Coding <i>Definition</i>
1) Grouped shades of the same colour, similarities of horse colour phenotype and interchangeable terminology. Grey and black horses remained ungrouped, as these were considered to be recognisably dissimilar to any of the other colours, from an equestrian's point of view (Kathman, 2014b).	Bay: (n=2218) <i>light bay, bay and dark bay</i> Chestnut: (n=773) <i>chestnut and dark chestnut</i> Dilutions: (n=126) <i>dun, buckskin, and palomino</i> Block Coloured: (n=241) <i>piebald and skewbald</i> Spotted: (n=61) <i>spotted, appaloosa, roan</i> Grey: (n=237) <i>grey</i> Black: (n=345) <i>black</i>
2) Grouped spotted and block coloured horses into the group white marked, as these horse colours can have similar phenotypes (appendix 1.4.3).	Bay: (n=2218) <i>light bay, bay and dark bay</i> . Chestnut: (n=773) <i>chestnut and dark chestnut</i> . Dilutions: (n=126) <i>dun, buckskin, and palomino</i> . Grey: (n=237) <i>grey</i> . Black: (n=345) <i>black</i> . White Marked: (n=302) <i>piebald, skewbald spotted, appaloosa and roan</i> .
3) Grouped grey and roan horses together as these can phenotypically be similar in young horses (appendix 1.4.1).	Bay: (n=2218) <i>light bay, bay and dark bay</i> . Chestnut: (n=773) <i>chestnut and dark chestnut</i> . Dilutions: (n=126) <i>dun, buckskin, and palomino</i> . Block Coloured: (n=241) <i>piebald and skewbald</i> . Black: (n=345) <i>black</i> . Grey/Roan: (n=254) <i>grey and roan</i> . Spotted: (n=44) <i>spotted and appaloosa</i> .
4) Grouped all 'solid' horse coat colours and all white marked. Used to test if broken and patched horse coat colours had an effect on evaluation scoring compared to a uniform colour.	Solid: (n=3699) <i>light bay, bay, dark bay, black, chestnut, dark chestnut, grey, dun, buckskin, and palomino</i> . White Marked: (n=302) <i>piebald, skewbald, spotted, appaloosa, and roan</i> .
5) Grouped light, medium and dark horse coat colours together. Used to test if shading of horse coat colour had an effect on evaluation scoring.	Dark: (n=911) <i>dark bay, dark chestnut and black</i> . Medium: (n=2350) <i>chestnut and bay</i> . Light: (n=438) <i>light bay, grey, roan, buckskin, dun and palomino</i> . Patterned: (n=302) <i>spotted, appaloosa, piebald and skewbald</i> .
6) Attempted to group horse coat colours as a comparison to athletes uniform colours.	Yellow: (n=101) <i>palomino and dun</i> . Red: (n=700) <i>chestnut</i> . Brown: (n=1725) <i>bay and light bay</i> . Black: (n=345) <i>black</i> . Grey/White: (n=237) <i>grey</i> . Patterned: (n=302) <i>spotted, appaloosa, piebald and skewbald</i> . Other: (n=608) <i>buckskin, roan, dark chestnut and dark bay</i> .

2.1.2.2 Horse Names

All entries were manually checked for repeated horse names and any duplicated data was deleted. Multiple entries have not been permitted by the BEF since 2012. Any individual horses with repeat entries in previous years i.e. had been evaluated for two disciplines, had the lettering a or b added to their name e.g. “Alderwood Hot Shot a” and “Alderwood Hot Shot b”. No horses had multiple entries in any one discipline as the BEF only allows a horse to be evaluated once in any year.

Occasionally entries would be unnamed or would only have the stud prefix e.g. Abbottsvalle in which cases a unique number 1-9 was assigned. Data on parentage, coat colour and year of birth were used to identify separate horses where necessary.

2.1.2.3 Component Scores

All component scores were recorded to two decimal places in agreement with BBF scoring (see section 1.3.1.2). There were some obvious data errors within the component scores e.g. missing or duplicated. There were also some apparent erroneous components score data e.g. jump scores >10 which are not possible, athleticism scores <10 which are highly unlikely given it is a double exponent score, and random component scores of 1 in data from horses with otherwise high scores (n=18) which are considered highly suspect. Typographical and/or copying errors are suspected e.g. it looks as if the jump and athleticism scores have been interchanged (n=3), or the athleticism score has not been multiplied by two (n=18). However, this was not assumed and all suspected erroneous data were removed before any subsequent analysis.

2.1.2.4 Venues and Regions

The various BBF venues around Great Britain were grouped geographically according to regions defined by British Dressage (British Dressage, 2015). These regional groupings (detailed in Table 4) were compiled to enable analysis of regional variability, besides not all coat colours were represented at all venues.

Table 5: BBF venues (2008-2014) grouped according to geographical regions within Great Britain

Region	Venues
Scotland	Fountain Equestrian Centre Aberdeen, Scottish National Equestrian Centre, SNEC West Lothian
Northern	Arena UK Grantham Lincs, Arena UK Lincolnshire, Richmond Equestrian Centre Yorkshire
North West	Alsager Equestrian Centre Stoke-on-Trent, Heart of England Stone Staffs, Myerscough College Lancashire, Myerscough Equestrian Centre Lancashire, Solihull Riding Club West Midlands, Southview Equestrian Centre Cheshire
Central	Catherston Stud Hampshire, Crofton Manor Hampshire
Eastern	College Equestrian Centre Bedfordshire, Writtle College Essex
Wales	Sunnybank Equestrian Centre Caerphilly, Triley Fields Equestrian Centre Monmouthshire
Southern	Plumpton College East Sussex
South West	Bicton College Devon, Hartpury College Gloucestershire, Tall Trees Cornwall, The Grange Devon

2.1.3 Statistical Analysis

2.1.3.1 Descriptive Statistics

Initial descriptive statistics were conducted on the 2012 data as it was available first. It included the creation of filtered pivot tables with conditional formatting

(Microsoft Excel 2013) and descriptive statistics (IBM SPSS Statistics 21). Trends identified in 2012 data were further investigated on the whole dataset.

2.1.3.2 Comparison of Mean BBF Scores

Premium scores were analysed according to the horse coat colour groupings (see Table 4) to test the hypothesis (H_1): Horse coat colour has a significant effect on awarded mean premium scores. One-way ANOVA with Tukey HSD post hoc analysis was used for pairwise comparisons between groups. The second hypothesis (H_2): The mean component scores in the BBF evaluations (veterinary evaluation, frame and build, walk, trot, canter, athleticism, and jump) differ significantly according to the horses' coat colour, was tested by one-way ANOVA and Tukey HSD post hoc analysis in IBM SPSS Statistics 22. ANOVA assumed normally distributed data, however, coat colour group sizes and the frequency of horses per discipline were not normally distributed and therefore Primer-E and PERMANOVA analysis were used to test the third and fourth hypotheses: (H_3) There are significant effect of year, region, and horse coat colour on BBF premium scores and (H_4) Horse coat colour, region and year have significantly different effects on BBF premium scores within the individual BBF disciplines (dressage, show jumping, eventing and endurance).

2.1.3.3 PRIMER-E and PERMANOVA

The multivariate and graphical routines of PRIMER (Plymouth Routines In Multivariate Ecological Research) make very few assumptions about the form of data (Clark and Gorley, 2001). PERMANOVA, the add on package to PRIMER, allows for even more complex sampling structures by using distance measures that are appropriate to the data, and uses permutations to make it distribution free

(Primer-E, 2014). Therefore, Primer and PERMANOVA can be used as a better ANOVA to test for differences between groups with unbalanced designs (Primer-E, 2014). PRIMER has primarily been used for analysing ecological and environmental data (Clark and Gorley, 2001), however, the straightforward techniques of assumption free multivariate analysis made PRIMER suitable for the analysis of this multivariate equine dataset.

Prior to analysis, it was necessary to reduce the large amount of data available, for the software to operate. This was done by combining the factors venue, year of BBF evaluation, discipline and horse coat colour (group 1) as a factor in Primer, and thereafter averaging the data according to this factor. Consequently, the data was reduced by a factor of four. Euclidean distances was implemented as resemblance measure on premium score samples (Clarke and Warwick, 2001).

ANOSIM two way cross with replication was used to analyse the effects of region and year of evaluation within the disciplines (dressage, eventing, show jumping and endurance). This was undertaken to investigate if any variability in scoring was a function of year or region. ANOSIM two way cross with replication was then conducted on the effect of region, year, and horse coat colour (group 1) within disciplines and between disciplines. Tests were run with 999 permutations using a significance level of 5%. ANOSIM was run as it allows R values to be interpretable. Three-way ANOSIM and MANOVA in PERMANOVA were also carried out to test for the effect of horse colour (group 1), year of evaluation and region on premium scores using 9999 permutations.

2.2 Results

2.2.1 Effect of Horse Colour on BBF Premium Scores

BBF premium scores were analysed according to the owner assigned horse coat colours and the six horse coat colour groups (Table 4).

2.2.1.1 BBF Owner assigned Horse Coat Colours

The mean premium scores of BBF evaluations from 2008 to 2014, according to owner assigned horse coat colours are shown in Figure 5. The mean premium scores ranged from 7.87 (appaloosa) to 8.67 (buckskin). With all patterned horse coat colours (skewbald, piebald, spotted, roan and appaloosa) clustering towards the lower premium range. Conversely, most solid colours clustered towards the higher mean premium scores.

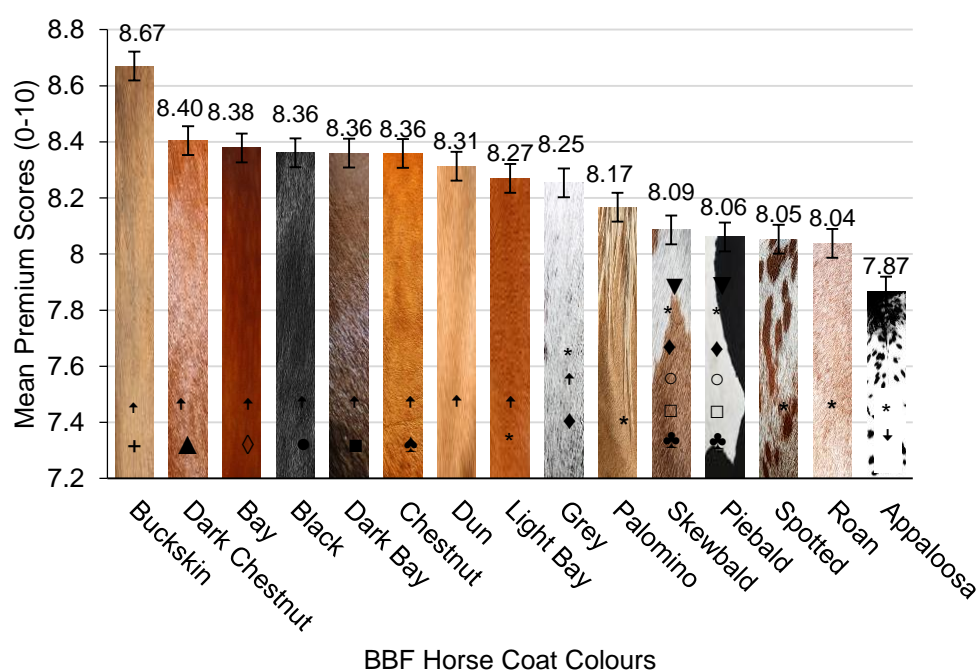


Figure 5 Mean BBF premium scores (with se bars) (2008-2014), according to owner assigned horse coat colours (i.e. buckskin n=25, dark chestnut n=73, bay n=1650, black n=345, dark bay n=493, chestnut n=700, dun n=45, light bay n=75, grey n=237, palomino n=56, skewbald n=196, piebald n=45, spotted n=16, roan n=17 and appaloosa n=28). Statistical significant differences between: † and †, + and *, ▲ and ▼, ◇ and ♦, ● and ○, ■ and □, ♣ and ♣.

The distribution of premium scores according to the owner assigned horse coat colours are displayed in Figure 6. Individual outliers in premium scores were present in all horse coat colours except light bay, piebald, spotted, roan and appaloosa coloured horses. It is noticeable that most premium scores of buckskin horses lie above the overall mean of premium scores, whereas the premium scores of most skewbald, piebald, spotted roan and appaloosa coloured horses lie below the mean. However, the lowest outliers were from bay horses. Hence, the lowest score of 5.68, which is not considered a premium (Table 1), belonged to a bay horse. The highest individual premium score of 9.90 (elite) was awarded to horses that were bay, dark bay and black.

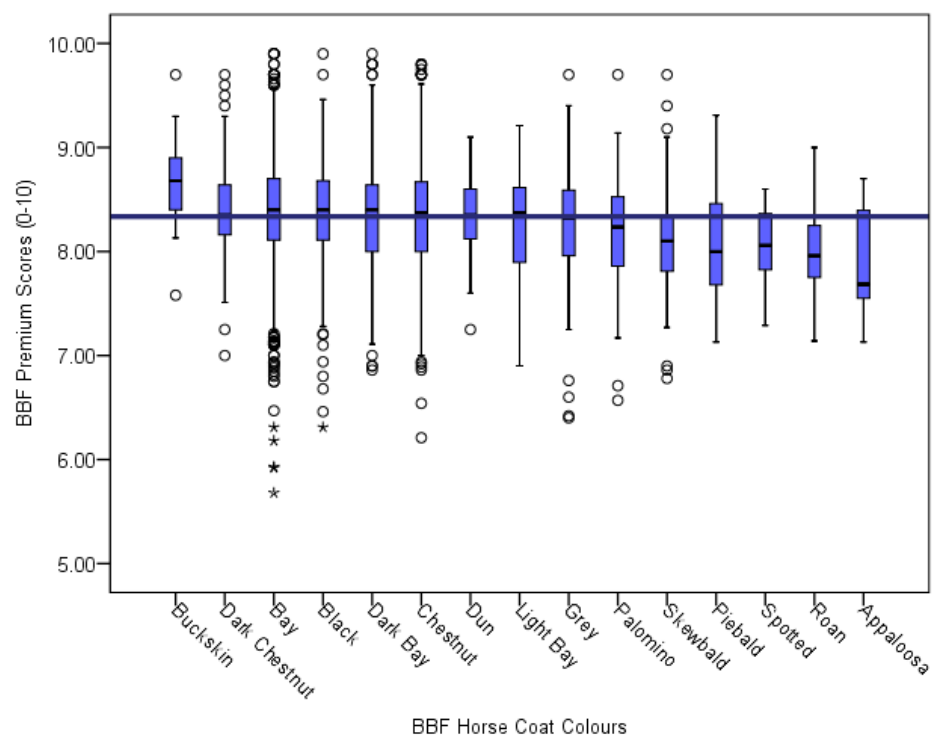


Figure 6 Distribution of BBF premium scores (2008-2014) according to owner assigned horse coat colours. The blue dark line represents the overall mean of premium scores.

Significant differences were found between mean premium scores according to owner assigned horse coat colours ($F_{14,3986}=10.48$, $p<0.0001$). Mean premium scores were significantly different between some colours ($p<0.05$) e.g. appaloosa coloured horses were significantly lower than grey, light bay, dun, chestnut, dark bay, black, bay and buckskin coloured horses.

2.2.1.2 Group 1 Horse Coat Colours

The mean premium scores of horse coat colour group 1 are shown in Figure 7. When grouped it is clear how spotted and block coloured horses have lower mean premium scores than solid coloured horses.

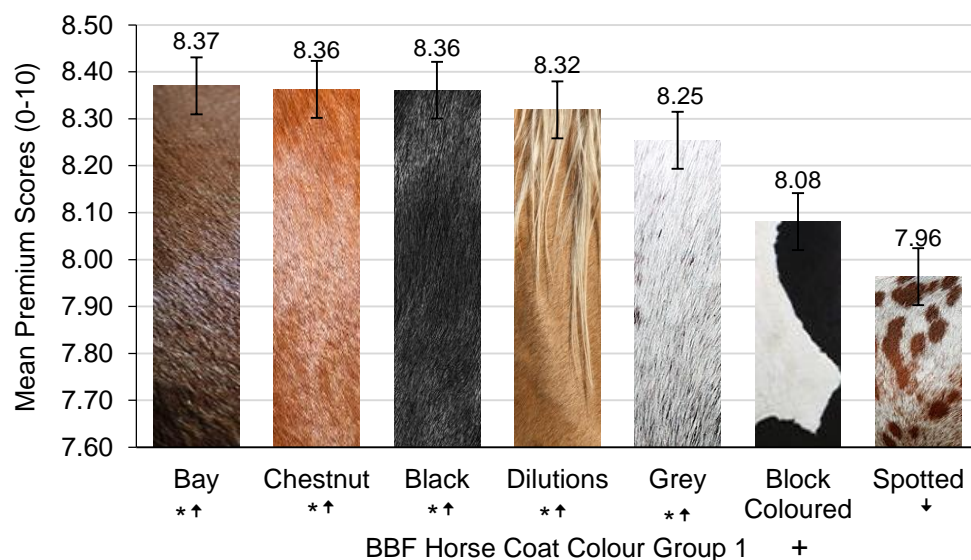


Figure 7 Mean BBF premium scores (with se bars) (2008-2014) of horse coat colour group 1 (def. Table 4) (i.e. bay $n=2218$, chestnut $n=773$, black $n=345$, dilutions $n=126$, grey $n=237$, block coloured $n=241$, and spotted $n=61$). Statistical significant differences ($p<0.05$) between *and+, †and†.

The distribution of premium scores of horse coat colour group 1 is shown in Figure 8. The median of premium scores from all solid coloured horses is very close to the overall mean of premium scores. However, the entire interquartile range of premium scores from block coloured and spotted horses lie below the overall mean. All but spotted horses have outliers. The lowest premium scores were of extreme outliers of a bay horse and the highest from outliers of bay and black horses.

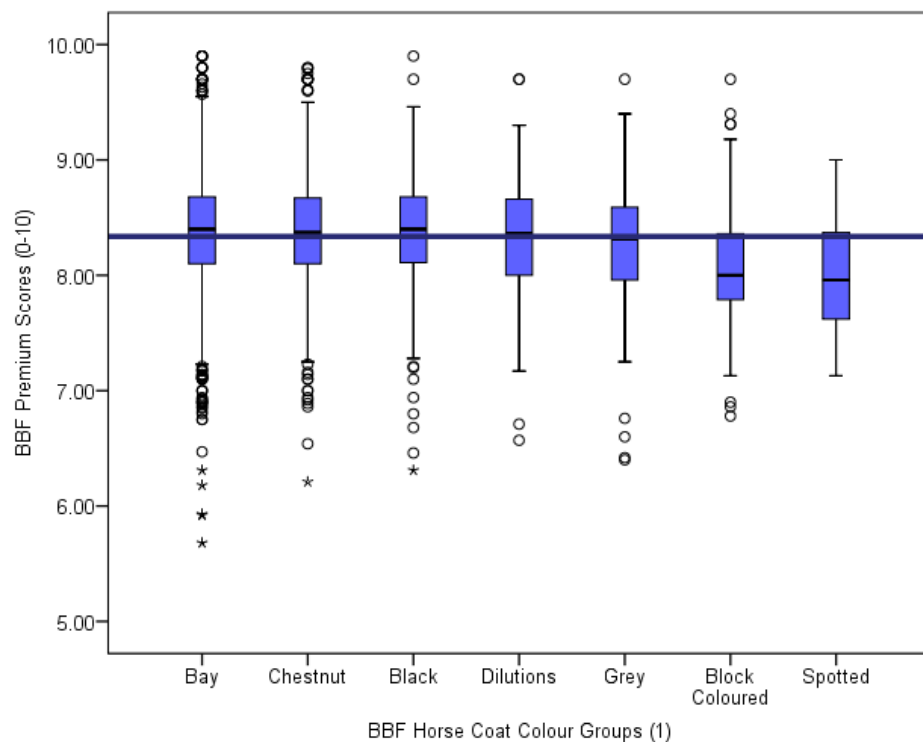


Figure 8 Distribution of BBF premium scores (2008-2014) from horse coat colour group 1 (def. Table 4). The dark blue line represents the overall mean of premium scores.

There was a statistical significant difference between premium score means of group 1 horse coat colours ($F_{6,3994}=20.22$, $p<0.0001$). Post-hoc Tukey's HSD test show that the mean premium score of block coloured horses were significantly lower to all other horse coat colours except spotted ($p<0.05$). Likewise, the mean premium score of spotted horses were significantly lower to all other horse coat colours except block coloured ($p<0.05$).

2.2.1.3 Group 2 Horse Coat Colours

The mean premium scores of Group 2 horse coat colours (Table 4) are shown in Figure 9. By combining all the white marked horses together this group became larger ($n=302$) than grey ($n=237$) and dilutions ($n=126$), and close to the sample size of black horses ($n=345$). However, the lowest mean premium score remains to be of white marked horses.

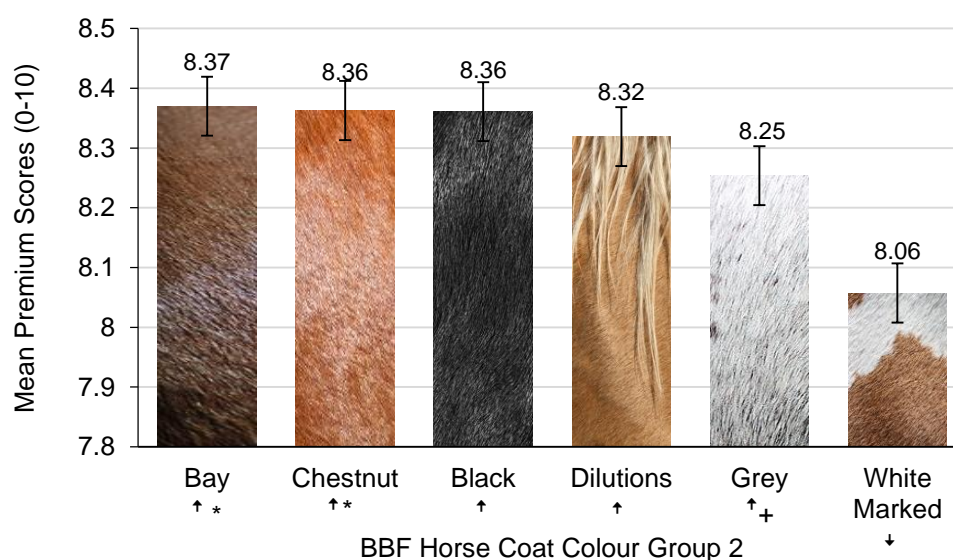


Figure 9 Mean BBF premium scores (with se bars) (2008-2014) of horse coat colour group 2 (def. Table 3) (i.e. bay $n=2218$, chestnut $n=773$, black $n=345$, dilutions $n=126$, grey $n=237$ and white marked $n=302$). Statistical significant differences ($p<0.05$) between ↑ and ↓, * and +.

The range of premium scores according to group 2 (Figure 10) shows that the interquartile range of white marked horses is below the overall mean of BBF premium scores. White marked horses also have the lowest scores, when outliers are excluded. The overall lowest premium scores of extreme outliers were still of bay horses.

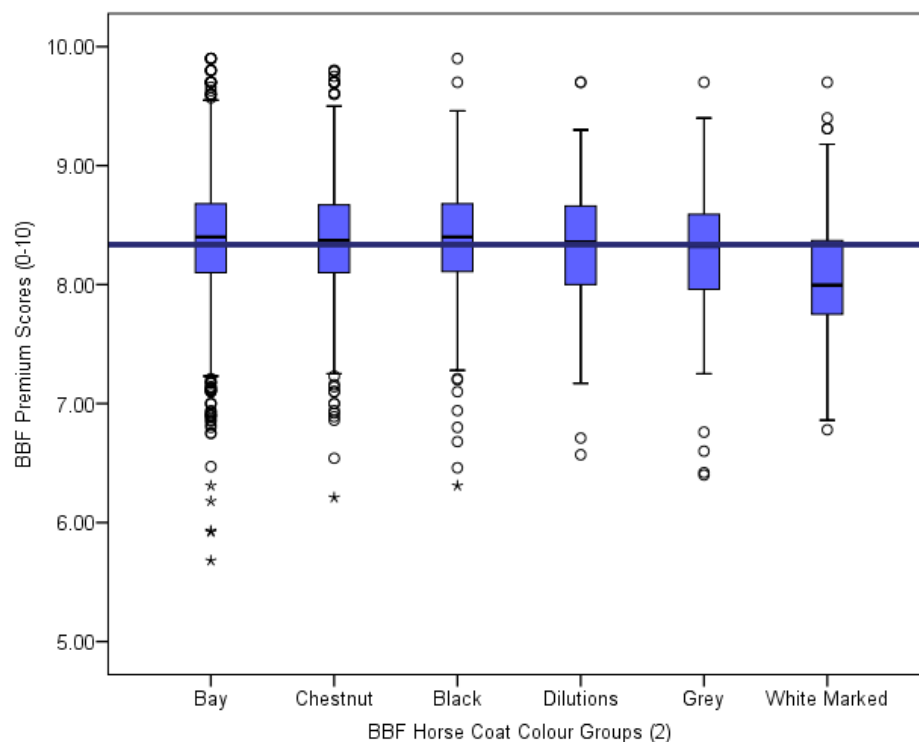


Figure 10 Distribution of BBF premium scores (2008-2014) of horse coat colour group 2 (def. Table 4). The dark line represents the overall mean of premium scores.

There were significant differences of premium score means between horse coat colour 2 groups ($F_{5,3995}=23.69$, $p<0.0001$). Post-hoc Tukey's HSD tests showed

premium score means of white marked horses were significantly lower than all other horse coat colour groups ($p<0.0001$). The mean premium scores of grey horses were also significantly different to bay ($p=0.007$) and chestnut ($p=0.033$) horses. No other horse colour groups were significantly different to each other.

2.2.1.4 Group 3 Horse Coat Colours

The mean premium scores according to group 3 coat colour is shown in figure 11. Grouping roan coloured horses with greys instead of spotted horses did not change the lowest rank of mean premium scores of block coloured and spotted horses.

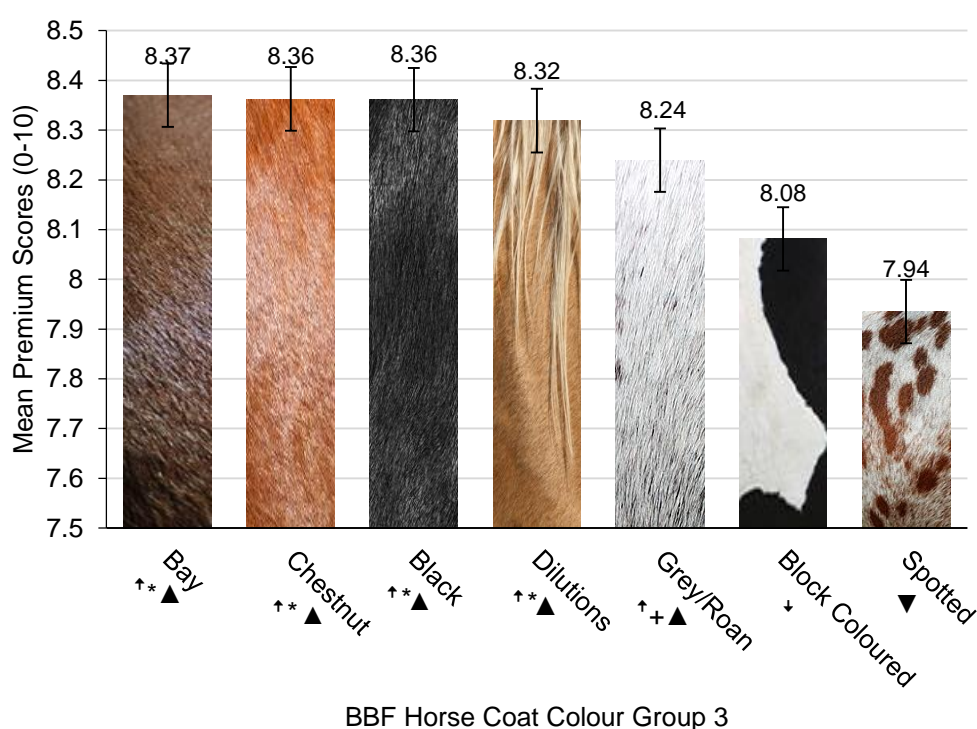


Figure 11 Mean BBF premium scores (se) (2008-2014) of horse coat colour group 3 (def. Table 4) (i.e. bay $n=2218$, chestnut $n=773$, black $n=345$, dilutions $n=126$, grey/roan $n=254$, block coloured $n=241$ and spotted $n=44$). Statistical significant differences ($p<0.05$) between † and ↓, * and +, ▲ and ▼.

The distribution of premium scores according to horse coat colour group 3 (Figure 12) shows similar trends to groups 1 and 2 i.e. the interquartile range of block coloured and spotted horses were below the overall mean of BBF premium scores, whilst the medians of solid horse coat colours were similar to the overall mean of premium scores.

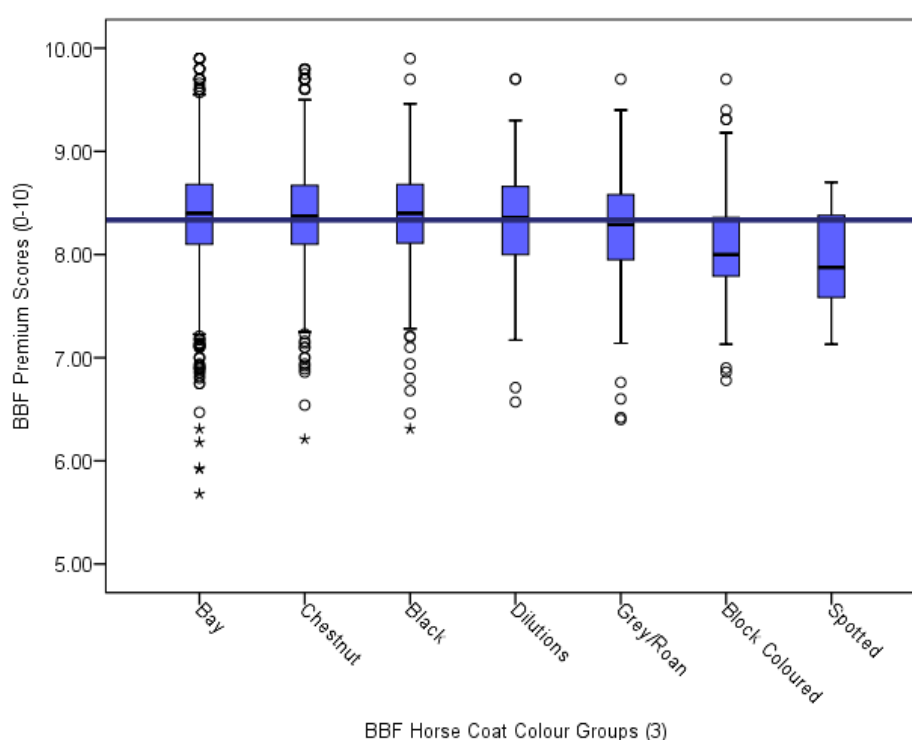


Figure 12 Distribution of BBF premium scores (2008-2014) of horse coat colour group 3 (def. Table 4). The dark line represents the overall mean of premium scores.

In agreement with Groups 1 and 2, there were also statistically significant differences of mean premium scores between horse coat colours of group 3 ($F_{6,3994}=19.78$, $p<0.0001$). Block coloured and spotted horses had significantly lower scores ($p<0.05$) than all other horse coat colour groups. Horses with

grey/roan coat colours were significantly different to all other horse colour groups ($p < 0.05$) except dilutions. No other coat colour groups had significantly different mean premium scores to another.

2.2.1.5 Group 4 Horse Coat Colours

The previous three groupings showed how horses with a white marked coat colour had lower premium scores than solid horse coat colours. Figure 13 also shows this trend by grouping all solid and all white marked horse coat colours.

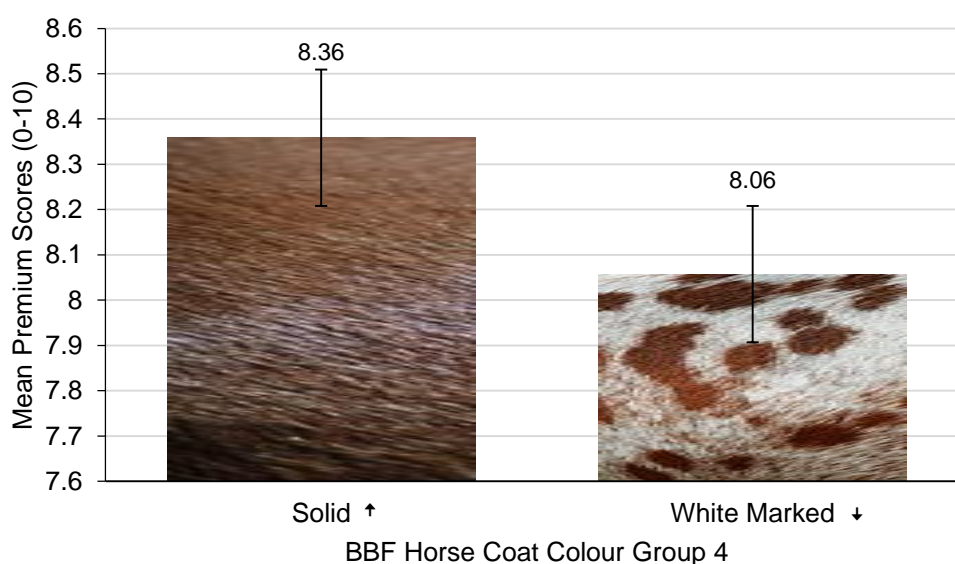


Figure 13 Mean BBF premium scores (2008-2014) (with se bars) of horse coat colour group 4 (def. Table 4) (i.e. solid $n=3699$ and white marked $n=302$). Statistical significant difference ($p < 0.05$) between ↑ and ↓.

The distribution of BBF premium scores of solid and white marked horses is displayed in Figure 14. The entire quartile of white marked horses is below the overall mean of premium scores, whereas the median of premium scores from all

'solid' coloured horses were very close to the mean. There were very few outliers of white marked horses, and therefore the mean is not likely to be skewed. However, many outliers (circles) and extreme lower outliers (stars) were present amongst in the premium scores of solid coloured horses.

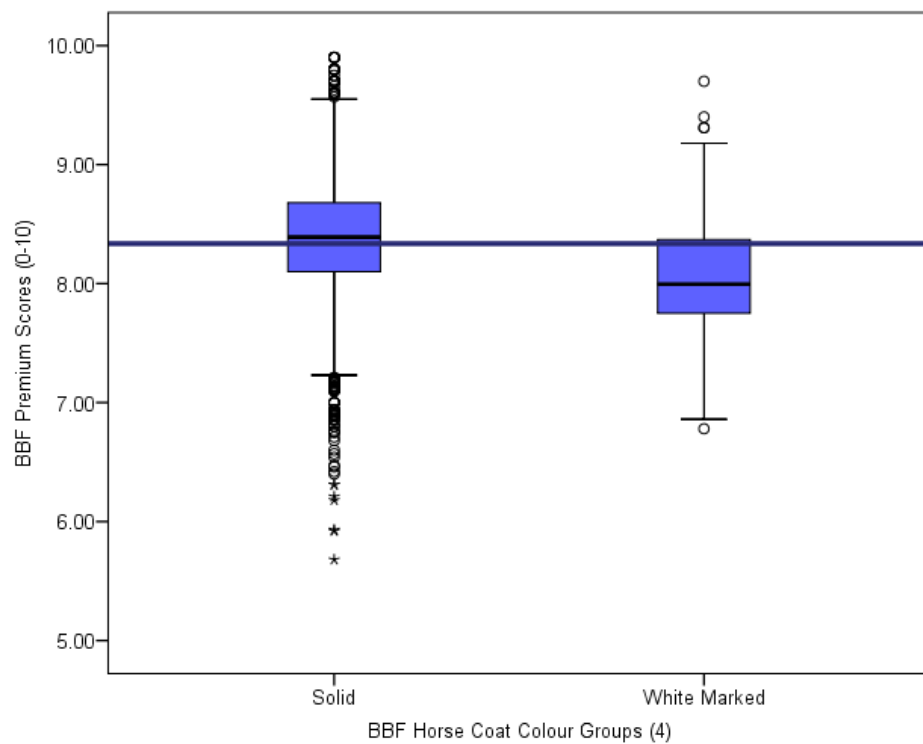


Figure 14 Distribution of BBF premium scores (2008-2014) of horse coat colour group 4 (def. Table 4). The blue dark line represents the overall mean of premium scores.

The difference in mean premium scores between solid coloured and white marked horses was statistically significant ($F_{1,3999}=105.29$, $p<0.0001$).

2.2.1.6 Group 5 Horse Coat Colours

Figure 15 shows the mean premium scores of evaluated horses when grouped according to the shade of the coat colours (group 5). Horses with dark (8.36) and medium (8.37) shaded coat colours have similarly high mean premium scores, followed by light coloured (8.28) and horses with a patterned coat (8.06).

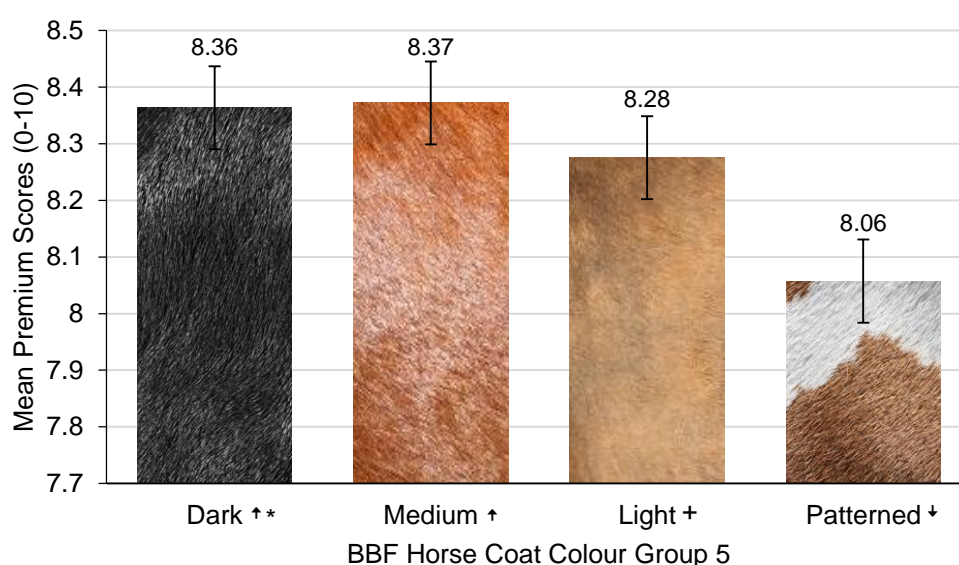


Figure 15 Mean BBF premium scores (with se bars) (2008-2014) of horse coat colour group 5 (def. Table 4) (i.e. dark n=911, medium n=2350, light n=438 and patterned n=302. Statistical significant differences ($p < 0.05$) between ↑ and ↓, * and +.

All four horse coat colour 'shade' groups had premium score outliers (see Figure 16). However, these were less pronounced with patterned horses compared to light, medium and dark shades of solid coloureds. The lowest premium scores belong to extreme outliers of individual horses with medium shaded coat colours. Removing the outliers, patterned horses had the lowest premium score, and the

quartile range of premium scores was below the overall mean. The premium score median of light shaded horses were similar to the overall mean, whilst the median premium scores of dark and medium shaded horses was just above the overall mean.

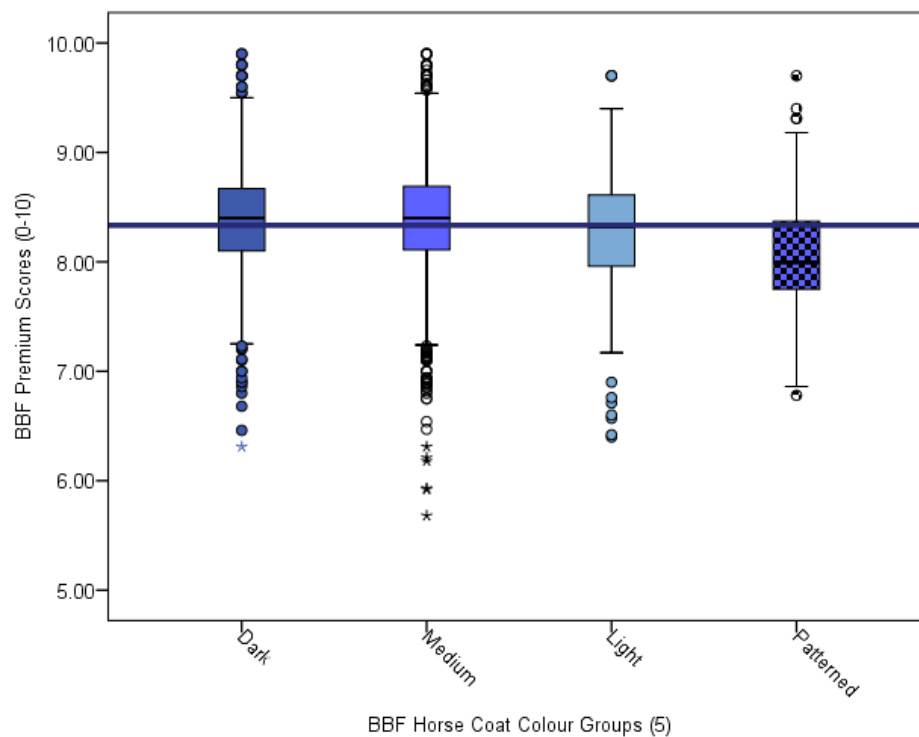


Figure 16 Distribution of BBF premium scores (2008-2014) of horse coat colour group 5 (def. Table 4). The dark blue line represents the overall mean of premium scores.

There was a statistical significance between the shades of horse coat colours in group 5 as determined by one-way ANOVA ($F_{3,3997}=40.04$, $p<0.0001$). The Turkey HSD post-hoc showed that patterned coloured horses had significantly lower mean premium scores than light, medium and dark shaded horses

($p < 0.0001$). Premium score means of light shaded horses were also significantly different to medium ($p = 0.001$) and dark shaded ($p = 0.010$) horses.

2.2.1.7 Group 6 Horse Coat Colours

Mean premium scores according to coat colour group 6 can be seen in Figure 17. Horse colours most similar to brown had the highest (8.37) mean premium scores followed by black and red (8.36), grey/white (8.25), yellow (8.23) and patterned (8.06).

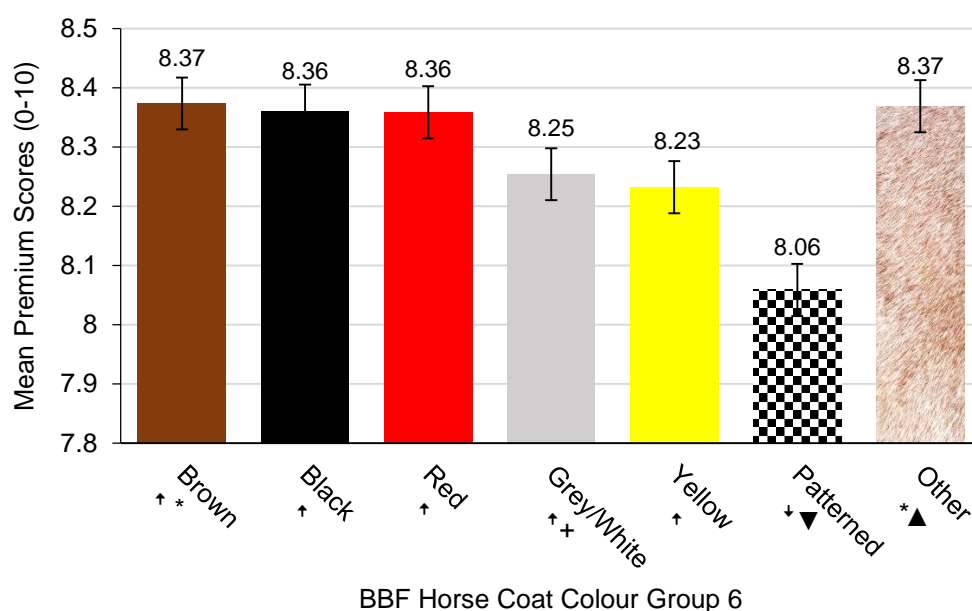


Figure 17 Mean premium scores (with se bars) (2008-2014) of horse coat colour group 6 (def. Table 4) (i.e. brown $n=1725$, black $n=345$, red $n=700$, grey/white $n=237$, patterned $n=285$ and others $n=608$). Statistical significant differences ($p < 0.05$) between ↑ and ↑*, * and +, ▲ and ▼.

The interquartile range of patterned coloured horses was below the overall mean of premium scores (Figure 18). The medians of all other colour groups were close

to the overall mean. Excluding the outliers, pattern horses also had the lowest premium scores. However, this was close to the lowest premium scores of the red horse coat colour group.

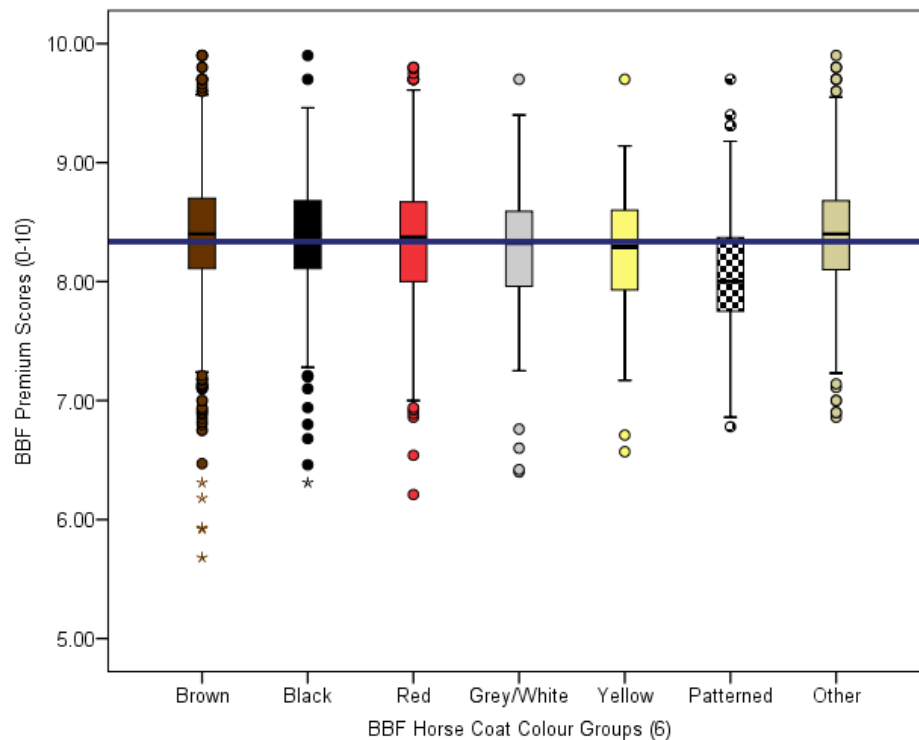


Figure 18 Distribution of BBF premium scores (2008-2014) of horse coat colour group 6 (def. Table 4). The dark blue line represents the overall mean of premium scores.

There were statistical significant differences between mean premium scores according to the sixth horse coat colour groups ($F_{6,3994}=19.59$, $p<0.0001$). Tukey's HSD Post-hoc analysis showed mean premium scores of patterned horses was significantly lower than all other horse coat colour groups ($p<0.05$). Grey/white horses were also significantly different to brown ($p=0.008$) and the 'other' horse colour group ($p=0.036$).

2.2.1.8 Conclusion

Across all groups block coloured and spotted (patterned/white marked) horses had significantly lower mean premium scores than all other horse coat colours ($p < 0.05$). Moreover, the distribution of premium scores from white marked horses were not dominated by outliers. Hence, the low mean was not a result of a few individuals, but collectively lower scores of all white marked horses. It can therefore be suggested that the BBF is scoring block coloured and spotted horses significantly lower than all solid coloured horses.

Grey coloured horses were the only other coat colour group with a statistical difference in mean premium scores compared to other coat colour groups. Furthermore, the difference in premium scores between light and dark/medium shaded horses was statistically significant ($p < 0.05$). This supports the apparent trend that light shaded horses receive lower scores than dark shaded. However, premium scores of buckskin coloured horses, a light coat colour, had significantly higher scores than the other light shaded horse colours (palomino, grey, light bay and roan). The only light shaded horse colour that buckskin horses were not statistically significant from was dun coloured horses. This is noteworthy as the horse colours dun and buckskin are phenotypically similar, and often the two genotypes are confused (see appendix 1.3). Furthermore, the distribution of premium scores from light shaded horses showed medians similar to the overall mean of premium scores, but with fewer outliers. Therefore, the significance of lower mean premium scores of light shaded horses compared to medium and dark, could be due to the dark and medium's individual outliers.

The mean premium scores of grey horses were consistently significantly different to all other horse coat colours: appaloosa ($p=0.007$), skewbald ($p=0.028$), bay ($p=0.021$) and buckskin ($p=0.005$). The significant difference in premium scores between grey and bay horses ($p<0.05$) were apparent throughout groups 1, 2, 3 and 6. However, the significance between grey and buckskin was not apparent when buckskin horses were grouped as dilutions. This suggests that grey horses (in addition to white marked) are receiving premium scores that are different to horses with other coat colours.

Group 6 was analysed in order to compare horse coat colours with the colour of athletes' uniforms (see section 1.4.2). Patterned horse coat colours had significantly lower premium scores than all other colour groups ($p<0.05$). Grey/white and brown were the only other colour group with significant difference in premium scores. Previous studies on bias according to athletes uniform colour has suggested that a white uniform is more visible during competitions (Rowe et al., 2005), but a competitor wearing light colours is considered weaker than athletes wearing other colours (LeMaire & Short, 2007). For this to compare to white/grey horses, significant differences would have to be present between grey and several other horse coat colours e.g. black, which was not the case. However, when grouped with roan, a phenotype which can be similar to grey in young horses (Hintz & Van Vleck, 1979), a significant difference in mean premium scores was found between grey/roan and bay ($p=0.001$), black ($p=0.043$), and chestnut ($p=0.009$) horses. Research on athletes uniform colour has also suggested that red and black significantly bias competition result e.g. red by association to aggression and danger, and black by association to villains

(Hagemann et al., 2008; Frank & Gilovich, 1988), but 'red' and 'black' horse colours did not show any significant difference in premium scores to horse colours other than patterned. In summary, horse colour cannot be directly compared to athletes' uniform colour. Nevertheless, there were an overall significant difference ($p < 0.0001$) in mean premium scores between horse coat colours from all six different horse coat colour groups. Therefore, significant difference in premium scores according to horse colour may be due to reasons other than those of athletes uniform colour bias. However, it is concluded that horse coat colour significantly effects the mean premium scores awarded at the BBF and the alternative hypothesis can be rejected.

2.2.2 Effect of Horse Colour on BBF Component Scores

The mean component scores of horse coat colour group 1 can be seen in Figure 19. The two lowest mean component scores for the veterinarian evaluation, frame and build, walk, trot, canter and athleticism belonged to spotted horses and block coloured horses. The jump score was the only component where block coloured and spotted horses did not have the lowest means. However, jump evaluations only contained 61 horses and only one spotted horse were responsible for the highest jump score.

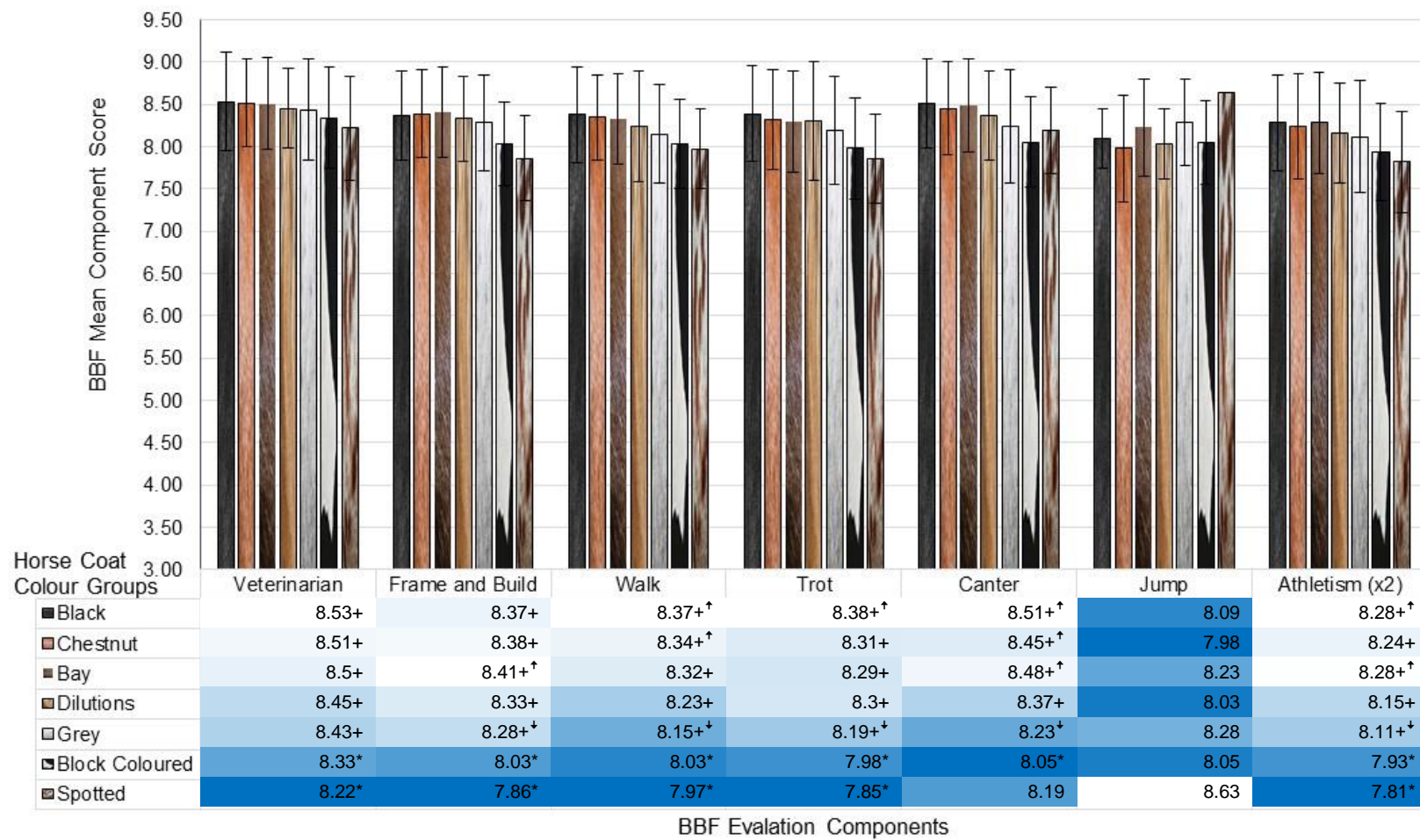


Figure 19 Mean BBF component scores (with std. dev. bars) of horse coat colour group 1 (def. Table 4). Mean scores are conditionally formatted from high (light) to low (dark) within components. Athleticism scores are multiplied by two when premium scores are calculated (see appendix ii). Statistical significant differences were found within component scores between + and *, [†] and [†].

2.2.2.1 Veterinarian Score

The definition for the veterinarian component is shown in Table 6. The veterinarian evaluation is the same for all four disciplines dressage, show jumping, eventing and endurance (see appendix ii).

Table 6: BBF veterinarian mark definition

Component Score	Definition
The Veterinary mark (scored out of 10 increments on scale of 0.25)	<p>For limbs, hooves and musculoskeletal frame. The vet's mark will be an average of the score they attribute today and the score they believe the horse would obtain when competing at maturity provided any veterinary advice is followed (1 & 2).</p> <p>Vet score explanation: Below 4 Some serious compromising features, 4 - 6 Some compromising features which will require management 7 Mainly good features, minor management may be required 8 Good features 9 Very good features, 10 Excellent features.</p>

(British Equestrian Federation, 2013e)

The range of veterinarian scores within horse coat colour group 1 is shown in Figure 20. Bay horses had both the highest (9.80) and the lowest (4.00) veterinarian score. Bay and chestnut horses had the lowest extreme outlier scores. Removing outliers, spotted horses had the lowest veterinarian scores. Bay, chestnut and black horses had median veterinarian scores above the overall mean. Dilutions, grey, block coloured and spotted horses all had median values close to the overall mean.

There was a statistical significant difference in mean veterinarian scores according to horse coat colour ($F_{6,3474}=6.04$, $p<0.0001$). Spotted and block coloured horses had significant lower mean scores than black, bay and chestnut

coloured horses ($p < 0.05$). No other horse colours had significantly different veterinarian scores.

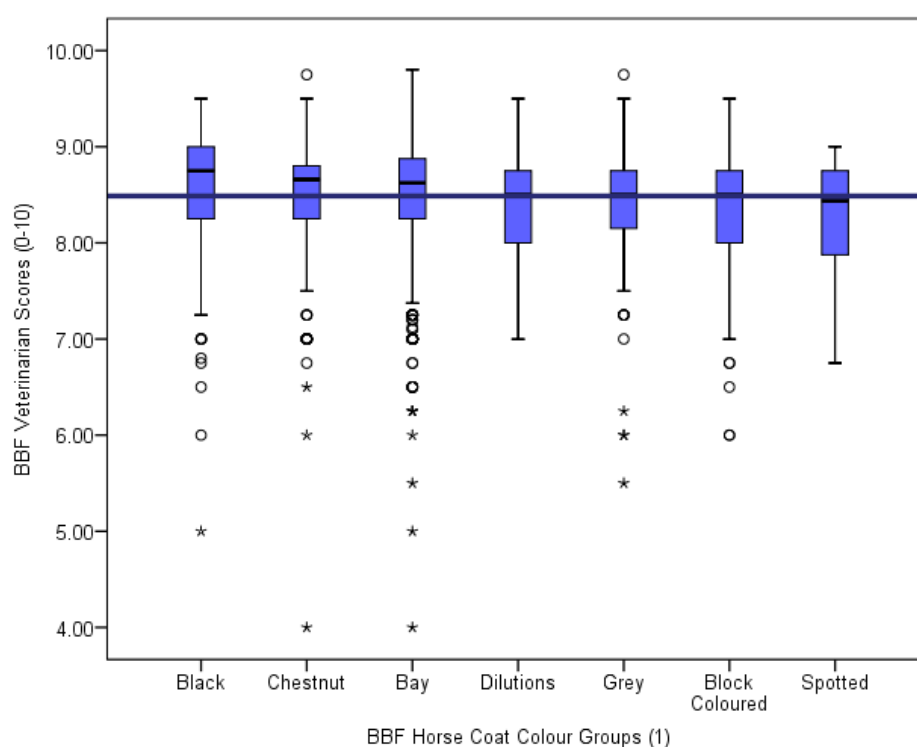


Figure 20 Distribution of BBF veterinarian scores (2008-2014) of horse coat colour group 1 (def. Table 4) (i.e. black $n=296$, chestnut $n=680$, bay $n=1933$, dilutions $n=117$, grey $n=199$, block coloured $n=204$ and spotted $n=52$). The dark blue line represents the overall mean of veterinarian scores.

2.2.2.2 Frame and Build Scores

The definition and distribution of the frame and build component scores are shown in Table 7 and Figure 21 respectively. The highest (9.92) frame and build scores (outliers) were from bay. The lowest scores were also extreme outliers from bay and chestnut horses (6.00). Removing outliers, the lowest frame and build scores were from spotted horses. The interquartile range of spotted and

block coloured horses scores was below the overall mean of frame and build scores. The median of grey and dilution coloured horses was also just below the overall mean, whereas the median of black, bay and chestnut horses was above the overall mean.

Table 7: BBF frame and build mark definition

Component Score and DISCIPLINE	Definition
Frame and build for DRESSAGE (scored out of 10, increments of 0.25)	Should have a rectangular build with horizontal back and proportional leg length. Supple poll and head/neck connection with clean throat latch. Longer, well set, arched neck, with muscling to top line rather than underneath. Appropriately but not over-muscled back and loin with well defined wither, sloping shoulder and excellent saddle position. The horse as a whole should give a proportional, balanced, harmonious impression with limbs well positioned underneath. Some warmblood horses which are very well developed at three may be heavy at maturity.
Frame and build for SHOWJUMPING (scored out of 10, increments of 0.25)	Should have a rectangular build with horizontal back and proportional leg length. Good poll and head/neck connection with clean throat latch. Longer neck length ideal, arched, neither set too high nor too low, with muscling to top line rather than underneath. Appropriately but not over-muscled back and loin with good wither, shoulder and saddle position. Should give a proportional, balanced impression with well positioned limbs.
Frame and build for EVENTING (scored out of 10, increments of 0.25)	Should have a rectangular build with horizontal back and proportional leg length. Supple poll and head/neck connection with clean throat latch. Good neck length, arched, neither set too high nor too low, with muscling to top line rather than underneath. Appropriately muscled back and loin with good wither, shoulder and saddle position. Should give a proportional, balanced impression, standing over sufficient ground with well positioned limbs.
Frame and build for ENDURANCE (scored out of 10, increments of 0.25)	Should have limbs and frame in proportion. Good poll and head/neck connection with clean throat latch. Well set neck. Balanced or uphill in skeletal structure. Appropriately but not over-muscled back and loin. Defined wither and saddle position. Powerful hindquarters, well formed forearm and second thigh, sloping shoulder, horizontal back. Neither base narrow nor base wide. Should give a proportional, balanced, harmonious impression with limbs well positioned underneath. Neither elbows nor stifles to hug the body.

(British Equestrian Federation, 2013e, 2013c, 2013b, 2013d)

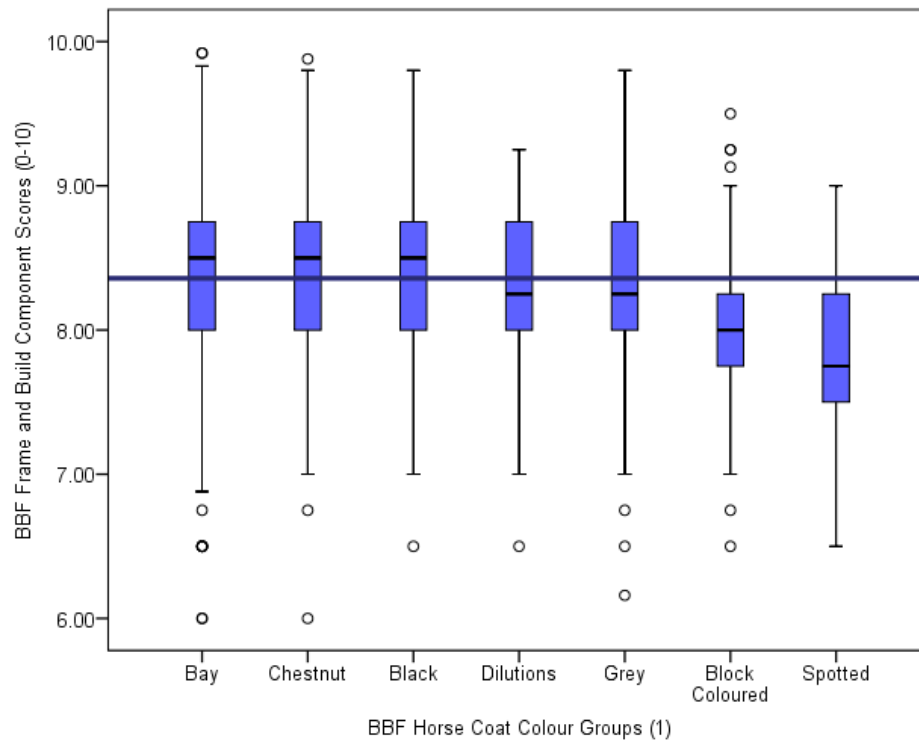


Figure 21 Distribution of BBF frame and build scores (2008-2014) of horse coat colour group 1 (def. Table 4) (i.e. black n=296, chestnut n=679, bay n=1934, dilutions n=117, grey n=199, block coloured n=205 and spotted n=52). The dark blue line represents the overall mean frame and build score.

Statistical significant differences were found between mean frame and build scores according to horse coat colour group 1 ($F_{6,3475}=24.53$, $p<0.0001$). Spotted and block coloured horses had a significantly lower mean frame and build scores compared to all other horse coat colour groups ($p<0.0001$). In addition, the mean frame and build scores of grey and bay coloured horses were significantly different ($p=0.021$). No other horse coat colours were statistically significant to each other ($p>0.05$).

2.2.2.3 Walk Score

The definition and distribution of the walk component scores for the equestrian disciplines are shown in Table 8 and Figure 22 respectively.

Table 8: BBF walk mark definition

Component Score and DISCIPLINE	Definition
Correctness of paces Walk for DRESSAGE (scored out of 10, increments of 0.25)	Should show an active 4 time marching straight gait with no tendency to become lateral, should have rhythm, considerable impulsion and purpose. Suppleness through the back and body, a swinging stride, freedom and reach in the shoulder, movement through all joints - elbow, hip and stifle with considerable but not excessive over track (it is possible for a walk to be "too big"). Allowances are made for a foal under 21 weeks ¹
Correctness of paces Walk for SHOWJUMPING (scored out of 10, increments of 0.25)	Should show an active marching straight walk with impulsion and purpose. Suppleness through the back and body, a swinging stride, freedom in the shoulder, elbow, hip and stifle and some over track but need not have excessive reach. Allowances are made for a foal under 21 weeks
Correctness of paces Walk for EVENTING (scored out of 10, increments of 0.25)	Should show a 4-time gait which is active, straight, rhythmical and has impulsion and purpose. Should show suppleness through the back and body, a swinging stride, freedom in the shoulder, elbow, hip and stifle and a noticeable over track. Allowances are made for a foal under 21 weeks
Correctness of paces Walk for ENDURANCE (scored out of 10, increments of 0.25)	Should show an active, marching, straight and supple gait. Should have rhythm, considerable impulsion and purpose. Limb travel should be straight. Suppleness through the back and body, a swinging stride, freedom and reach in the shoulder, movement through all joints - elbow, hip and stifle with over track. Allowances are made for a foal under 21 weeks

(British Equestrian Federation, 2013e, 2013c, 2013b, 2013d) ¹Recent research had shown that very young foals are more prone to lateral walks and this usually rectifies with time, development and strength (Denham et al., 2012)

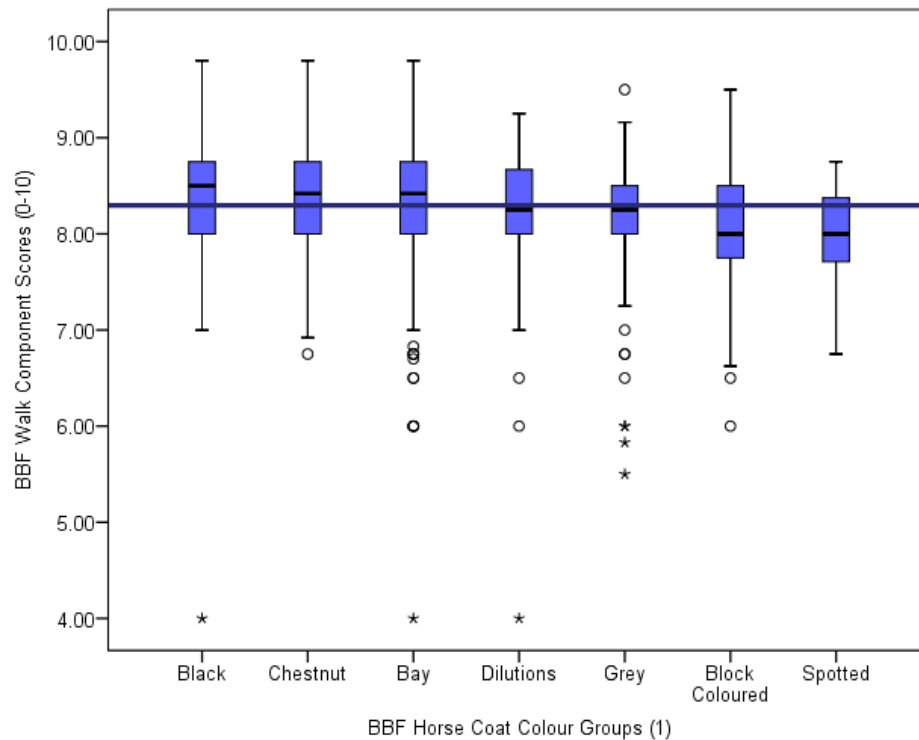


Figure 22 Distribution of BBF walk scores (2008-2014) of horse coat colour group 1 (def. Table 4) (i.e. black n=296, chestnut n=679, bay n=1932, dilutions n=117, grey n=199, block coloured n=205 and spotted n=52). The dark blue line represents the overall mean walk score.

Bay, black and chestnut coloured horses (9.80) had the highest walk scores.

Extreme outliers from bay, black and dilution coloured horses (4.00) were the lowest. Removing outliers, the lowest walk scores were from block coloured horses. The median scores of block coloured and spotted horses were well below the overall mean. Dilutions and grey coloured horses had medians around the overall mean, and chestnut, black and bay horses had medians above the overall mean walk score.

There was a statistical significant difference in walk scores according to horse coat colour groups, as determined by one-way ANOVA ($F_{6,3473}=17.14$, $p<0.0001$). Post-hoc analysis showed that block coloured and spotted horses had

significantly lower walk scores than bay, black, chestnut and dilution coloured horses ($p<0.05$). Mean walk component scores were also significantly different between grey and bay, black and chestnut horses ($p<0.05$).

2.2.2.4 Trot Score

The definition and distribution of scores for trot are shown in Table 9 and Figure 23 respectively.

Table 9: BBF trot mark definition

Component Score and DISCIPLINE	Definition
Correctness of paces Trot for DRESSAGE (scored out of 10, increments of 0.25)	Should show a 2-time gait which is active, straight, elastic, rhythmical and has impulsion and purpose. Should be supple through the body with balance and self carriage on the straight and on the turns. There should be considerable lightness of footfall and a rounder action in preference to straight. Engagement of the hindquarter should give a noticeable uphill direction.
Correctness of paces Trot for SHOWJUMPING (scored out of 10, increments of 0.25)	Should show a 2-time gait which is active, straight, rhythmical and has impulsion and purpose. Should be supple through the body with balance on the straight and on the turns. There should be some lightness of footfall.
Correctness of paces Trot for EVENTING (scored out of 10, increments of 0.25)	Should show a 2-time gait which is active, straight, rhythmical and has impulsion and purpose. Should be supple through the body with balance and self carriage on the straight and on the turns. A "rounder" action is preferred to a straight one and there should be a noticeable lightness of footfall.
Correctness of paces Trot for ENDURANCE (scored out of 10, increments of 0.25)	Should show a gait which is active, straight, light footed, ground covering and energy efficient. It should have enough balance to be maintained over distance, engaging the hindquarter sufficiently. Any efficient gait permissible including jog and pace. A straighter leg action is preferable to high knee action. The trot should appear easy, fluid and rhythmical.

(British Equestrian Federation, 2013e, 2013c, 2013b, 2013d)

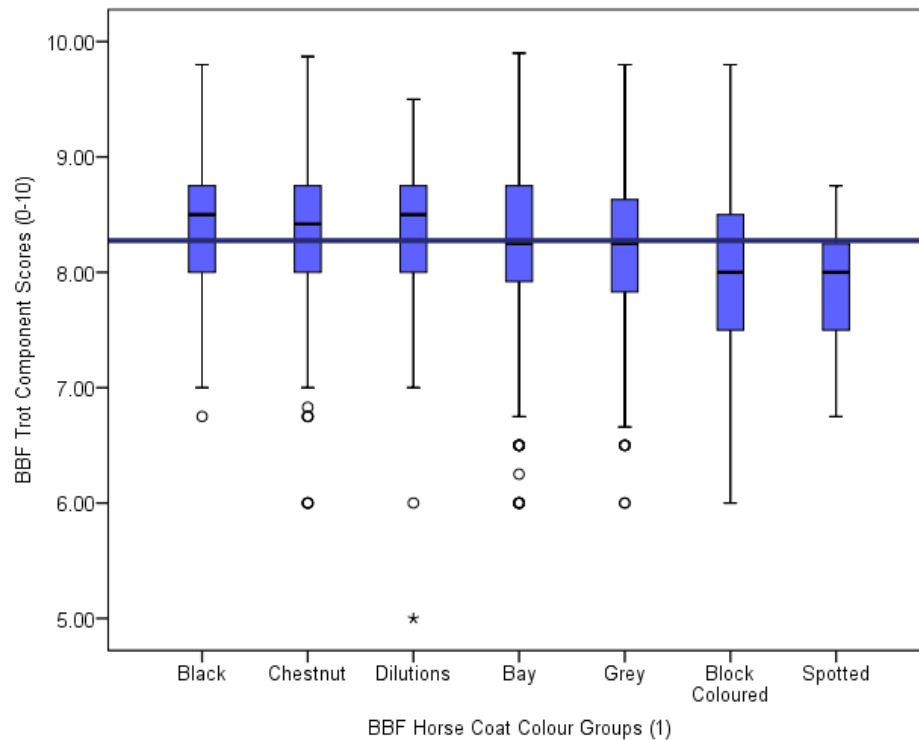


Figure 23 Distribution of BBF trot scores (2008-2014) of horse coat colour group 1 (def. Table 4) (i.e. black n=296, chestnut n=678, bay n=192), dilutions n=117, grey n=199, block coloured n=204 and spotted n=52). The dark blue line represents the overall mean trot score.

An extreme outlier from a diluted horse (5.00) had the lowest trot score. The highest scores were from bay horses (9.90). No high outliers were present. Removing outliers, block coloured horses received the lowest trot scores. The median of trot scores from block coloured and spotted horses was below the overall mean trot score. The entire interquartile range for spotted horses was below the mean. The median trot score of dilutions and grey coloured horses were very close to the overall mean compared to black, bay and chestnut horses, which were above the overall mean. One-way ANOVA highlighted significant statistical differences in trot component scores between horse coat colour groups ($F_{6,3464}=15.80$, $p<0.0001$). The post-hoc analysis showed the differences to be

significant between block coloured and spotted horses ($p < 0.05$) and all other horse coat colour groups. Trot scores of grey horses was also significantly lower than black horses' ($p = 0.006$). No other mean trot scores were significantly different to each other.

2.2.2.5 Canter Score

Table 10: BBF canter mark definition

Component Score and DISCIPLINE	Definition (<i>British Equestrian Federation, 2013e, 2013c, 2013b, 2013d</i>)
Correctness of paces Canter for DRESSAGE (scored out of 10, increments of 0.25)	Shows a 3-time gait which is active, straight, rhythmical, balanced and has impulsion and purpose. Shows suppleness through the back and body with well placed limbs and engagement of the hindquarter demonstrating an uphill direction, balance and self carriage on the straight and on the turns/direction changes/transitions. Should be able to lengthen and shorten its stride without loss of rhythm or balance. There should be a considerable lightness of footfall.
Correctness of paces Canter for SHOWJUMPING (scored out of 10, increments of 0.25)	Of all paces this is of the greatest importance for a showjumper. Shows a 3-time gait which is active, rhythmical, balanced and has impulsion and purpose. Shows suppleness through the back and body and balance and self carriage on the straight and on the turns/direction changes/transitions. Should be able to lengthen and shorten its stride without loss of rhythm or balance. There should be a lightness of footfall and the body should remain horizontal or have a slight rise/lift in front. A good jumper will have a good canter.
Correctness of paces Canter and Gallop for Eventing (scored out of 10, increments of 0.25)	Canter: Horse shows a 3-time gait which is active, straight, rhythmical and has impulsion and purpose. Shows suppleness through the back and body and balance and self carriage on the straight and on the turns/direction changes/transitions. Should be able to lengthen and shorten its stride without loss of rhythm or balance. There should be a lightness of footfall and the body should remain horizontal or have a slight rise/lift in front. A good jumper will have a good canter. Gallop: This should be free, light, forward-going and ground covering. Should be a noticeable difference in pace between the canter and the gallop and balanced upward and downward transitions, the body should be lowered when travelling at speed but footfall should not be excessively heavy.
Correctness of paces Canter for ENDURANCE (scored out of 10, increments of 0.25)	Shows a 3-time gait which rises, not falls, in front, is active, straight, rhythmical, balanced and light footed. It should be ground covering and show impulsion and enough purpose to be maintained over distance. Should be able to maintain rhythm during transitions and changes of direction. Body should remain horizontal.

The definition and distribution of canter score marks are displayed in Table 10 and Figure 24 respectively.

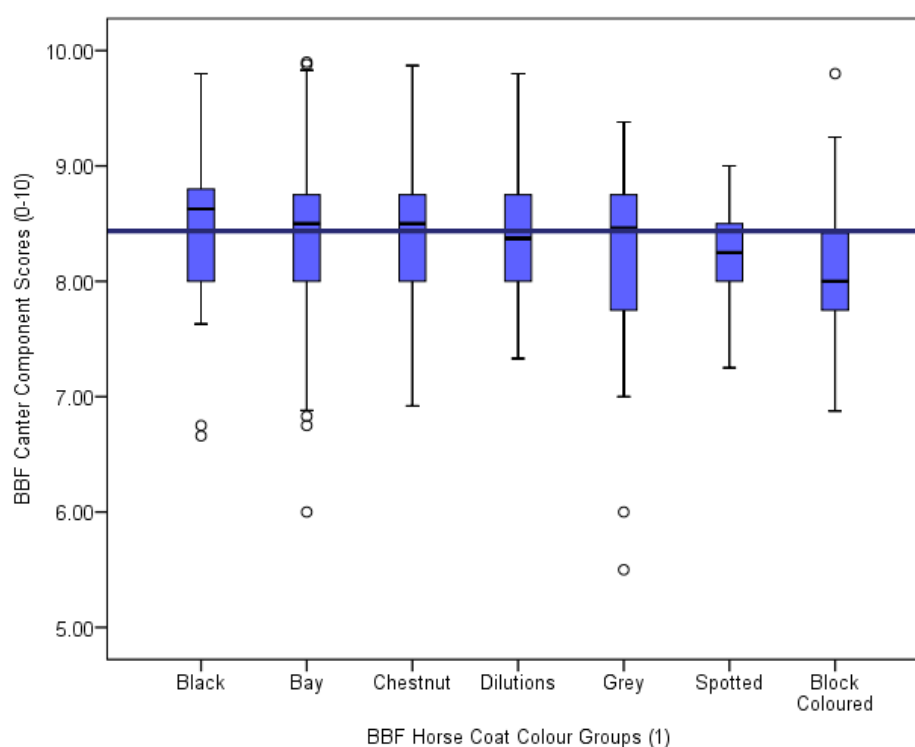


Figure 24 Distribution of BBF canter scores (2012-2014) of horse coat colour group 1 (def. Table 4) (i.e. black n=130, bay n=833, chestnut n=271, dilutions n=52, grey n=78, block coloured n=65 and spotted n=18). The dark blue line represent the overall mean of canter scores.

The highest canter score (an outlier) were from bay horses (9.90), the lowest (outlier) from a grey horse (5.50). Removing outliers, the lowest scores were from bay and block coloured horses. However, the entire interquartile range of canter scores from block coloured horses was below the overall mean. The median for bay horses was just above the overall mean. Almost the entire interquartile range of spotted horses' canter scores was also below the overall mean. The median

of bay, chestnut, dilutions and grey horses were close to the overall mean, whereas black horses had median canter scores above the overall mean.

There were statistical significant differences in canter scores between coat colour groups ($F_{6,1440}=8.98$, $p<0.0001$). Post-hoc analysis showed block coloured horses had significantly lower canter scores than black ($p<0.0001$), bay ($p<0.0001$), chestnut ($p<0.0001$) and dilutions ($p=0.034$). Grey horses had significantly lower canter scores than bay ($p=0.003$), black ($p=0.011$) and chestnut ($p=0.047$) horses. No other coat colour groups had significantly different mean canter scores.

2.2.2.6 Jump Scores

Jump scores are only awarded to three year old horses in show jumping and eventing (British Equestrian Federation, 2013e, 2013d). The jump score description is shown in Table 11.

Table 1: BBF jump mark definition

Component Score	Definition
Jump for three year olds only (scored out of 10, increments of 0.25)	Able to collect in the final canter stride before the jump but can also take off on a long stride when required. Places hind legs well underneath the body in preparation for take off which should have thrust. Jumps with an uplift in the wither. Quickness of reflex to draw the forearm horizontally and fold the cannon bone back under the forearm. Tucks the hindlegs and draws them up and away from the fence in the latter part of the bascule. Lands lightly and canters away easily and freely. Is careful, efficient and has real scope. If the horse makes a mistake when jumping, tackles a fence differently next time showing an ability to quickly assimilate information and self corrects if the stride is wrong. Goes forward boldly and willingly down the jumping lane, if tightness in the back or tension exist, it dissipates, horse focuses on the fences and uses energy efficiently and with purpose.
(British Equestrian Federation, 2013e, 2013d)	

The distribution of jump scores are displayed in Figure 25.

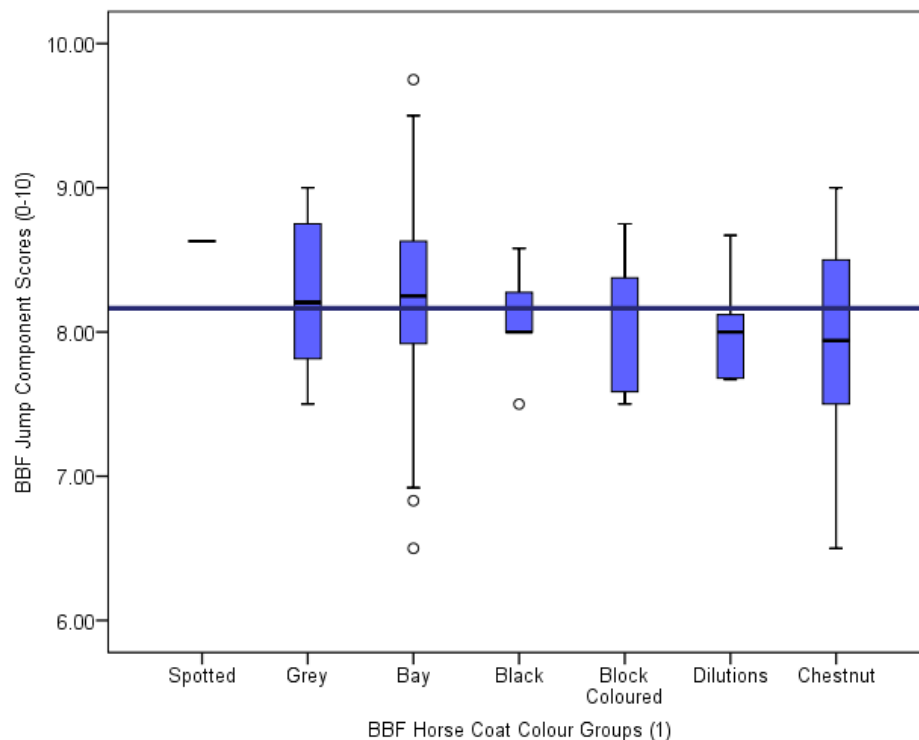


Figure 25 Distribution of BBF jump scores (2012-2014) of horse coat colour group 1 (def. Table 4) (i.e. spotted n=1, grey n=12, bay n=82, black n=7, block coloured n=7, dilutions n=5 and chestnut n=25). The dark blue line represent the overall mean jump component score.

The highest outlier score was from a bay horse (9.75). The lowest scores (6.50) were from chestnut and bay (outlier) horses. Removing outliers, chestnut horses still had the lowest jump component scores. The median jump scores from chestnut horses were below the overall mean. The entire interquartile range of dilution horses was also below the overall mean. Only one spotted horse was represented with a jump component score of 8.63, which was above the overall mean jump score of 8.16. Generally, distribution of jump scores according to coat colour did not follow the same trend as the other component scores e.g. there were less outliers and extreme values, and scored were not evenly distributed

(visualised by uneven whiskers). Furthermore, there were no statistical significant difference in jump scores according to horse coat colour group ($F_{6,133}=0.96$, $p=0.46$).

2.2.2.7 Athleticism Score

The definition and distribution of athleticism scores according to disciplines are displayed in Table 12 and Figure 26.

Table 2: BBF athleticism mark definition

Component Score and DISCIPLINE	Definition
Athleticism for DRESSAGE (scored out of 20, increments of 0.25)	Should show good joint flexion in shoulder, knee and hock. Should have a good muscular and coordinated connection through the body enabling the thrust of the hindquarter to result in a lift in front and effective balance and carriage on the turns, direction changes and transitions. Desire to move forward and upward in all paces without excessive encouragement. Suppleness through the topline, without inversion or tension impairing suppleness.
Athleticism for SHOWJUMPING (scored out of 20, increments of 0.25)	Should show good joint flexion and effective use of the body to balance and carry the horse through turns and direction changes. Desire to move forward in all paces without excessive encouragement. Suppleness through the topline, without inversion and excessive tension.
Athleticism for EVENTING (scored out of 20, increments of 0.25)	Should show good joint flexion and effective use of the body to balance and carry the horse through turns and direction changes. Desire to move forward in all paces without excessive encouragement. Suppleness through the topline, without inversion and excessive tension.
Athleticism for ENDURANCE (scored out of 20, increments of 0.25)	An overall ability to maintain economical paces over distance without undue effort. Light footed paces and a slight lift in front is favoured to minimise the impact to the forelimbs means that the thrust from the hindquarter should be evident. Should show good shoulder flexion and have a good muscular and coordinated connection through the body. Suppleness through the topline, without inversion or tension which consumes unnecessary energy.

(British Equestrian Federation, 2013e, 2013c, 2013b, 2013d)

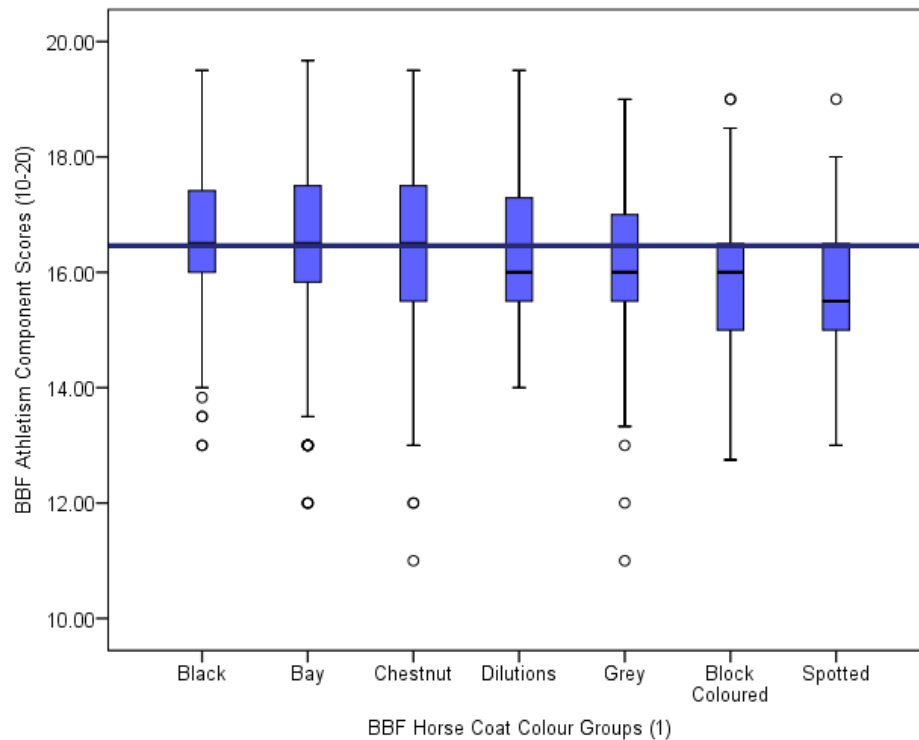


Figure 26 Distribution of BBF athleticism scores (2008-2014) of horse coat colour group 1 (def. Table 4) (i.e. black n=295, bay n=1923, chestnut n=677, dilutions n=115, grey n=198, block coloured n=203 and spotted n=52). The dark blue line represent the mean athleticism score.

The highest scores were from bay horses (19.67). The lowest scores (outliers) were from chestnut and grey horses (11.00). Removing outliers, block coloured horses had the lowest athleticism component scores. The entire interquartile range of athleticism scores from block coloured and spotted horses were below the overall mean. The median scores of grey and dilution horses were below the mean, whilst the median of black, bay and chestnut horses were very close to the overall mean athleticism scores (16.46). There was a significant difference between the mean athleticism according to horse coat colour group ($F_{6,3465}=16.06$, $p<0.0001$). Block coloured and spotted horses has significantly lower mean scores than all other horse colour groups ($p<0.05$). Grey coloured

horses also had significantly lower athleticism scores than bay ($p=0.006$) and black ($p=0.048$) horses. No other horse colour groups were significantly different to each other.

2.2.2.8 Conclusion

Overall, the most significant difference in component scores were the lower mean scores of block coloured, spotted horses, and partially grey horses compared to all other horse colour groups. Post-hoc analysis showed that block coloured and spotted horses had significantly lower mean scores compared with all other horse coat colours for frame and build, trot and athleticism components. Block coloured horses also had significantly lower scores than black, bay, chestnut and dilutions (not veterinarian) for the walk, canter and veterinarian sections. Similarly, spotted horses also had significantly lower mean scores than bay, black, chestnut and dilutions (walk only) in the walk and veterinarian parts. Grey horses had significantly lower frame and build, walk, canter, and athleticism scores compared to bay horses; significantly lower walk, trot, canter and athleticism scores than black horses, and significantly lower walk and canter scores than chestnut coloured horses. Furthermore, the component score distributions show that block coloured and spotted horses often have the entire interquartile range of scores below the overall mean. The median component scores for grey horses were closer to the overall mean, where low outliers negatively skewed the mean component scores of grey horses.

The fact that canter and jump scores of spotted horses were not significantly different from other coat colour groups could have several reasons. Canter component scores were only available for three years (2012-2014), hence the

number of spotted horses analysed were lower than any other horse colour group (n=19). Besides, the distribution of canter scores from spotted horses displayed a median below the overall mean, but spotted horses had a relatively high minimum canter score (7.25). Moreover, only three years of data were available for the analysis of jump scores (2012-2014), and in addition only three year old horses receive jump scores, which meant that data of jump scores were limited (n=140). Therefore, some colour groups (e.g. spotted n=1) were not well represented. Furthermore, this could contribute to the general lack of significant differences found between colours for jump scores.

In conclusion, it can be suggested that component scores (except jump scores) are significantly influenced by horse coat colour especially by block coloured, spotted and partially by grey horses, and the alternative hypothesis can be rejected.

2.2.3 Effect of Horse Colour, Year and Region on BBF Premium

Scores

Mean premium scores from the seven years of BBF evaluations (2008-2014) according to horse coat colour group 1 are seen in Table 13 and Figure 27 respectively. The overall mean premium scores generally increased linearly with time from 2008 to 2014. Scores of block coloured and spotted horses were consistently lower with a few exceptions: 2008 black horses had lower mean premium scores than block coloured horses, 2009 dilutions had the lowest mean

premium scores and in 2013 grey horses had lower scores than block coloured horses (see Table 13).

Table 13: Mean BBF premium scores according to evaluation year (2008-2014)

Horse Coat Colour Group 1	Year of BBF Evaluations							Overall Colour Mean
	2008	2009	2010	2011	2012	2013	2014	
Bay	8.15	8.20	8.33	8.36	8.46	8.52	8.59	8.37
Chestnut	8.15	8.26	8.30	8.39	8.43	8.44	8.61	8.36
Black	7.93	8.19	8.27	8.43	8.50	8.46	8.67	8.36
Dilutions	8.10	7.80	8.33	8.36	8.45	8.45	8.56	8.32
Grey	8.00	8.19	8.44	8.22	8.30	8.05	8.52	8.25
Block Coloured	7.98	8.02	8.10	8.06	8.16	8.07	8.31	8.08
Spotted	7.55	7.85	8.04	7.93	8.27	8.20	7.88	7.96
Overall Yearly Mean	8.10	8.18	8.31	8.33	8.43	8.45	8.58	8.34

Conditionally formatted (dark lowest-light highest) within horse coat colour groups and across total means.

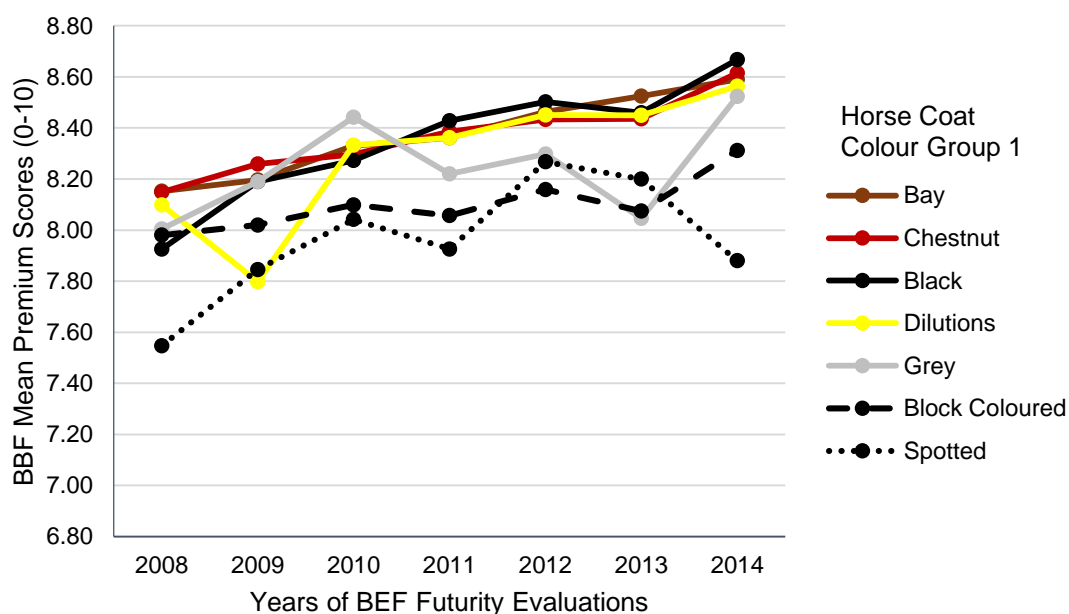


Figure 27: Mean premium scores of horse coat colour group 1 (def. Table 4) from 7 years (i.e. 2008 n=418, 2009 n=599, 2010 n=628, 2011 n=864, 2012 n=590, 2013 n=485 and 2014 n=417).

The mean premium scores (horse coat colour group 1) within defined regions (see section 2.2.2.4) for 2008-2014 are shown in Table 14. The venues contributing to each region are shown in Table 5. Overall, block coloured and spotted horses received the lowest premium scores irrespective of evaluation region. Exceptions to this trend are (1) for Scotland the lowest mean score was dilutions, (2) for Central the second lowest mean score was also for dilutions, and (3) for Wales black horses were the second lowest with block coloured. BBF evaluations in Wales had the lowest overall mean premium score (8.06), whereas the Eastern region had the highest mean premium score (8.41).

Table 14: BBF mean premium scores according to horse coat colour and evaluation region 2008-2014

Horse Coat Colour Groups 1	BBF Regions 2008-2014 ¹								Colour Mean
	E	C	N	NW	SW	S	Sc	Wa	
Bay	8.45	8.42	8.38	8.41	8.36	8.25	8.21	8.03	8.37
Chestnut	8.39	8.48	8.38	8.35	8.41	8.29	8.11	8.11	8.36
Black	8.49	8.36	8.36	8.37	8.46	8.14	8.29	8.06	8.36
Dilutions	8.45	8.17	8.61	8.31	8.21	8.18	7.90	8.70	8.32
Grey	8.26	8.28	8.19	8.30	8.23	8.08	8.33	8.17	8.25
Block Coloured	8.11	8.30	8.16	8.03	8.06	7.99	7.98	8.06	8.08
Spotted	8.21	7.70	7.93	8.11	7.82	7.76	8.13	7.77	7.96
Regional Mean	8.41	8.40	8.36	8.36	8.34	8.21	8.19	8.06	8.34

¹Horse Coat Colour Group 1 conditionally formatted (dark lowest-light highest) mean premium scores according to the region of evaluations: Eastern (E), Central (C), Northern (N), North West (NW), South West (SW), South (S), Scotland (Sc), and Wales (Wa).

Permutational MANOVA (PERMANOVA) showed significant differences in premium scores within horse coat colour groups ($df=6$, $F=6.11$, $p=0.001$), regions ($df=7$, $F=5.07$, $p=0.001$), and year of evaluation ($df=6$, $F=12.30$, $p=0.001$).

2.2.3.1 Differences within BBF Horse Coat Colours

Three-way cross ANOSIM (analysis of similarities), which tested for differences between horse coat colour groups across all regions and years, showed a significant difference in premium scores ($R=0.094$, $p=0.0001$). The significant differences were between bay and spotted ($R=0.308$, $p=0.001$), block coloured ($R=0.281$, $p=0.0001$), grey ($R=0.133$, $p=0.0001$), dilutions ($R=0.229$, $p=0.001$) and black ($R=0.09$, $p=0.001$) horses. There were also significant differences in premium scores between chestnut and spotted ($R=0.164$, $p=0.007$), block coloured ($R=0.167$, $p=0.0001$), and dilutions ($R=0.098$, $p=0.01$), and between block coloured and black ($R=0.066$, $p=0.029$) and block coloured and dilutions ($R=0.193$, $p=0.003$).

2.2.3.2 Differences within BBF Regions

A significant difference in premium scores was also found between regions, across all colour groups and year of evaluations ($R=0.027$, $p=0.028$). However, this difference was not as strong as the horse colour effect. There were significant regional differences in premium scores between Wales and the North, North West, South and South West. There were also significant differences between Central and the South and North West.

2.2.3.3 Differences within BBF Years

Testing for differences between years of BBF evaluations across all horse coat colour groups and regions, showed a significant difference in premium scores

($R=0.082$, $p=0.0004$). This difference in premium scores over time was larger than any regional effects, but not as large as horse coat colour. However, there were significant differences in premium scores between 2008 and 2009-2014 ($p<0.05$), 2009 and 2012-2014 ($p<0.05$), 2010 and 2012 ($R=0.121$, $p=0.02$), 2010 and 2014 ($p=0.135$, $p=0.028$) and between 2013 and 2014 ($R=0.135$, $p=0.035$).

2.2.3.4 Conclusion

Block coloured horses had significantly different premium scores than bay, chestnut, black and dilutions. Spotted horses also had significantly different premium scores compared to bay, chestnut and dilution horses supporting that a negative bias could exist towards block coloured and spotted horses in the BBF. In addition, bay coloured horses had significantly different scores than black, grey and dilutions. Suggesting bay horses' large and widespread distribution of premium scores further sets them aside in the BBF evaluation from all but chestnut horses.

Geographical variability in premium scores also suggest a smaller effect of venue/region. There are many forms of location bias e.g. nationalistic bias, home advantage (see section 1.4), which could lend support to this small apparent regional bias within the BBF Futurity. However, geographical effects could also reflect areas of different quality of horses e.g. overall relatively lower quality in Wales.

The general increase in premium scores since 2008 could be due to more generous scoring; alternatively, it could reflect an upward progression in the overall quality of horses being presented to the BBF.

The differences in premium scores with horse coat colour ($R=0.094$) are larger than the differences over subsequent years ($R=0.082$), and even larger again than regional differences ($R=0.027$). The differences in premium scores according to horse coat colour were not statistically significantly different across regions ($p=0.078$) suggesting that any likely colour bias is consistent over the different regions of Great Britain. Therefore, the alternative hypothesis 3 can be rejected for the 2008-2014 Futurity dataset, and horse coat colour bias can further be supported.

2.2.4 Effect of Horse Colour, Year and Region on BBF Premium

Scores depending on Discipline

The frequencies of horses split into coat colour group 1 and disciplines (dressage, show jumping, eventing and endurance) are shown in Table 15. All horse colour groups were represented within all disciplines but distribution varied. The majority of horses presented were bay ($n=2218$, 55%) and regardless of discipline, bay horses were the most common horse colour. In comparison black ($n=345$, 6%) were third most common colour overall and in dressage, but only fifth in eventing and show jumping and fourth in endurance. The least common colours were dilution and spotted horses which comprised only 3% ($n=126$) and 1.5% ($n=61$) respectively. The most popular discipline entered was dressage ($n=1608$, 40%), followed by eventing ($n=1574$, 39%), show jumping ($n=754$, 19%) and endurance ($n=65$, 2%).

Table 15: Numbers of horses evaluated as a function of colour and discipline

Horse Coat Colour Group 1	BBF Disciplines (n)				Colour N
	Dressage	Eventing	Show Jumping	Endurance	
Bay	799	966	432	21	2218
Chestnut	357	263	138	15	773
Black	244	67	30	4	345
Block Coloured	90	103	45	3	241
Grey	38	106	79	14	237
Dilutions	60	40	20	6	126
Spotted	20	29	10	2	61
Discipline N	1608	1574	754	65	4001

One-way ANOVA analysis showed no overall statistical differences in mean premium scores between disciplines ($F_{3,3997}=0.76$, $p=0.576$). However, mean premium scores of horse coat colour groups varied slightly across the disciplines (see Figure 28). Mean scores of bay horses were very similar between dressage (8.37), show jumping (8.39) and eventing (8.37) but lower for endurance (8.03). In contrast, mean scores of block coloured horses were the highest for endurance (8.67) and lower for the other three disciplines (>8.09).

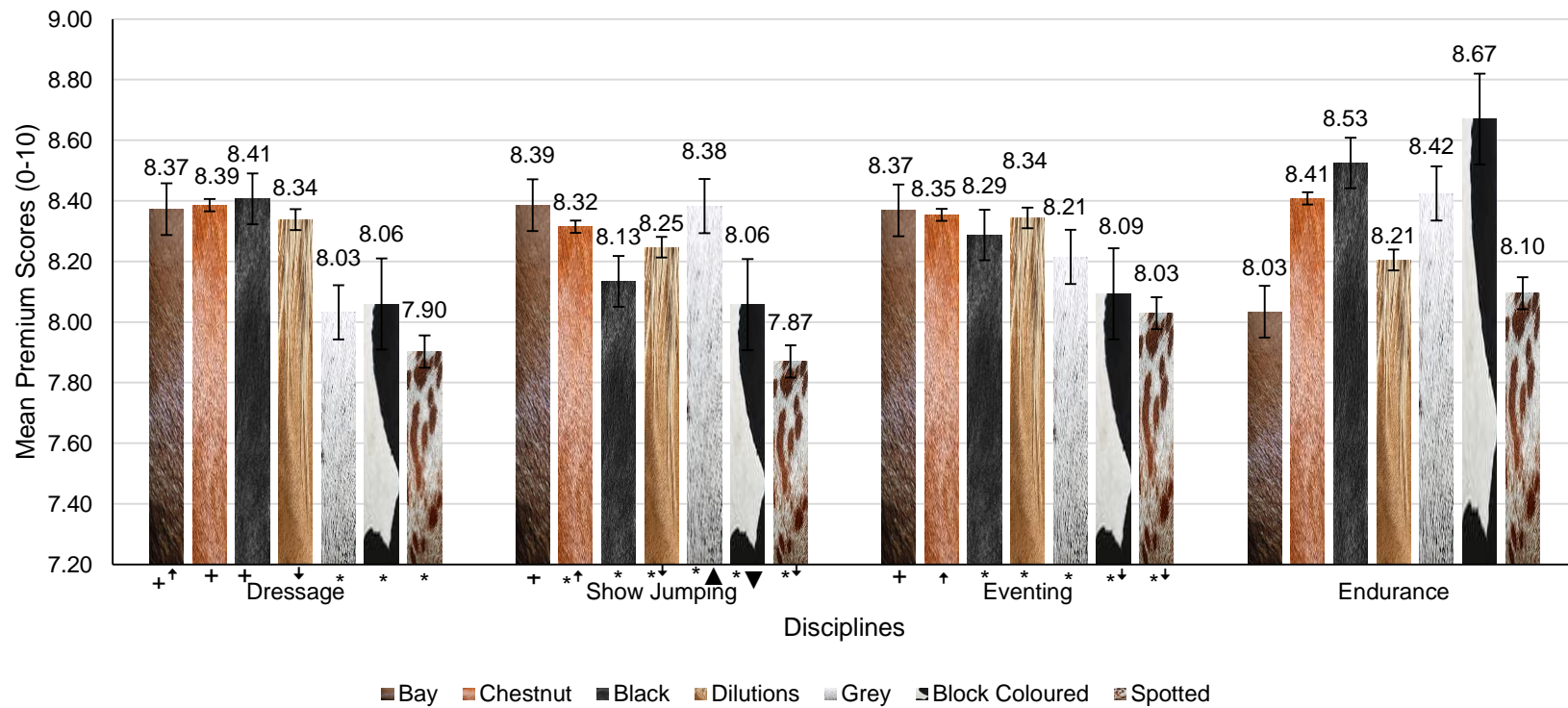


Figure 28: Mean premium scores (with se bars) of horse coat colour group 1 (def. Table 4) according to evaluation disciplines. Statistical significant differences were found within disciplines between + and *, \uparrow and \uparrow^* , \blacktriangle and \blacktriangledown .

Chestnut and dilutions mean scores were similar between all four disciplines; whereas scores of black and grey varied more between the disciplines e.g. grey horses had the second lowest mean score for dressage (8.03) but the second highest for show jumping (8.38). Mean scores of spotted horses were the lowest for dressage (7.90), show jumping (7.87), eventing (8.03), and second lowest for endurance (8.10).

2.2.4.1 Dressage

2.2.4.1.1 Regional and Year effects

Two-way ANOSIM (with replication) which examined the effect of region and years of evaluation on premium scores, showed no statistical significant difference in dressage scores with region ($R=0.012$, $p=0.243$). However, there was a significant difference between years of evaluation ($R=0.09$, $p=0.001$). Premium scores from 2008 were significantly lower than all other years ($p<0.05$). Dressage scores from 2009 were also significantly different from 2012, 2013 and 2014 ($p<0.05$). Scores from 2010 were also significantly different to all other years ($p<0.05$) except 2011. Additionally 2011 was significantly different to all other years ($p<0.05$), except 2013. However, 2012 was not significantly different to 2013 or 2014, and 2013 were not different to 2014 i.e. the main differences were observed in the former years.

2.2.4.1.2 Horse Coat Colour and Regional effects

Similar, two-way ANOSIM showed no significant difference in dressage scores across all horse coat colour groups with region ($R=0.02$, $p=0.136$) e.g. bay scores were the same across all regions. However, there was a significant difference

across all regions with horse coat colour ($R=0.102$, $p=0.001$) i.e. a significant difference in dressage scores according to horse colour. This difference were seen between spotted ($p<0.05$) and black, bay and chestnut, block coloured ($p<0.05$) and black, bay and chestnut, and grey ($p<0.05$) and black, bay and chestnut (see Figure28). Dilution coloured horses also had significantly different scores than bay coloured horses ($R=0.161$, $p=0.009$).

2.2.4.1.3 Horse Coat Colour and Year effects

There were, within horse coat colour groups, a significant difference in dressage scores with year of evaluation ($R=0.122$, $p=0.001$). However, there were no statistical significances ($p>0.05$) between consecutive years i.e. between 2008 and 2009, 2010 and 2011, 2011 and 2012, 2012 and 2013, or 2013 and 2014. There was also no difference between 2011 and 2013, or 2012 and 2014. Within the seven years of the BBF evaluations there was a statistical significant difference in dressage scores according to horse coat colour ($R=0.108$, $p=0.001$). The significant differences were between the same horse coat colour groups as when testing for horse colour effect within BBF regions above.

2.2.4.2 Show Jumping

2.2.4.2.1 Regional and Year effects

There was a significant difference in show jumping premium scores with regions ($R=0.09$, $p=0.001$). Scores from Central and Wales ($R=0.543$, $p=0.006$) and from Central and Northwest were significantly different ($R=0.308$, $p=0.001$). Show jumping scores from Northwest and Southwest were also significantly different ($R=0.095$, $p=0.027$). In addition to the Southwest and Northern ($R=0.108$,

$p=0.031$), there was also a significant difference between years ($R=0.082$, $p=0.001$). The differences were between 2008 and 2009, 2010, 2013 and 2014, 2009 and all other years (except 2013) ($p<0.05$) and between 2010 and 2014 ($R=0.224$, $p=0.003$).

2.2.4.2.2 Horse Coat Colour and Regional effects

There were a significant difference in show jumping premium scores across all horse coat colour groups within region ($R=0.052$, $p=0.039$) i.e. region had an effect on scores from different coloured horses. There were also a significant difference in show jumping premium scores across all regions according to horse coat colour ($R=0.148$, $p=0.001$) i.e. horse colour had an effect on scores. The significant difference of show jumping premium scores were between bay and all other horse coat colours ($p<0.05$). In addition to bay, the difference were between chestnut and spotted ($R=0.305$, $p=0.016$), chestnut and dilutions ($R=0.142$, $p=0.029$), and between grey and block coloured horses ($R=0.199$, $p=0.035$).

2.2.4.2.3 Horse Coat Colour and Year effects

There was a significant difference in show jumping scores within the horse coat colour groups with year of evaluation ($R=0.041$, $p=0.014$). However, this was only statistically significant between 2008 and 2014 ($R=0.135$, $p=0.025$), 2009 and 2012-2014 ($p<0.05$) and 2010 and 2014 ($R=0.189$, $p=0.004$). The effect of horse coat colour within the years was also significant ($R=0.13$, $p=0.001$). The differences were the equivalent to those across regions i.e. bay coloured horses and all other horse colour groups ($p<0.05$) and spotted and chestnut ($R=0.266$,

$p=0.014$). There was also a significant difference in scores between block coloured and black horses ($R=0.146$, $p=0.028$) (see Figure 28).

2.2.4.3 Eventing

2.2.4.3.1 Regional and Year effects

There was no significant difference in eventing scores with region of evaluation ($R=0.011$, $p=0.24$). Neither was there a significant difference according to year of evaluation ($R=0.037$, $p=0.05$).

2.2.4.3.2 Horse Coat Colour and Regional effects

No significant difference in eventing scores were found across the horse coat colour groups, according to the region of evaluation ($R=0.027$, $p=0.082$). However, a significant difference was found across all regions with respect to horse coat colour ($R=0.093$, $p=0.001$) i.e. between bay and black, grey, dilutions, spotted and block coloured horses ($p<0.05$). Chestnut horses also had significantly different show jumping scores to spotted ($R=0.182$, $p=0.0014$) and block coloured ($R=0.135$, $p=0.004$) horses.

2.2.4.3.3 Horse Coat Colour and Year effects

There was a significant difference in eventing premium scores across all horse coat colour groups according to the year of evaluation ($R=0.04$, $p=0.003$). The differences were between 2008 and 2010-2014 ($p<0.05$), 2009 and 2012 ($R=0.119$, $p=0.003$), 2009 and 2014 ($R=0.14$, $p=0.001$) and between 2010 and 2014 ($R=0.082$, $p=0.014$). There was also a significant difference in eventing premium scores for all years according to horse coat colour ($R=0.069$, $p=0.001$).

The differences were between the same colours as those across regions stated above (see Figure 28).

2.2.4.4 Endurance

2.2.4.4.1 Regional and Year effects

No statistical significant differences were found for endurance scores between the regions ($R=0.107$, $p=0.172$). Similarly, there were no significant differences according to the year of evaluations ($R=-0.009$, $p=0.497$).

2.2.4.4.2 Horse Coat Colour and Regional effects

Endurance scores showed no significant differences across the horse coat colour groups with region ($R=0.215$, $p=0.088$), or across all regions according to horse coat colour ($R=0.084$, $p=1.98$).

2.2.4.4.3 Horse Coat Colour and Year effects

There were no significant difference in endurance premium scores amongst horse coat colour groups according to the year of evaluation ($R=0.008$, $p=0.40$). There was also no significant differences in the seven years of evaluations according to horse coat colour group ($R=0.097$, $p=0.113$).

2.2.4.5 Conclusion

Dressage: There was a significant difference in dressage scores with year of evaluation particularly when comparing the earliest with the most recent years. However, no significant difference were found between the last three years which could either suggest there has not been any significant increases in the quality of dressage horses in the last ~3 years of evaluations or simply that Evaluators

marks have become more consistent between individuals and over time. The location of the evaluations had no significant effect on awarded scores, and therefore not considered to influence dressage scores. This could also reflect a more consistent quality of dressage horses throughout the country. However, there was a significant effect of horse coat colour on dressage scores within the regions, suggesting that horse colour does effect awarded premiums. Significant differences were found between bay, black and chestnut horses compared to block coloured, spotted and grey horses within all regions and years of evaluations. Mean dressage scores were the lowest for spotted, block coloured and grey horses, suggesting a negative bias. Therefore, the alternative hypothesis can be rejected for year and colour effect on dressage premium scores, but not for effect of location/region.

Show Jumping: Horse coat colour also had a significant effect on show jumping scores within all regions and years. However, the significant differences were between slightly different horse colours than for dressage, e.g. between bay and all other colours and between grey and block coloured. Furthermore, grey had the second largest mean show jumping score, suggesting grey is not negatively biased in show jumping but block coloured and spotted horses might still be in comparison to bay, chestnut and black horses. Region and year of evaluations also had a significant effect on show jumping premiums. Year effect was similar to dressage, suggesting quality of show jumping horses increased within the seven years of BBF evaluations, but less so recently. In comparison to dressage, show jumping showed regional effects generally between the north and south of the country, suggesting a higher quality of show jumpers presented from the

North. Therefore, for show jumping the alternative hypothesis can be rejected with no exclusions.

Eventing: Horse coat colours had a statistically significant effect on eventing scores within both region and year. In agreement with dressage and show jumping analysis, the significant differences were between bay/chestnut horses and spotted/block coloured horses. Comparable with show jumping bay horses also had significantly different scores than most other colours, suggesting a possible superiority of bay horses, which might be due to the excessive number of evaluated bay horses. Eventing scores did not statistically differ significantly between regions. This suggest that differences in scores were not due to regional variability. Within horse coat colour group 1, year did have a significant effect on eventing scores (as with dressage and show jumping). Overall, this suggests that the quality of eventing horses has increased over time, but has stabilised in the last three years. In summary, the alternative hypothesis can be rejected for eventing, except for effect of location/region.

Endurance: Mean premium scores according to horse colour were very different for endurance compared to the other disciplines e.g. block coloured horses received the highest mean score in endurance. Furthermore, neither horse coat colour, year or region had a significant effect on the scores for endurance horses. This could suggest that these evaluations are not influenced by the same factors (bias) as the other three disciplines. However only 65 horses were evaluated in the endurance discipline over the seven years. Consequently, not all horse coat colours were represented in all years at all venues. Therefore, the analysis of endurance scores is perhaps not directly comparable to the other disciplines.

However, for the data available for endurance, the alternative hypothesis 4 can be supported.

2.3 Discussion and Conclusion

Differences in premium scores according to horse coat colour were compared by using both ANOVA approaches (assuming data was normally distributed) and by using a permutation based statistical approach (based on Euclidean distances). Both sets of analysis concluded that there were significant differences in overall premium scores that were attributed to different horse coat colours (with significantly lower scores of spotted, block coloured and in part grey horses). In addition, this approach identified that variability in scores due to colour were greater than the effects over time (where scores have gradually increased), and location.

Out of all the disciplines, endurance scores were not found to be affected by either colour, year or location. However, this conclusion is based on a much smaller total number of samples compared to the other disciplines, and may not be representative of endurance horses in general.

Component scores were also analysed and all showed significant differences between horse coat colours, except the jump score. Jumping ability might be less prone to evaluator bias compared to the other component scores as jumping ability is arguably less subjective, e.g. horse unable to make distance and knocks poles down. However, jumping ability is only evaluated in three year old eventing and show jumping horses and so has a much smaller dataset than other

components. Interestingly, show jumping horses were the only discipline to exhibit significant regional variability. As the BBF evaluation venue and ultimately the region determines the evaluator panel, this could suggest a bias amongst evaluators. However, as no other disciplines had this regional bias, the results are more likely due to a regional difference in the quality of show jumping horses e.g. top show jumping breeders situated in the north of England.

The quality of horses evaluated appears to have increased during the seven years of BBF evaluations. The differences in premium scores for dressage, show jumping and eventing evaluations were most significant between the early and later years of the evaluations. The increase in horse quality could have stopped or slowed. Alternatively, assessment and awarding of marks by evaluators could have become more consistent both between individuals and over time. The increase in mean premium scores over the seven years was more pronounced for bay, black, chestnut and dilutions (except 2009). Trends in grey horses were more variable over time, although have recently (2014) been very similar to the other solid colours. Conversely, the yearly means for block coloured and spotted horses were consistently below bay/black/chestnut despite an overall increase.

In conclusion, since horse coat colour effect on premium scores were larger than any regional or progressive variability, it is suggested that the significantly lower scores of spotted and block coloured (spotted, appaloosa, roan, piebald and skewbald) and potentially grey horses (in dressage and eventing) lends support to a negative horse colour bias in the BBF. However, it is possible that this apparent negative colour bias is due, perhaps at least in part, to a lack of genetic ability/potential or quality in the evaluated block and spotted horses in particular.

3 Investigating Genetic (Bloodline) Contribution to Perceived Horse Coat Colour Bias

Apparent bias within the BBF evaluations according to horse coat colour was previously suggested. However, former analysis and conclusions did not allow for the possibility of genetic superiority resulting in variant performance results. Therefore, the data were analysed further in order to reveal any superior genetic potential or lack of, that could help explain this apparent colour bias.

3.1 Method

The World Breeding Federation for Sport Horses (WBFSH) sire ranking is highly valued by the equine sport and breeding industry as a standard for comparing performance horses and studbooks (WBFSH, 2015). Consequently, the WBFSH sire ranking was used as a way to evaluate potential genetic superiority in BBF evaluated horses. The rankings are calculated from a maximum of eight competitions/tests each year (e.g. in dressage) and are based on percentages scored at international competitions under FEI rules. Bonus points are awarded for high profile competitions like the Wold Cup and the Olympic Games (WBFSH, 2015). Top 100 WBFSH stallion rankings are presently available online for 2010-2014 for the disciplines dressage, show jumping and eventing (WBFSH, 2014). WBFSH stallion lists were downloaded (21.07.2015) directly from the WBFSH website (WBFSH, 2014).

BBF data used for analysis included horse coat colour, premium scores, component scores, evaluation discipline, breed register and names of sire and dam sire. Horse coat colour group 1 (see Table 3) was used for colour analysis. However, it was necessary to regroup colours owing to limited data.

3.1.1 Initial Data Handling

3.1.1.1 **Selecting WBFSH Stallion Discipline**

The WBFSH ranking does not include endurance riding rendering it unsuitable to assess quality of endurance bloodline. Moreover, previous analysis showed different trends for endurance scores than the other disciplines therefore endurance data was excluded.

Eventing competitions include elements of both dressage and show jumping; therefore, breeders can use stallions from dressage, show jumping or eventing backgrounds depending on the individual breeding goals i.e. from all three WBFSH lists. Show jumping breeders also use stallions from both the eventing and show jumping stallion ranking lists. However, breeders of dressage horses are perhaps less likely to use exclusively show jumping or eventing stallions, although this dependent on the unique breeding goals. It was necessary to select a sub set of the data because analysis of the parentage of >4000 horses was considered overly ambitious within the scope of this study. Dressage was selected as a subset for analysis and only the dressage WBFSH stallion ranking lists were used to evaluate bloodlines of BBF dressage horses.

3.1.1.2 Selecting Year of BBF Evaluation

It was assumed the year that a breeding decision was made was the year before birth; consequently, that year's WBFSH list was used for data grouping. The earliest top 100 WBFSH stallion ranking available was 2010. Therefore, BBF evaluated horses born in 2010 and earlier had to be excluded from analysis (i.e. 2008-2010). The BBF evaluates foals to three year olds. Consequently, BBF evaluated horses born in 2010 appeared in data of BBF evaluations from 2010-2013. Subsequently, to exclude horses born in 2010 and to avoid repeated data of other horses being evaluated in multiple years, data from 2014 were selected for analysis (n=173). Total numbers of dressage horses evaluated were foals (n=98), yearlings (n=26), two year olds (n=21) and three year olds (n=43). Therefore WBFSH top 100 dressage stallion lists from 2010-2013 were used for bloodline analysis.

3.1.1.3 Identification of the Top 100 WBFSH stallions in the BBF data

Sports ponies were not included on the WBFSH sire ranking and therefore excluded from analysis. Sports ponies were sorted by comparing horse names in data with the BBF results published online (identified by (sp)) (<http://www.britishbreeding.org/futurityResults.aspx>) .

Dressage stallions from the top 100 WBFSH list were identified in 2014 dressage BBF horses' sires and dam sires. Initially the data on sires and dam sires were filtered using customised filtering in Microsoft Excel 2013, according to the WBFSH top 100 stallions. However, typing errors in the BBF data made by horse owners meant the top 100 lists had to be manually compared to the sire and dam sires. Individual horses were highlighted according to the presence of a sire

(n=8), a dam sire (n=29), or both a sire and a dam sire (n=4) on the WBFSH dressage top 100 list (and subsequently coded as sire, dam sire, sire and dam sire, or none).

3.1.1.4 Horse Coat Colour Grouping

Coat colours of BBF horses were grouped according to group 1 (see Table 4): black n=23, bay (bay n=46, dark bay n=25 and light bay n=1), chestnut (chestnut n=23, dark chestnut n=5), grey n=3, dilutions (buckskin=1 and palomino n=1), and block colours (piebald n=2 and skewbald n=2). There were no spotted, roan or dun coloured horses amongst the 2014 BBF evaluated dressage horses.

3.1.2 Statistical Analysis

Descriptive statistics were determined using IBM SPSS Statistics 21, pivot tables and conditional formatting (in Microsoft Excel 2013). One-way ANOVA with post hoc Tukey HSD (IBM SPSS Statistics 22) were used to analyse statistical differences between the mean premium and component scores, and the different levels of WBFSH stallion influence in horses' bloodlines to test the hypothesis (H_5) that mean BBF scores increases with genetic (bloodline) superiority. One-way ANOVA with post hoc Tukey HSD was also implemented to analyse differences between mean premium scores of horses without WBFSH stallion influence according to horse colour to test (H_6) if horse coat colour had significant effect on mean BBF premium score irrespective of genetic (bloodline) superiority. A significance level of 0.05 (95%) was applied in all tests.

3.2 Results

3.2.1 Horse Colour and Breed Register effect on BBF Premium

Scores

Table 16 displays breed registers' mean BBF premium scores in descending order divided above and below their average. Displayed are also mean scores which are conditionally formatted within the individual registers according horse colour (high to low), and overall according to the mean scores below the overall average (8.34). Within the top ten highest mean BBF premium scores, eight out of ten horse breed registers did not have any block coloured horses evaluated. Only one breed register in the top ten had spotted horses evaluated i.e. KSGB (Knapstrupper Society Great Britain). The lowest ten mean premium scored breed registers contained zero block coloured horses, and only three spotted which were SHAPS (Spotted Horse And Pony Society) registered. However, within the two horse breed registers in the top ten with block coloured horses i.e. trak (Trakehner) and old (Oldenburg), the block coloured horses received the lowest mean BBF premium scores within those breeds. Block coloured Oldenburg registered BBF horses received mean BBF premium scores below the overall average (8.18), despite the breed register in total receiving the tenth highest mean score (8.55). This trend of block coloured horses receiving below average mean premium scores, despite the total mean score of the breed register being above average, is apparent with several registers e.g. BHHS (The British Hanoverian Horse Society), AES (Anglo European Studbook), WBB(UK) (British Stud Books Warmblood Breeders UK) and WBYS (Weathersby).

Table 16: Mean BBF premium scores According to breed registration and horse coat colour

BBF Horse Breed Register	n	Horse Coat Colour Group 1							Total Mean
		Bay	Chestnut	Black	Dilutions	Grey	Block Coloured	Spotted	
WBS (UK)	1	9.10							9.10
Holst	2	8.56				9.11			8.84
Hann	28	8.63	8.86	8.81		8.62			8.75
BElite	11	8.54			9.11	9.14			8.65
Trak	8	8.73	8.60	8.86		8.45	8.34		8.65
IHB	1	8.61							8.61
KSGB	1							8.60	8.60
VNIK	1			8.57					8.57
AQHA (UK)	2				8.57				8.57
Old	240	8.59	8.57	8.51		8.71	8.18		8.55
BHHS	441	8.49	8.46	8.44		8.32	8.06		8.47
DV	4	8.11	8.80						8.45
Dales	1					8.45			8.45
Westf	34	8.45	8.27	8.86		8.66		9.00	8.44
KWPN	205	8.41	8.39	8.65	8.54	8.65	8.32	7.74	8.43
DSP	3	8.43							8.43
SPSS	141	8.36	8.46	8.45	8.59	8.21	8.95	8.33	8.42
Pal	5				8.40				8.40
DRP	11	8.13			8.54	8.30	8.25		8.37
ISH	12	8.50	7.99			7.86			8.36
AES	716	8.39	8.33	8.27	8.57	8.33	8.06	8.33	8.35
WBB (UK)	420	8.35	8.26	8.39	8.43	8.16	8.08	8.21	8.32
SHB (GB)	103	8.36	8.38	8.04	7.87	8.11	7.92	8.04	8.30
Rhld	4	8.29							8.29
BSPS	1							8.28	8.28
Wbys	62	8.13	8.40		8.41	8.45	7.57		8.25
Trak (UK)	80	8.37	8.11	8.13		8.13	8.06	7.29	8.25
EU	3	8.00	8.70						8.23
NPS	9	8.12	8.50		8.24				8.23
AHS	103	8.10	8.25	8.51	8.03	8.32	8.52		8.22
n/a	7	8.10	8.57	8.27					8.21
SSH	85	8.30	8.10	8.37	8.07	7.96	8.05		8.21
KNN	4	8.47		8.00				8.12	8.18
NewFor	6	8.64	7.90	8.50	8.70		7.73	7.58	8.18
NIHB	1					8.17			8.17

Table 16 continued: Mean BBF premium scores according to breed registration and horse coat colour

BBF Horse Breed Register	n	Horse Coat Colour Group 1							Total Mean
		Bay	Chestnut	Black	Dilutions	Grey	Block Coloured	Spotted	
CHAPS	60	8.64	8.14	8.18	8.19	8.36	8.14	7.26	8.16
BWP	2	8.44				7.88			8.16
ZfDP	24	8.26	8.39	8.51	7.93		8.08	8.04	8.15
WPCS	93	8.00	8.17	8.22	8.06	8.31	8.28	7.90	8.11
Conn	5			7.89	8.34	8.05			8.07
BSPA	16	8.08		7.89		7.71	8.06		8.03
IDHS	42	8.12	7.87	8.16		8.04		7.65	8.01
EquinC	1	8.00							8.00
Zang	5	7.85				8.39			7.96
APHC (UK)	5							7.94	7.94
BSHA	2	8.13						7.75	7.94
BWBS	2	7.92							7.92
GypCob	1	7.89							7.89
B App	17		8.09					7.81	7.88
SF	2	7.86							7.86
DK Old	3	7.86	7.73						7.82
HPA	2	7.72							7.72
BAPSH	12	7.72		8.07		7.56			7.67
Bav	5	7.61							7.61
Highl	1				7.60				7.60
ClevBay	4	7.31	8.36						7.57
Clyde	2	7.48							7.48
Zweib	1	7.36							7.36
SHAPS	3							7.35	7.35
Luso	1	7.13							7.13

Conditionally formatted mean premium scores high (light) to low (dark), from all evaluated horses in 2008-2014 (n=4001) according to breed registration and horse coat colour group 1 (see Table 3). Mean premium scores below the overall average (8.34) are in red.

A similar trend is apparent with spotted horses e.g. within KWPN (Royal Warmblood Studbook of the Netherlands) and trak(UK) (Trakehner United Kingdom). This could support that block coloured and spotted horses are being biased against, however, in some breed registrations block coloured and spotted horses do not receive the lowest scores e.g. in SPSS (Sports Pony Studbook

Society), AHS (American Hanoverian Society) and Westf (Westfalen Riding Horse/Dutch warmblood).

Fifteen horse breed registers were represented within the BBF evaluated dressage horses in 2014 (n=173) and these are shown in Table 17.

Table 17: Mean BBF premium scores according to breed registration and horse coat colour of 2014 dressage evaluated horses

BBF Horse Breed Registers	N	Horse Coat Colour Groups (1)						Total Mean
		Bay	Black	Chestnut	Dilutions	Grey	Block Coloured	
Rhld	1	9.10						9.10
Trak	2	8.88	8.86					8.87
Old	33	8.84	8.86	8.69		8.45		8.79
BHHS	48	8.79	8.77	8.82				8.79
Hann	4	8.51	8.85					8.77
KWPN	12	8.65	8.96	8.75				8.69
Westf	3	8.38	8.86	8.74				8.66
AES	10	8.59		8.57				8.59
Trak(UK)	4	8.51	8.70					8.56
WBB(UK)	34	8.63	8.42	8.52	8.55	8.41	8.20	8.56
SPSS	1	8.51						8.51
Wbys	1			8.49				8.49
SHB(GB)	15	8.50	8.28	8.46			7.91	8.41
CHAPS	4		8.36			8.14	8.34	8.29
WPCS	1			7.49				7.49
Total	173	8.70	8.70	8.63	8.55	8.33	8.20	8.67

Conditionally formatted mean premium scores high (light) to low (dark), for all dressage evaluated horses in 2014 (n=173) according to breed registration and horse coat colour group 1 (def. Table 3). Mean premium scores below the overall average for 2014 dressage horses of 8.67 are in red.

Spotted horses were not represented in the 2014 dressage entries. Three different horse breed registers had block coloured horses evaluated i.e. WBB(UK) (British Stud Book Warmblood Breeders United Kingdom), SHB(GB) (Sport Horse Breeding Great Britain) and CHAPS (Coloured Horse and Pony

Society). Block coloured horses within WBB(UK) and SHB(GB) received the lowest mean premium scores within their register. The lowest mean scores of CHAPS registered horses were grey. One way ANOVA showed a significant difference in mean BBF premium scores according to horse breed register, within the 2014 BBF dressage evaluated horses ($F_{14,158}=2.80$, $p=0.001$).

3.2.2 Effect of Bloodline on BBF Scores

The effect of possible superior bloodlines (defined as genetic influence from stallions on the WBFSH top 100 lists) on BBF scores were analysed on both premium and component scores from 2014 dressage evaluated horses ($n=173$).

3.2.2.1 Premium Scores

The range of premium scores according to the different degrees of WBFSH stallion influence can be seen in Figure 29.

The median of premium scores of horses without WBFSH stallions in the immediate bloodline is close to the overall mean. Whereas scores of horses with a sire and those with a dam sire has a median below the overall mean. The entire interquartile range of premium scores from horses with both a sire and a dam sire on the WBFSH top 100 stallion list are above the overall mean. Both high and low outliers exist for horses without WBFSH stallion influence. These outliers belong to bay and chestnut coloured horses. Between the four different categories of WBFSH stallion influence, the highest mean premium score was awarded to horses with both a sire and a dam sire on the WBFSH top 100 list (8.79). However, the second highest mean score were awarded horses without

any WBFSH stallion influence in the immediate bloodline (8.69), the third to horses with a dam sire on the WBFSH top 100 list (8.61) and then a sire (8.54) on the list. Yet, the differences in mean premium scores between the four categories were not statistically significant ($F_{3,169}=0.66$, $p=0.578$).

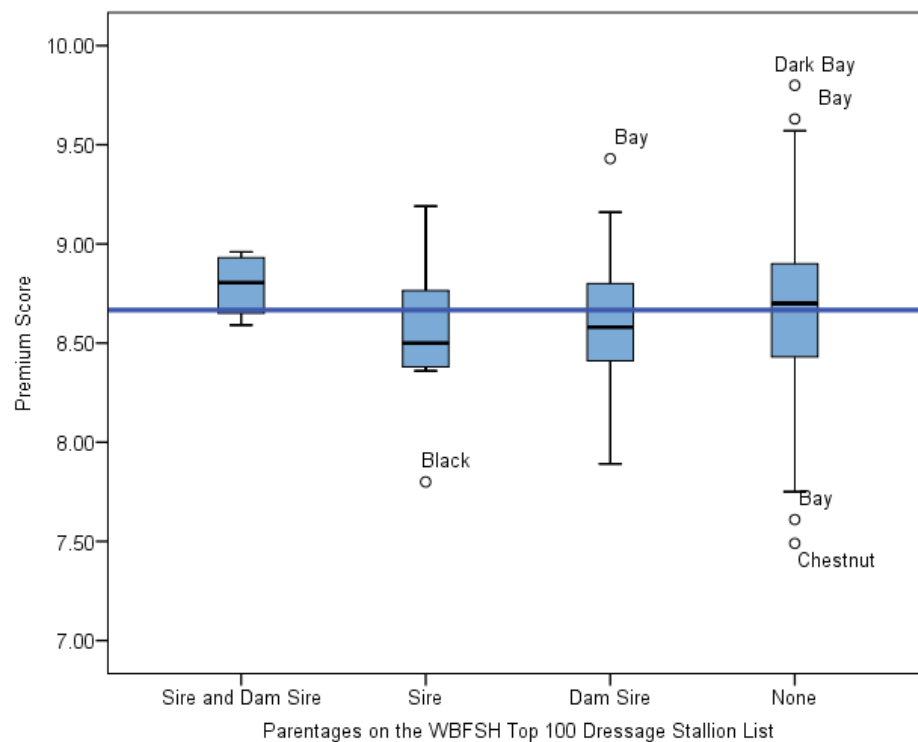


Figure 29 Range of BBF dressage premium scores (2014) of horses with different genetic superiority (i.e. with a sire only on the WBFSH Top 100 $n=8$, a dam sire only on the list $n=29$, both a sire and a dam sire on the list $n=4$, or no immediate parentages on the list $n=132$) The dark blue line represents the mean premium score (8.67).

3.2.2.2 Component Scores

BBF component scores of horses with the four different categories of WBFSH stallion influence can be seen in Figure 30. Horses with only a sire on the WBFSH list have consistently lower component scores than the other three groups, with

the exception of athleticism scores which were lower for horses with only a dam sire on the list.

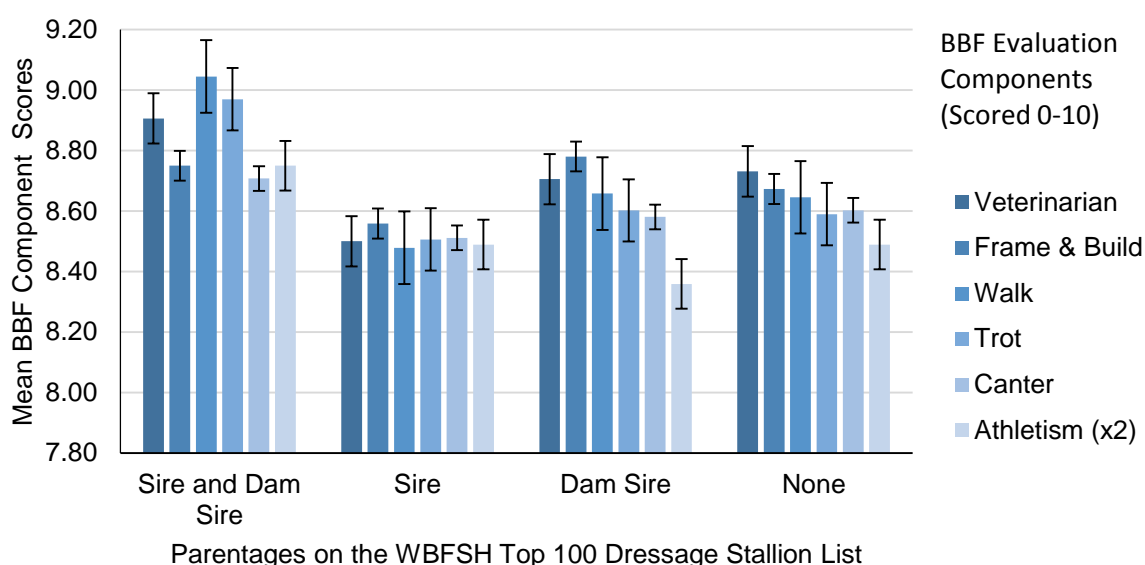


Figure 30 Mean BBF dressage component scores (with se bars) (2014) of horses with different genetic superiority (i.e. with both a sire and a dam sire on the WBFSH list n=4, sire only on the list n=8, dam sire only on the list n=29, or none immediate parentages on the list n=132).

3.1.1.1.1 Veterinarian Scores

Looking at the range of veterinarian marks (Figure 31) it is apparent that scores below the overall mean (8.72) primarily belonged to the lower quartile of horses with only a sire, a dam sire or no parents on the WBFSH list. The entire interquartile range of veterinarian marks from horses with a sire and a dam sire on the WBFSH stallion list were above the overall mean. Outliers were chestnut and bay horses without any WBFSH stallion influence. The mean veterinarian

marks of the four different categories of WBFSH stallion influence showed a similar trend as the premium scores. The highest veterinarian mean score belonged to horses with both a sire and a dam sire on the WBFSH top 100 list (8.91), > horses without any WBFSH stallion influence (8.73) > with just a dam sire on the list (8.71) > with only a sire on the list (8.50). This difference in mean scores were not statistically significant ($F_{3,167}=1.47$, $p=0.225$).

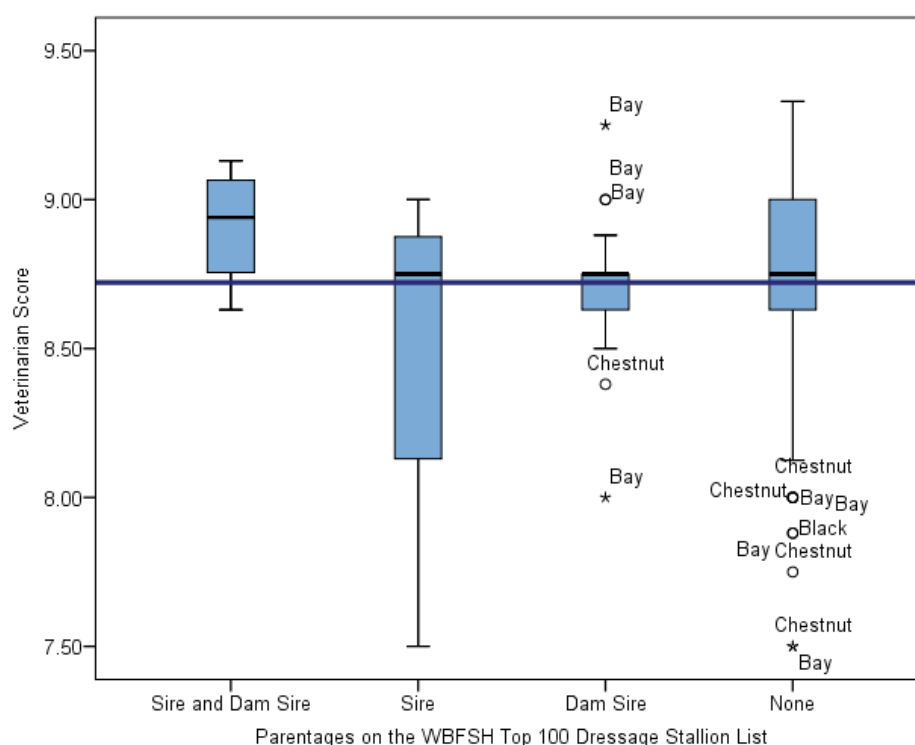


Figure 31 Range of BBF dressage veterinarian scores (2014) of horses with different genetic superiority (i.e. with only a sire on the WBFSH list $n=8$, only a dam sire on the list $n=29$, both a sire and a dam sire on the list $n=4$, or no immediate parentages on the list $n=132$). The dark blue line represent the mean score (8.72).

3.1.1.1.2 Frame and Build Scores

The range of frame and build scores for horses without any WBFSH stallion influence, and those with only a dam sire on the top 100 list were large (see

Figure 32). However, scores from horses with both a sire and a dam sire on the WBFSH list had no whiskers, and no outliers were present from any category of WBFSH stallion influence. In fact, the median of all four categories, were similar and close to the overall mean.

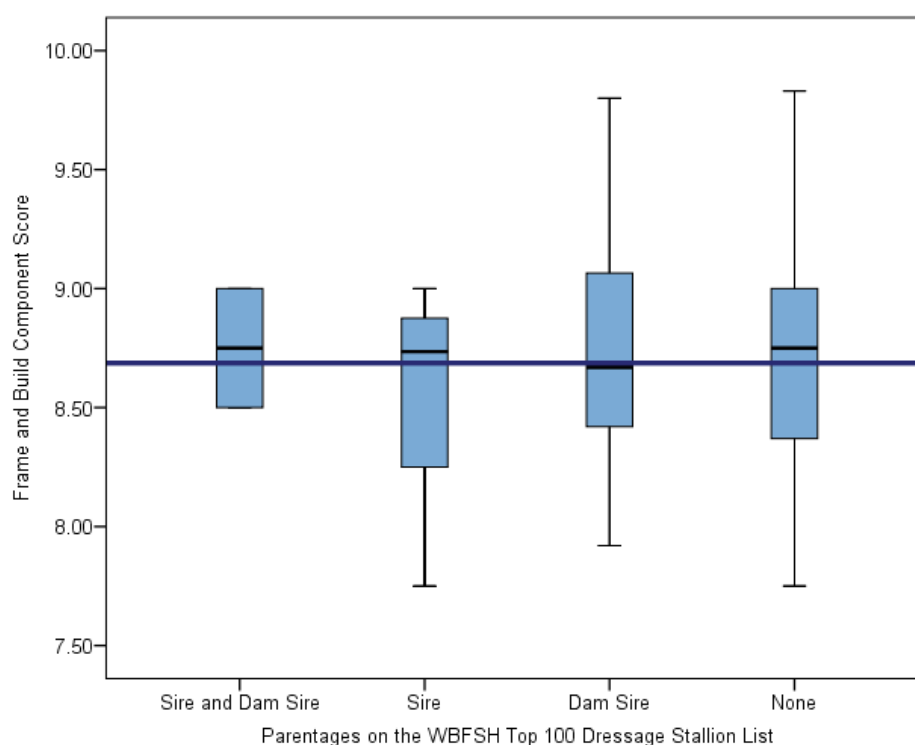


Figure 32 Range of BBF dressage frame and build scores (2014) of horses with different genetic superiority (i.e. with only a sire on the WBFSH list n=8, only a dam sire on the list n=29, both a sire and a dam sire on the list n=4, or no immediate parentages on the list n=132). The dark blue line represent the mean score (8.69).

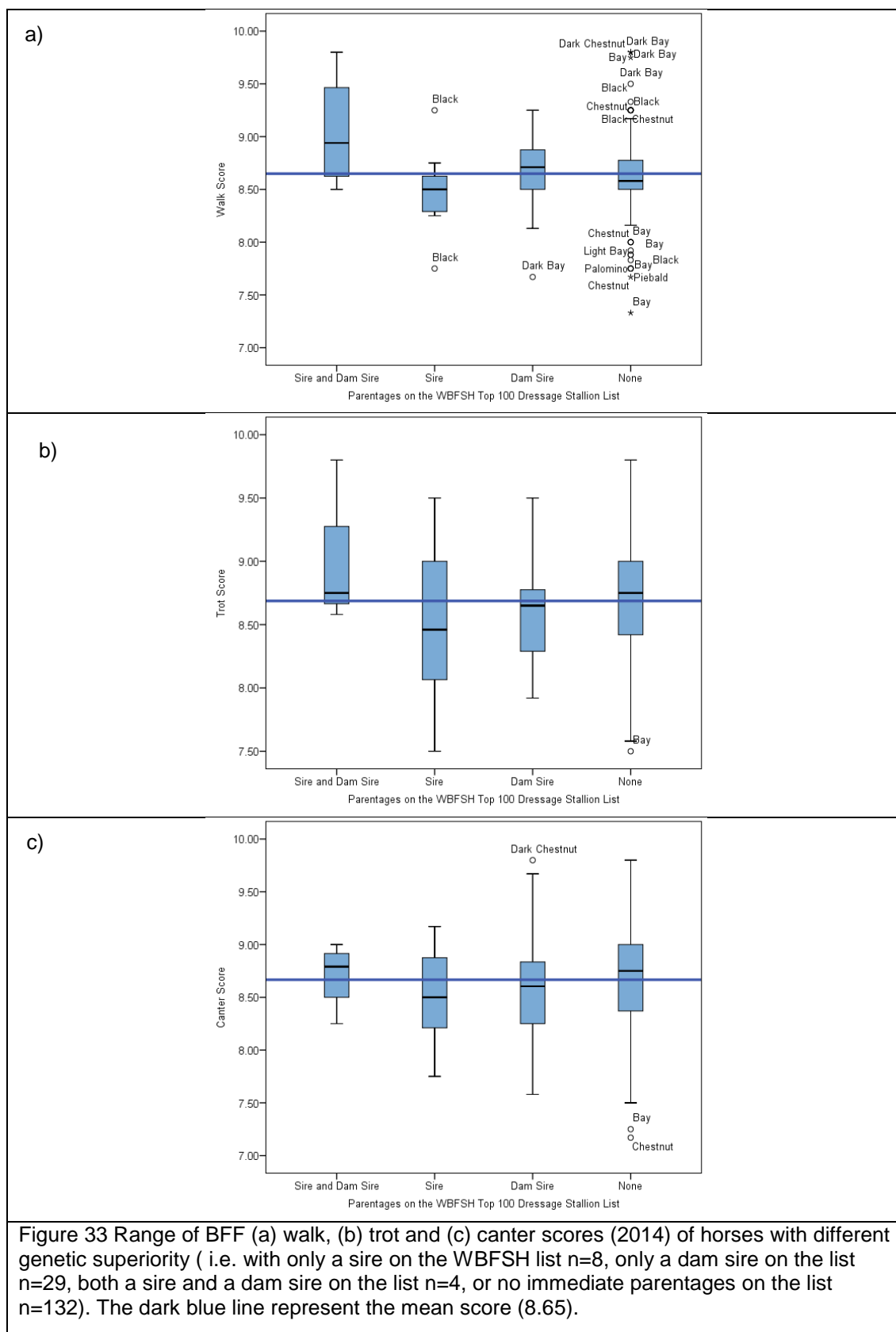
Mean frame and build component scores demonstrated a different trend to the veterinarian mark. The highest mean belonging to horses with only a dam sire on the WBFSH list (8.78), which was very close to those horses with both a sire and a dam sire (8.75), followed by horses without any WBFSH stallion influence (8.67)

and horses with only a sire on the list (8.56). As with the other scores the difference in means was not statistical significant ($F_{3,167}=0.62$, $p=0.605$).

3.1.1.1.3 Walk, Trot and Canter Scores

The gait scores (walk, trot and canter) showed similar trends to the premium and veterinarian scores. The highest means belonged to horses with both a sire and a dam sire on the WBFSH top 100 list (walk=9.09, trot=8.97, canter= 8.71). The lowest means belonged to horses with only a sire on the list (walk=8.98, trot=8.51, canter=8.51). In between were horses without any WBFSH stallion influence (walk=8.65, trot=8.59, canter=8.60) or with just a dam sire on the WBFSH list (walk=8.60, trot=8.60, canter=8.58). However, as with the other BBF scores the difference in means were not statistically significant ($p>0.05$).

Walk scores of horses without any WBFSH stallion influence had many outliers (see Figure 33). The outliers above the upper quartile belonged to bay, chestnut and black horses, whereas the outliers below the lower quartile additionally included dilutions and block coloured horses. In contrast, there were very few outliers for trot and canter scores, but instead large range of scores for horses without any WBFSH stallion influence. The entire interquartile range of walk and trot scores were above the overall average for horses with both a sire and a dam sire on the WBFSH stallion list. Additionally, the median of canter scores for these horses were well above the overall mean.



3.1.1.1.4 Athleticism Scores

The highest mean BBF athleticism score were awarded to horses with both a sire and a dam sire on the WBFSH top 100 list (17.5), followed by horses without any WBFSH stallion influence (17.11), horses with only a sire on the list (16.98) and horses with only a dam sire on the list (16.72). However, the difference in means were not statistically significant ($F_{3,164}=0.78$, $p=0.505$). Outliers below the lower quartile of horses without any WBFSH stallion influence were bay or chestnut in colour (Figure 34).

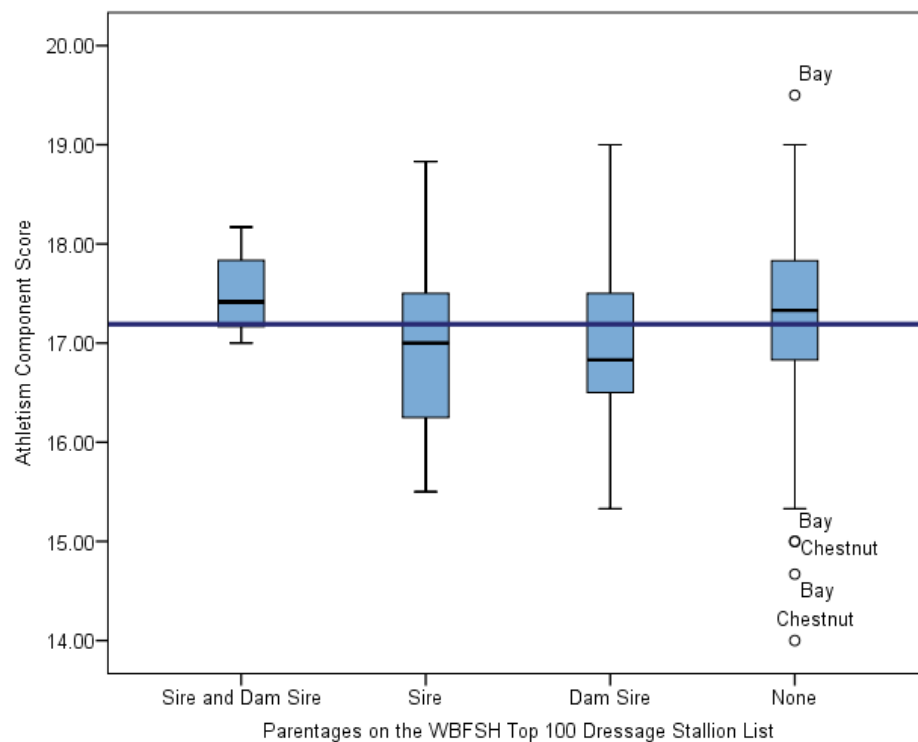


Figure 34 Range of BBF athleticism scores (2014) of horses with different genetic superiority (i.e. both a sire and a dam sire on the WBFS list $n=4$, only a sire on the list $n=8$, only a dam sire on the list $n=29$, or no immediate parentages on the list $n=132$). The dark blue line represent the mean score (17.05).

The entire interquartile range of athleticism scores for horses with both a sire and dam sire on the WBFSH list were above the overall mean. Furthermore, as with the other component scores these horses had less variability in scores than the other categories i.e. no outliers and small whiskers.

3.2.2.3 Conclusion

Throughout premium and component scores a trend was found of the highest mean scores of horses with both a sire and a dam sire on the WBFSH top 100 dressage stallion lists i.e. horses with the most superior bloodlines. Furthermore, the range of scores from these horses showed little variability i.e. had no outliers and small whiskers. However, the difference in mean scores between the four levels of genetic influence from stallions on the WBFSH top 100 lists were not statistically significant. Furthermore, mean scores did not decrease with reduced genetic superiority in bloodline i.e. horses with a sire on the WBFSH list had lower mean scores than horses without any apparent WBFSH stallion influence in the bloodline.

In conclusion, the alternative hypothesis has to be supported. However, horses in this subset of data with stallions from the WBFSH top 100 dressage lists in the immediate bloodline were limited i.e. 41 versus 132 without. Hence, the trend seen of greater scores from horses with superior genetics compared to those with less might be significant within a larger dataset. Furthermore, the parentage of horses without stallions from the WBFSH dressage lists may have been genetically superior in other ways e.g. bred with frozen semen from retired WBFSH stallions or from top national performing stallions, or had superior dams in the bloodline.

3.2.3 Bloodline Quality Related to Horse Colour

Horses with a sire (n=8) or a dam sire (n=29) on the WBFSH top 100 list were bay, chestnut and black, while horses with both a sire and dam sire on the WBFSH top 100 list (n=4) were bay and black only. The largest group were horses without recorded parental influence from the WBFSH stallion list (n=132) and contained bay, black, chestnut, dilutions, grey and block coloured horses (see Figure 35).

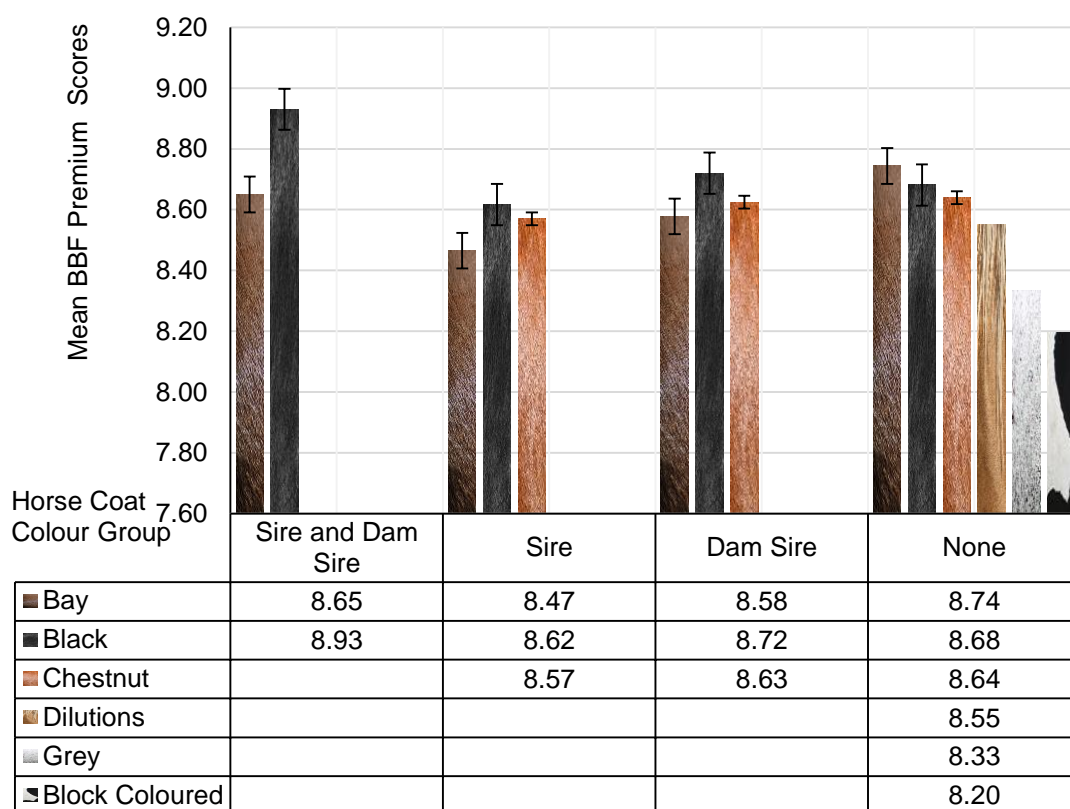


Figure 35 Mean dressage BBF premium scores (with se bars) (2014) of horses with different genetic superiority (i.e. with both a sire and a dam sire on the WBFSH list n=4, sire only on the list n=8, dam sire only on the list n=29, or no immediate parentages on the list n=132) by horse coat colour group 1 (def. Table 4).

This distribution, in its own right, could have significance, despite the relatively low total numbers analysed compared to the entire dataset. However, in order to further understand the effect of horse colour on premium scores, in respect to genetic superiority, the larger group of horses without any WBFSH top 100 stallion influence in the immediate bloodline were analysed, as this group contained almost all horse coat colours.

Mean premium scores of horses without immediate parentages on the WBFSH list decreased in the order according to horse colours as follows bay > black > chestnut > dilutions > grey > block coloured horses. This trend were similar to that found in BBF data from all years and disciplines (see 2.3.1). However, the differences in mean premium scores of horses without any WBFSH stallion influence according to horse coat colour were not statistically significant ($F_{5,125}=2.13$, $p=0.066$). However, the range of premium scores showed the entire interquartile range (and whiskers) of block coloured and grey horses' to be below the overall mean (8.68) (see Figure 36).

In contrast, the medians of bay, black and chestnut horses were close to the overall mean, whilst dilution coloured horses had a median below the overall mean. Bay, black and chestnut coloured horses had a larger spread of premium scores with some notable outliers, compared to the other horse coat colours. There was a large size difference between colour groups i.e. bay ($n=72$), chestnut ($n=28$) and black ($n=23$) versus dilution ($n=2$), block coloured ($n=4$) and grey ($n=3$). It was therefore assessed that difference in sample size could have influenced the ANOVA analysis.

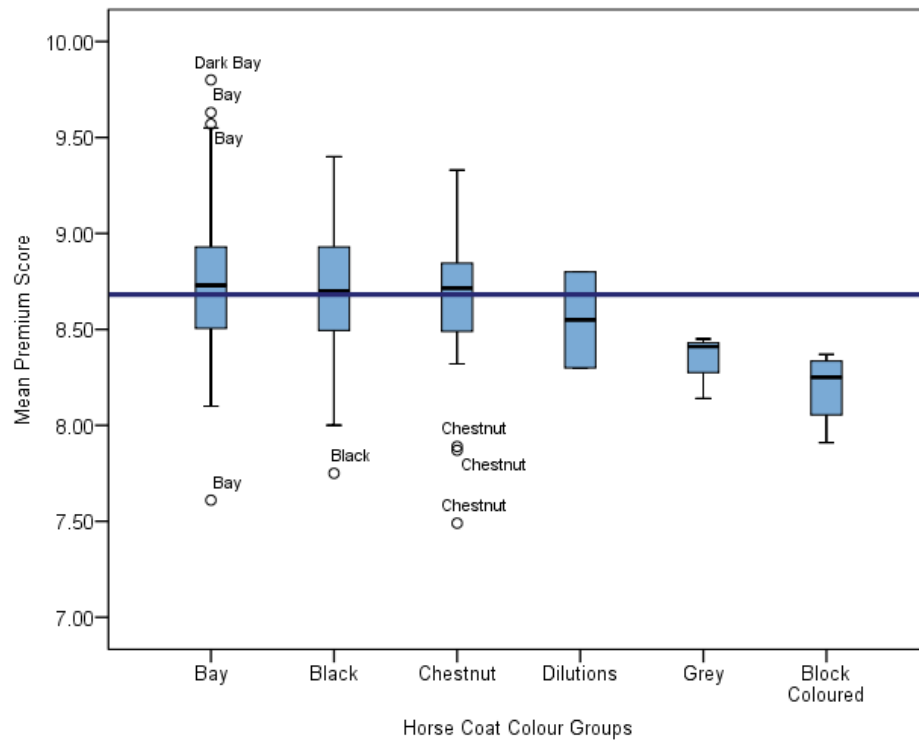


Figure 36 Range of BBF dressage premium scores (2014) of horses without any immediate parentages on the WBFSh Top 100 dressage stallion list (n=132), according to horse coat colour group 1 (def. table 4). The dark blue line represents the mean score (8.68).

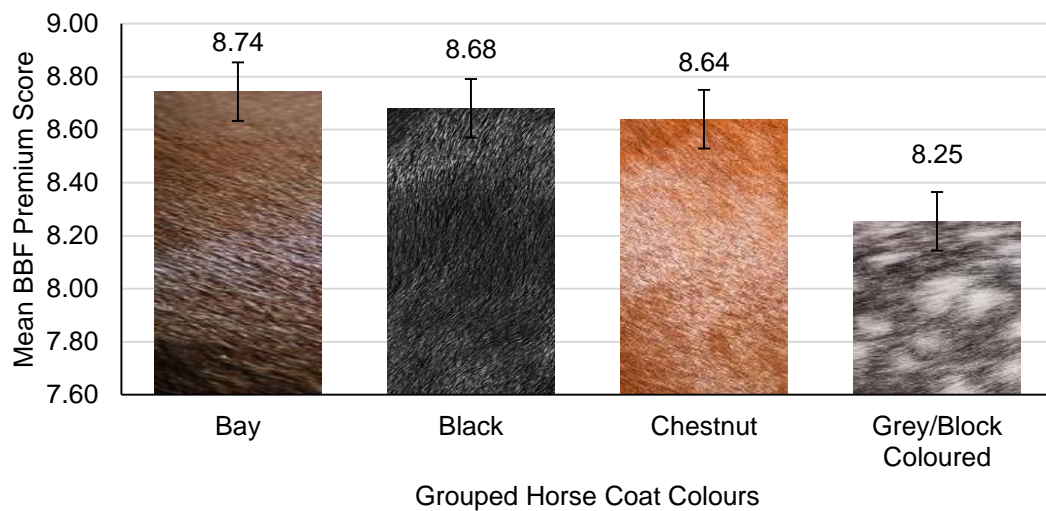


Figure 37 Mean Premium Scores (with se bars) of horses without any influence from stallions on the WBFSh list in the immediate bloodline by grouped horse coat colours 1 (def. Table 4).

Therefore, block coloured and grey horses were grouped together, and dilutions excluded (see Figure 37) before tests were rerun. This time there was a significant difference in premium scores between horse colours ($F_{3,126}=3.42$, $p=0.019$). Post hoc analysis showed this difference were between bay and grey/block coloured horses ($p=0.012$).

3.2.3.1 Conclusion

Dressage evaluated BBF horses with WBFSH stallion influence in the bloodline were only bay, black or chestnut in colour which could suggest horses of superior bloodlines are associated with these colours only. Furthermore, the range of premium scores from horses without WBFSH stallion influence in the immediate bloodline, illustrated how block coloured ($n=4$) and grey ($n=4$) horses had scores well below the mean premium score, compared to the larger groups of bay ($n=72$), chestnut ($n=28$) and black ($n=23$) horses, despite greater variability of the latter groups. Mean premium scores of grey and clock coloured horses were also lower than all other colours, a trend similar to that shown in Chapter 2 (all data). However, this difference was not statistically significant. This was assessed to be due to the large differences in group sizes, and when regrouped block coloured and grey horses together were statistically significant different to bay horses. Therefore, the alternative H6 hypothesis was rejected.

3.3 Discussion and Conclusion

Data of BBF evaluated horses were grouped according to breed registration (passport issuing office) and superiority in bloodline (using the WBFSH top 100 lists). Dressage horses from the 2014 BBF evaluation were chosen as a subset

(n=173) and subsequently analysed by horse colour in order to reveal if any superior genetics were resulting in the apparent colour bias in scores.

There was a significant difference in premium scores of horses from different breed registrations and a trend was evident that block coloured horses received below average scores, despite the total mean for each breed register being above average. This could suggest that even within the same type of horse, block coloured horses are receiving lower BBF premium scores, further supporting a possible coat colour bias.

While there was no statistical significant difference in scores between horses with different levels of WBFSH stallion influence in the bloodline, horses with both a sire and dam sire on the WBFSH top 100 list received both higher mean component and premium scores than horses with less WBFSH stallion influence in the bloodline. It was concluded that the limited amount of BBF horses with WBFSH stallion influence in the bloodline could have resulted in the differences not being statistical significant, besides other ways of evaluating genetic superiority were not considered in analysis.

Nevertheless, premium scores of horses without WBFSH stallion influence in the immediate bloodline (i.e. with a similar genetic potential) showed a trend comparable to that found in chapter 2 e.g. block coloured and grey horses received the lowest mean scores of all horse colours. Together grey and block coloured horses had significantly lower mean scores than bay horses further supporting the negative bias of block coloured and grey horses.

Furthermore, horses with WBFSH stallion influence in the bloodline were only bay, black and chestnut, which could suggest horses of superior bloodlines, at least in dressage, are associated with these colours only. It is therefore possible that the apparent colour bias is rooted outside the BBF amongst breeders and British equestrians in general.

4 Survey on the Perception of Horse Coat Colour Bias amongst British Equestrians

A questionnaire was designed targeting British equestrians in order to investigate current horse colour trend/fashion qualitatively. The aim of the survey was also to investigate British equestrian's perception of equine colour bias, in relation to anecdotal feedback received from BBF participants.

4.1 Method

4.1.1 Questionnaire Design

An online *ad hoc* cross-sectional questionnaire was designed using SurveyMonkey free online survey making tool (see figure 38).

The survey was designed to try to attain respondents' personal opinion with minimal suggestion bias. This was implemented by initial questions focussing on general horse experience and favourite horse colours, without the context of bias or the BBF. Initial impersonal questions, ensuring respondents' were part of the targeted population, progressing to more specific questions on horse colour bias and finally the BBF (McCormack and Hill, 1997). Skipping individual questions without an answer was not possible. This would prompt an error message requiring the respondents to select the "do not know" option. The questionnaire was deliberately kept limited to ten questions in order to retain participants' attention/focus and to increase the likely number of fully completed returns.

Research Masters in Equitation Science

Welcome

This survey is part of a Research Masters thesis in Equitation Science, undertaken at Plymouth University, in partnership with Duchy College.

The aim of the questionnaire is to investigate horse coat colour preferences of British equestrians. If you are not British or not currently living in Britain, please do NOT submit a response.

The questionnaire consists of 10 questions and completion should only take about 10 minutes. All answers are collected anonymously.

Any questions or concerns can be emailed to the researcher: anna.fiskerhansen@plymouth.ac.uk

Thank you for taking part.

Equestrian Experience

*1. What type of horse related activities are you/have you been involved in?

Pick all the options that apply to you.

- ☐ I have never taken part in any horse related activity
- ☐ Working in a horse related industry (e.g. tack shop, feed company, insurance company etc)
- ☐ Working with horses - UNPAID (e.g. work experience, volunteering, holiday job)
- ☐ Working with horses - PAID PART TIME (e.g. groom, veterinarian, farrier, riding instructor, show judge etc)
- ☐ Working with horses - PAID FULL TIME (e.g. groom, veterinarian, farrier, riding instructor, show judge etc)
- ☐ Studying/teaching equine subjects at college or university
- ☐ Breeding horses (owned a brood mare and/or stallion)
- ☐ Competing in a horse showing class
- ☐ Competing in endurance riding
- ☐ Competing in eventing
- ☐ Competing in show jumping
- ☐ Competing in dressage
- ☐ Taking riding lessons
- ☐ Sharing one or more horses
- ☐ Owning one or more horses
- ☐ Other (please specify)

Equine Coat Colour Preference

Figure 38 the online questionnaire Q1

Research Masters in Equitation Science

*2. Do you have a favorite horse colour? If yes, what is it?

- ☐ Chestnut
- ☐ Palomino
- ☐ Buckskin
- ☐ Spotted (e.g. appaloosa spottings)
- ☐ Bay
- ☐ Skewbald (any colour and white e.g. bay tobiano)
- ☐ Piebald (black and white e.g. black tobiano)
- ☐ Black
- ☐ Dun
- ☐ Roan (any roan)
- ☐ Grey/White
- ☐ I don't have a favorite horse colour
- ☐ Other (please specify)

Equine Coat Colour Preference

*3. Do you have a least favorite horse colour? If yes, what is it?

- ☐ Buckskin
- ☐ Roan (any roan)
- ☐ Piebald (black and white e.g. black tobiano)
- ☐ Spotted (e.g. appaloosa spottings)
- ☐ Dun
- ☐ Black
- ☐ Palomino
- ☐ Grey/White
- ☐ Skewbald (any colour and white e.g. bay tobiano)
- ☐ Chestnut
- ☐ Bay
- ☐ I don't have a least favorite horse colour
- ☐ Other (please specify)

Judging Bias according to Equine Coat Colour

Figure 38 continued: the online questionnaire Q2-3.

Research Masters in Equitation Science

***4. How influential do you think horse coat colour is to the judging of equine sport performance?**

	Not influential	Slightly influential	Moderately influential	Very influential	Extremely influential	I do not know about equine sport performance
In show jumping?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
In endurance riding?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
In eventing?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
In dressage?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

British Breeding Futurity Evaluations

***5. Have you ever taken part in the British Breeding Futurity young horse evaluations?**

If yes, how did you take part? Choose all applicable.

- ☐ Judging the Futurity evaluations in the performance phase
- ☐ Being a sponsor to a Futurity event
- ☐ Showing a horse in the evaluation (leading the young horse/dam in the arena)
- ☐ Being the breeder of an evaluated horse
- ☐ Owning an evaluated horse
- ☐ Judging the Futurity evaluations in the veterinarian phase
- ☐ Being a spectator at a Futurity event
- ☐ I have never taken part in a British Breeding Futurity event
- ☐ Other (please specify)

Equine Coat Colour Bias in the Futurity Events

***6. How influential do you think horse coat colour is on the judging of The British Breeding Futurity?**

	Not influential	Slightly influential	Moderately influential	Very influential	Extremely influential	I do not know the Futurity events
In the veterinarian evaluations	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
In the performance evaluations	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Equine Coat Colour Bias in the Futurity Events

Figure 38 continued: the online questionnaire Q4-6.

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*7. What horse colours do you think are favored and least favored by judges at the British Breeding Futurity?

Please rank the colours from most favored by judges (1) to least favored by judges (10).





<input type="checkbox"/>  Spotted (e.g. appaloosa spotting)	<input type="checkbox"/> I do not think judges favor any colour/I do not know the Futurity events
<input type="checkbox"/>  Skewbald (any other colour than black, and white e.g. bay tobiano)	<input type="checkbox"/> I do not think judges favor any colour/I do not know the Futurity events
<input type="checkbox"/>  Chestnut	<input type="checkbox"/> I do not think judges favor any colour/I do not know the Futurity events
<input type="checkbox"/>  Roan (any roan)	<input type="checkbox"/> I do not think judges favor any colour/I do not know the Futurity events

Figure 38 continued: the online questionnaire Q7.

Research Masters in Equitation Science	
	events
<input type="checkbox"/> Grey/White	I do not think judges favor any <input type="checkbox"/> colour/I do not know the Futurity events
<input type="checkbox"/> Palomino	I do not think judges favor any <input type="checkbox"/> colour/I do not know the Futurity events
<input type="checkbox"/> Piebald (black and white e.g. black tobiano)	I do not think judges favor any <input type="checkbox"/> colour/I do not know the Futurity events
<input type="checkbox"/> Dun/Buckskin	I do not think judges favor any <input type="checkbox"/> colour/I do not know the Futurity events
	I do not

Figure 38 continued: the online questionnaire Q7 continued.

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Black

Bay

think judges favor any colour/I do not know the Futurity events

I do not think judges favor any colour/I do not know the Futurity events

Equine Coat Colour Bias in the Futurity Events

***8. Do you believe that a horse you entered in the Futurity evaluations were scored favorably/less favorably because of its coat colour? Please rate your agreement.**

	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree	I have never entered a horse in the Futurity evaluations
My horse was LESS FAVORABLY scored because of its colour	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
My horse was FAVORABLY scored because of its colour	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Gender

Now, to make statistical comparison would you mind telling your gender?

9. What is your gender?

☐ Male

☐ Female

Figure 38 continued: the online questionnaire Q7-9.

Research Masters in Equitation Science

Equine Coat Colour Bias

Do you have any additional thoughts on horse coat colour influencing equine performance judging, especially at the Futurity evaluations?

10. Why do you think horse coat colour does/does not influence Futurity judging?

Please write your comments below.

Thank you!

Thank you for taking part in this survey.

The questionnaires will be part of a Research Masters thesis, using data from the British Breeding database, to investigate evaluator bias when assessing potential performance horses in regards to horse coat colour.

The thesis, with the results from this survey, will be submitted in September 2015.
All answers are anonymous.

Any questions or comments can be send to the author by emailing:
anna.fiskerhansen@plymouth.ac.uk.

Thank you again
Anna Fisker Hansen, BSc (Hons) Equine Science

Figure 38 continued: the online questionnaire Q10.

A range of question formats including multiple response, ranking, scaled, and a free-text attitude statement were designed to ascertain respondents' feelings or attitudes towards horse coat colour bias. All multiple response questions were randomised to eliminate ordinal and serial effects as sources of variation (Oppenheim, 1992). Closed questions included an "other please specify" option, so as not to limit the answers of respondents. Five point, unipolar rating scales were labelled to optimise reliability and validity of the answers obtained (Krosnick, 1999). Additionally, a Likert scale question was used to obtain a multi-dimensional overview of the participants' experience of horse colour bias in the BBF (McCormack and Hill, 1997). The wording used for the Likert rating scale was as used by Mahoney (2009) i.e. disagree, somewhat disagree, neither agree nor disagree, somewhat agree, agree.

4.1.2 Sampling

The survey was distributed through social media i.e. Facebook and LinkedIn. On the LinkedIn website a link to the survey was posted on the 30.07.14 using the authors' own network, and the groups 'UK Equine' and 'Horses UK'. On Facebook the survey link was shared on the authors' own wall, and by a BBF evaluator and sport horse breeder. The survey link was also posted in the Facebook group 'Equine Colour Genetics' (see Figure 39). The specific groups and networks were chosen to target British equestrians. Summer was selected as the optimal time for distribution, due to it correlating with the BBF evaluations, and participants were more likely to be actively engaged in or with equine sports competitions.



Figure 39 Survey link shared in the Facebook group Equine Colour Genetics

4.1.3 Initial Data Handling

All survey data was downloaded into Microsoft Excel, PowerPoint and Pdf files for analysis. The following quality control filters were applied to the data before further statistical analysis.

- 1) Survey responses from one participant stating being from the US was removed as the survey was targeted specifically for British equestrians, resulting in 65 responses. Equally, answers from one participant with 'no horse experience' was after the initial frequency analysis in question one, excluded from analysis of the remaining questions (n=64).
- 2) Horse coat colours were grouped according to similar phenotypes, and in accordance with horse colour group 1 used in the BBF data (see table 18). Additional horse colours added in the "other" option were categorised

according to the horse colour groups defined by BBF. A contradictory response of least favourite “grey/white and chestnut due to skin problems” was adjusted to “no least favourite”.

Table 18: Horse colour terminology used

Horse colour groups as used in analysis	Horse colours as used in survey
Bay	Bay, brown
Chestnut	Chestnut, liver chestnut
Black	Black
Grey	Grey/white
Spotted	Spotted, roan
Block coloured	Piebald, skewbald, coloured
Dilutions	Palomino, buckskin, dun

- 3) In survey question one, answers were defined as a multiple response set in SPSS Statistics, with a separate variable ranking from 0-10 according to the level of horse experience (see table 19). An “other” answer of “recreational riding and training”, was deleted as the participants had already stated, “Owning one or more horses”, and “Studying/teaching equine subjects at college or university”.

Table 19: Ranking of participant horse experience

Horse Experience	Ranked Level of Horse Experience
No experience	0
Working in horse related industry	1
Taking riding lessons	2
Unpaid work with horses	3
Sharing a horse	4
Competing with horses	5
Part time paid work with horses	6
Owning a horse	7
Breeding horses	8
Working full time with horses	9
Academic education concerning horses	10

- 4) Incomplete answers of “What horse colours do you think are favoured and least favoured by judges at the British Breeding Futurity?” (Q7) were changed to “I do not think judges favour any colour/I do not know the Futurity events” (n=12).
- 5) Contradictory reply of “not having entered a horse in the Futurity event” and disagreeing that own horse was less favourably scored in the Futurity (Q8) was edited to “not having entered a horse in the Futurity event”.

4.1.4 Statistical Analysis

All data were analysed in IBM SPSS Statistics 21. One-sample Chi-square tests were used to examine differences in the distribution of favourite and least favourite horse colours. One-sample Binominal tests were used to determine significant differences between participants with or without a favourite/least favourite horse colour. These tests were also used for analysis of assumption of bias in equine sports performance judging and the assumption of bias in the BBF. Cross-tabulation Chi-square tests: Pearson Chi-square and Likelihood Ratio were applied where assumptions of expected values were met. Symmetric measures of Phi and Cramer's V, were used to analyse data on opinion of judging bias as a function of horse experience, the opinion of judging bias in the BBF as an effect of BBF experience, and the relationship between participants' gender and their favourite/least favourite horse colour. All tests used the significance level of 0.05 (95%).

Ranking of BBF evaluators favourite horse colours, as perceived by survey participants (Q7), were obtained using weighted averages as depth in SurveyMonkey's online survey tools.

Table 20 describes which questions were used to tests the different hypotheses.

Table 20: Hypotheses relation to survey question

Hypotheses	Survey Question
H₇ Surveyed equestrians have particular horse colour preferences (favourite and least favourite) which are indicative of current horse coat colour fashion.	Q2, Q3, Q9, Q10
H₈ There is an assumption, that the British Breeding Futurity is biased by horse coat colour.	Q6, Q7, Q8, Q10
H₉ The opinion on existence and extent of horse coat colour bias, within the BBF, is effected by previous experience of the BBF evaluations.	Q5, Q6, Q8

4.2 Results

4.2.1 Q1 Survey Participants' Equestrian Experience

Survey participants (n=64) had varied horse backgrounds, and as a result identified with all the likelihoods of equine experience in the multiple response answers (see Table 21).

Table 21: Frequency of participants' horse experience

Horse experience/background	Multiple responses	
	N	% ¹
Horse owner	54	83.1
Dressage competitor	44	67.7
Taken riding lessons	36	55.4
Showing competitor	34	52.3
Horse breeder	25	38.5
Show jumping competitor	25	38.5
Paid part time horse work	18	27.7
Academic horse background	17	26.2
Unpaid horse work	16	24.6
Eventing competitor	16	24.6
Paid full time horse work	14	21.5
Horse sharer	8	12.3
Work in horse related industry	7	10.8
Endurance competitor	2	3.1
No horse experience	1	1.5
Total	317	487.7%

1 N divided by total respondents (n=65) multiplied by 100

The majority of survey participants had a variation of horse experience, and selected multiple options for the question. The mean number of horse experiences per participants were 4.8, with three different types of equine experiences being most common (17% of participants, n=11).

The ranked levels of participants' horse experiences made it apparent that the surveyed population were highly experienced equestrians. Twenty seven percent of participants had being a horse owner as the highest equine experience (rank 7/10), 22% horse breeder (ranked 8/10), and 27% had a horse related academic background (ranked 10/10) (see Table 22).

Table 22: Participants' horse experience ranked according to highest level

Horse Experience	Ranked Level of Horse Experience	N	% ¹
No experience	0	1	1.5
Working in horse related industry	1	2	3.1
Taking riding lessons	2	1	1.5
Unpaid work with horses	3	0	0
Sharing a horse	4	3	4.6
Competing with horses	5	2	3.1
Part time paid work with horses	6	1	1.5
Owning a horse	7	17	26.2
Breeding horses	8	14	21.5
Working full time with horses	9	7	10.8
Academic education concerning horses	10	17	26.2
Total		65	100

1 N divided by total respondents (n=65) multiplied by 100

4.2.2 Q2 Survey Participants' Favourite Horse Colour

The majority of survey participants indicated having a favourite horse colour (n=42, 66%). Piebald was the only horse colour not chosen as a favourite by any participant. Of the participants indicating a favourite horse colour, black was the

most popular (n=9, 21%) and roan the least popular (n=1, 2%). A graphical illustration of the phenotypically grouped favourite horse colours (as described in section 4.2.3 Table 18) is displayed in Figure 40.

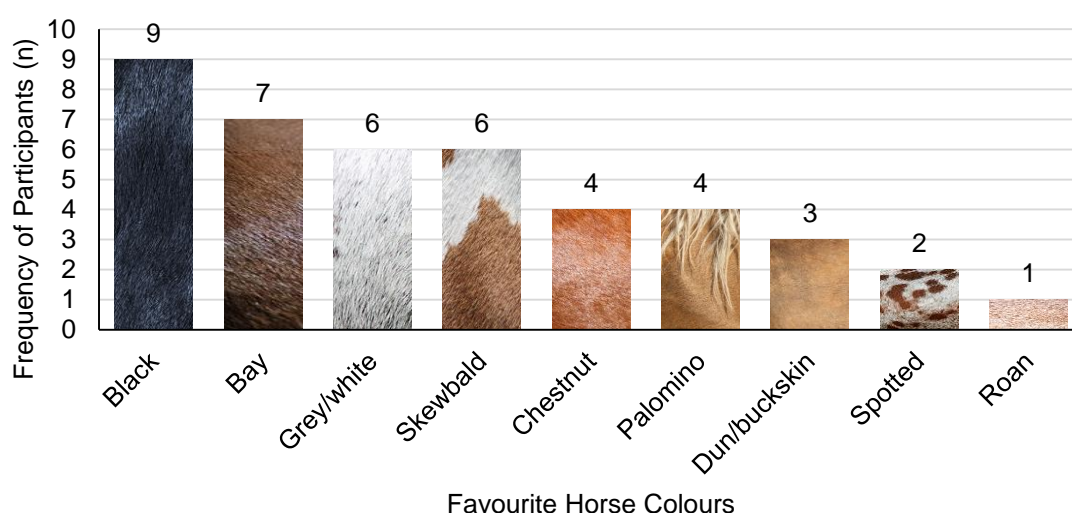


Figure 40 Frequency of participants' favourite horse colours (n=42).

4.2.3 Q3 Survey Participants' Least Favourite Horse Colour

Most survey participants also indicated having a least favourite horse colour (n=39, 61%). Out of these, 28% (n=11) indicated spotted was their least favourite horse colour. No participants indicated black as their least favourite horse colour. Phenotypically grouped least favourite horse colours (as described in section 4.2.3 Table 18) is displayed in Figure 41.

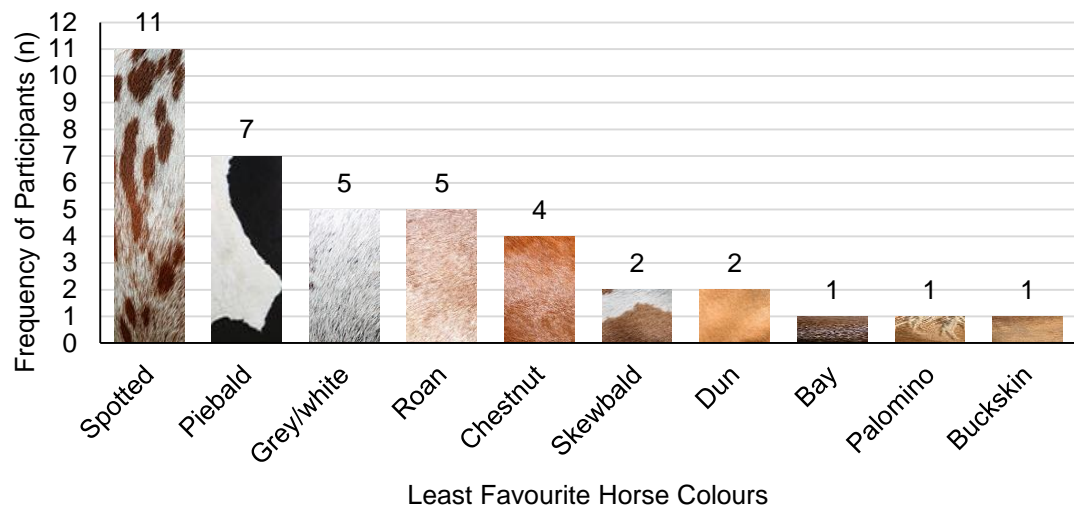


Figure 41 Frequency of participants least favourite horse colours (n=39).

4.2.4 Q4 Survey Participants' Perception of Horse Colour Bias in Equestrian Sport Performance Judging

One participant indicated not knowing dressage and show jumping competitions, and two participants not knowing eventing and endurance, leaving a response rate for question four of n=62 and n=61 respectively. The frequency of participants' perception of horse colour influence on equestrian sports judging is displayed in Figure 51. A significant amount of surveyed equestrians (70%, 43 out of 62) thought that dressage competitions could be biased according to the colour of the horse ($p=0.002$), with 5% of participants (3 out of 62) believing horse coat colour were extremely influential in judging. However, a significant amount of participants did not think show jumping, eventing or endurance were influenced by horse coat colour bias ($p<0.001$).

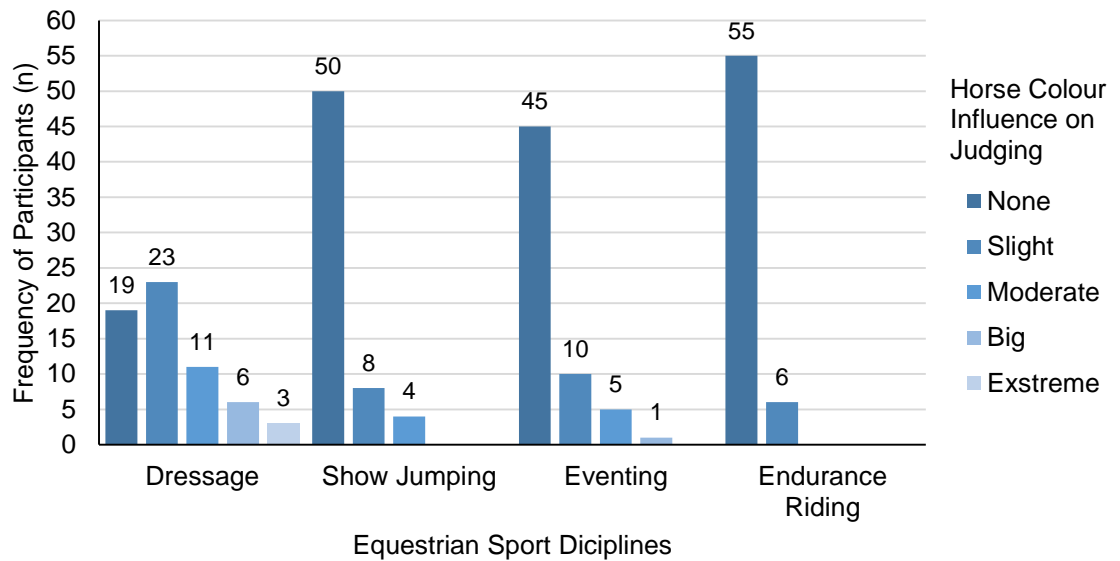


Figure 42 Frequency of participants perception of the influence of horse colour on judging of dressage (n=62), show jumping (n=62), eventing (n=61) and endurance riding (n=61).

4.2.5 Q5 Survey Participants' Involvement in the BBF

Sixty-one percent of participants indicated not having any experience with the BBF evaluations (39 out of 64). The remaining 39% (25 out of 64) of participants indicated all available options of BBF involvement in the survey answers, with an additional "other" option added as "writing for a judge" (see Table 23). Most survey participants only had one type of experience with the BBF, with spectator experience being chosen by 60% (15 out of 25) of the BBF experienced participants.

Table 23: Frequency of participants' experience with the BBF

British Breeding Futurity experience	Multiple Responses		% of cases ²
	N	% ¹	
Written for judges	1	1.8	4.0
Sponsor	3	5.5	12.0
Spectator	15	27.3	60.0
Veterinarian judge	1	1.8	4.0
Performances judge	2	3.6	8.0
Owner of evaluated horse	11	20.0	44.0
Breeders of evaluated horse	10	18.2	40.0
Handler of evaluated horse	12	21.8	48.0
Total multiple responses	55	100.0%	220.0%

1: N divided by total multiple responses (n=55) multiplied by 100. 2: N divided by total responses with futurity experience (n=25) multiplied by 100

4.2.6 Q6 Survey Participants' Perception of Horse Coat Colour Bias in the BBF

Twenty-eight percent of participants (18 out of 64) indicated not knowing about the BBF/not believing in bias within the BBF, and one participant ended the survey here (see Tables 24). Within the remaining 45 participants the majority (60%, n=27) thought the performance evaluation phase of the BBF could be biased according to the colour of the horse (slightly, moderately and very influential), whereas only 31% (n=14) thought the same about the veterinary phase and (see Figure 43).

Table 24: Participants' perception of horse colour bias within the BBF

Perceived Influence of Horse Colour	BBF Evaluations Performance Phase			BBF Evaluations Vet Phase		
	N	% ¹	Valid % ²	N	% ¹	Valid % ²
None	18	28.1	40.0	31	48.4	68.9
Slight	12	18.8	26.7	10	15.6	22.2
Moderate	13	20.3	28.9	3	4.7	6.7
Very	2	3.1	4.4	1	1.6	2.2
Total	45	70.3	100.0	45	70.3	100.0
N/A	18	28.1		18	28.1	
Missing	1	1.6		1	1.6	
Total	19	29.7		19	29.7	
Total	64	100.0		64	100.0	

1: N divided by total respondents (n=64) multiplied by 100.2: N divided by total of respondents indicating BBF experience (n=45) multiplied by 100

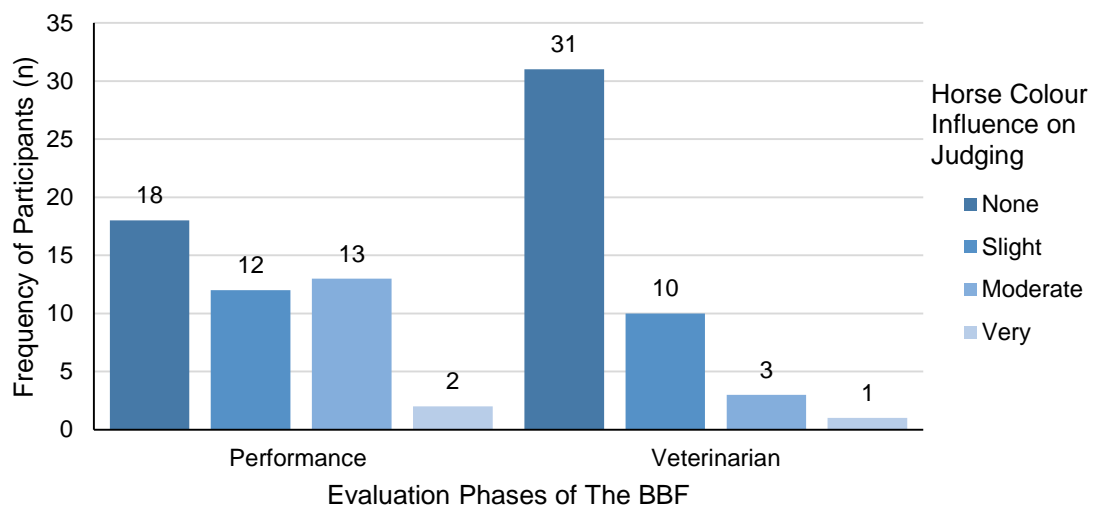


Figure 43 Frequency of participants' perception of the influence of horse colour on judging in the BBF performance and veterinarian evaluation phase (n=45).

4.2.7 Q7 Survey Participants' Perceived Horse Colour Preferences of BBF Judges

Table 25 displays the horse colour ranking made by respondents when asked to rank ten horse colours from most favoured by BBF judges (1) to least favoured by BBF judges (10). Twelve participants had not completed the full ranking, and the answers of these were therefore manually changed to "I do not think judges favour any colour/I do not know the Futurity events". This group in total consisted of 33 participants (55%). Four participants choose to end the survey at this stage, leaving n=27 participants completing question seven's ranking.

Table 25: Ranking of BBF judges preferred horse colours as perceived by participants

Horse	Ranking from 1-10 (n)										Total N	Mean
Colours	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th		
Bay	12	7	3	1	0	0	0	4	0	0	27	2.63
Black	8	10	3	1	1	1	0	0	1	2	27	3.00
Chestnut	1	4	12	4	2	0	2	0	1	1	27	3.85
Grey/White	2	1	3	8	3	3	0	4	1	2	27	5.15
Dun/Buckskin	1	1	1	4	5	3	5	3	3	1	27	5.96
Palomino	1	1	1	4	6	3	2	3	5	1	27	6.04
Roan	0	1	4	1	1	3	7	0	9	1	27	6.70
Skewbald	0	1	0	1	4	5	9	2	3	2	27	6.74
Piebald	1	0	0	2	3	8	0	6	1	6	27	7.00
Spotted	1	1	0	1	2	1	2	5	3	11	27	7.93

4.2.8 Q8 Survey Participants' Experience of Horse Colour Bias in the BBF

One participant ended the survey at this stage, and 68% (n=40) of the remaining survey participants had never entered a horse in the BBF evaluations. Nineteen participants had entered a horse in the BBF, but only 16% (n=3) “somewhat” agreed to their horses’ coat colour having favourably influenced the evaluation results. One participants (5%) “somewhat” agreed to having had unfavourable evaluation results as a result of their horses’ coat colour. However, no participants fully “agreed” to having experienced either positive or negative horse coat colour bias within the Futurity evaluations (see figure 44).

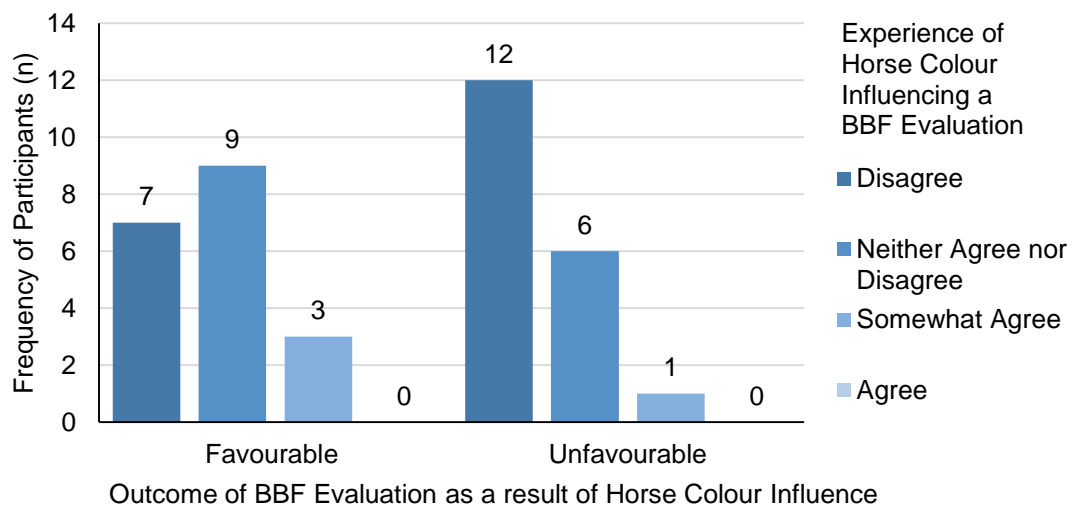


Figure 44 Participants' agreement range to own experience of horse colour (favourable or unfavourable) influence in the BBF evaluations (n=19).

4.2.9 Q9 Survey Participants' Sex

Early termination of the survey by some participants, resulted in only n=58 people answering Question 9, which described their sex. Eighty-eight percent of participants were female (55 out of 58) and 15% male (7 out of 58).

4.2.10 Q10 Free Text Attitudinal Responses on Equine Coat Colour Bias

Complete answers (n=26) to the free text option in the survey can be found in appendix iii. Trends in answers were categorised into similar themes:

- 1) Bias according to horse coat colour is a result of certain colours being associated with certain breeds of horses (which are more suitable as sports horses) (n=3).
- 2) Bias according to horse colour is a result of tradition/history of sport horse colour (n=4).
- 3) Bias according to horse colour is a result of colour obscuring conformation in a negative way (n=2).
- 4) Bias according to horse colour is a result of colour emphasising the horse in a positive way (n=5).
- 5) There is no such thing as horse coat colour bias (n=8)
- 6) Horse coat colour bias may be a possibility (n=4).

Thirty-one percent (8 out of 26) of the free text survey participants did not think horse coat colour bias exists, and many used the phrase “a good horse is never a bad colour”. Fifteen percent (4 out of 26) expressed an optimism that

evaluations such as the BBF are objectively judged, but did not completely disregard horse coat colour bias. Trends in the reasons given for, and against horse colour bias emerged. One popular answer arguing against horse colour bias was that the breed of horse dictates the colour, and horses especially suited to certain equestrian disciplines would have the appropriate coat colours, and therefore any apparent colour bias would merely be an indicator of the breed. To the contrary, other answers suggested that horse colour largely reflected the current fashion or trend and the most popular colours would always be positively biased. Survey participants also discussed the visual aspect of horse coat colour. Here opinion was divided between (a) those who thought specific horse colours could effectively mask the conformation and gaits of a horse, which could result in a negative bias and, (b) those of the opinion that a horse colour could highlight favourable aspects of conformation and gaits, and make the horse stand out, effectively causing positive bias.

4.2.11 Current Horse Colour Preferences

The majority (66%, 42 out of 64) of survey participants expressed a favourite horse colour. Binominal tests showed a significant difference when compared to equal probability of having a favourite horse colour and not having a favourite horse colour ($n=64$, $SE=4$, $p=0.018$), but no significant difference in participants having or not having a least favourite horse colour ($n=64$, $SE=4$, $p=0.104$) (see figure 45).

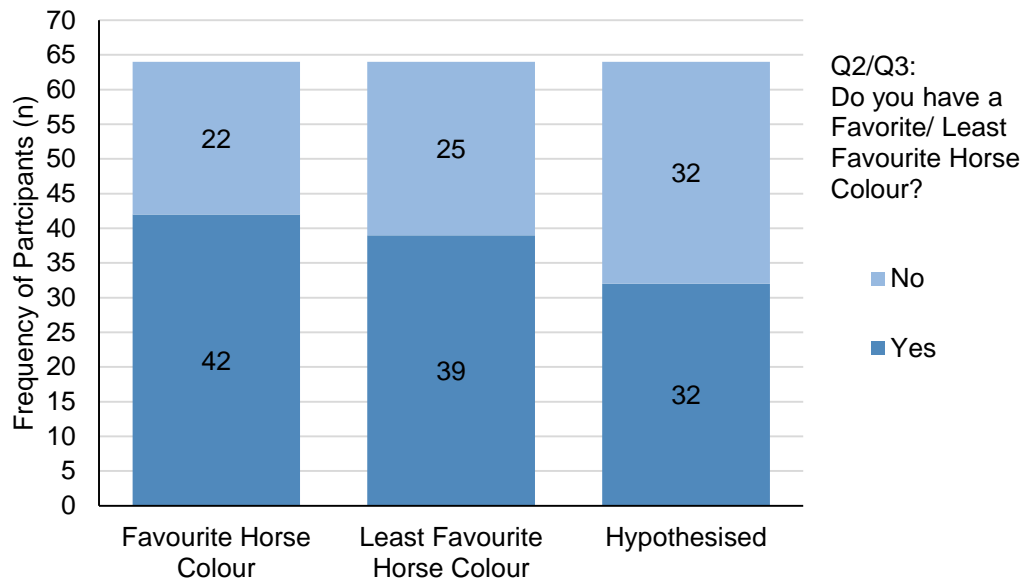


Figure 45 Observed frequency of participants (N=64) having a favourite (n=42) and least favourite (n=39) horse colour compared to a hypothesised equal probability (N divided by the 2 answers=32).

Participants chose black (9 out of 42 responses, 21%) as their most favourite horse colour, and black continued to be the most favourite horse colour, after the grouping of horse colours with similar phenotypes (defined in section 4.2.3 Table 18). However Chi-square tests showed no significance in the probability of selected favourite horse colour either in the ungrouped colours (n=42, df=8, p=0.194,) or grouped colours (n=42, df=6, p=0.677). The expected hypothesised value of the ungrouped colours were 4.67 which does not meet the tests assumption of above five. However, when colours were grouped the expected value met the test assumption (see Figure 46).

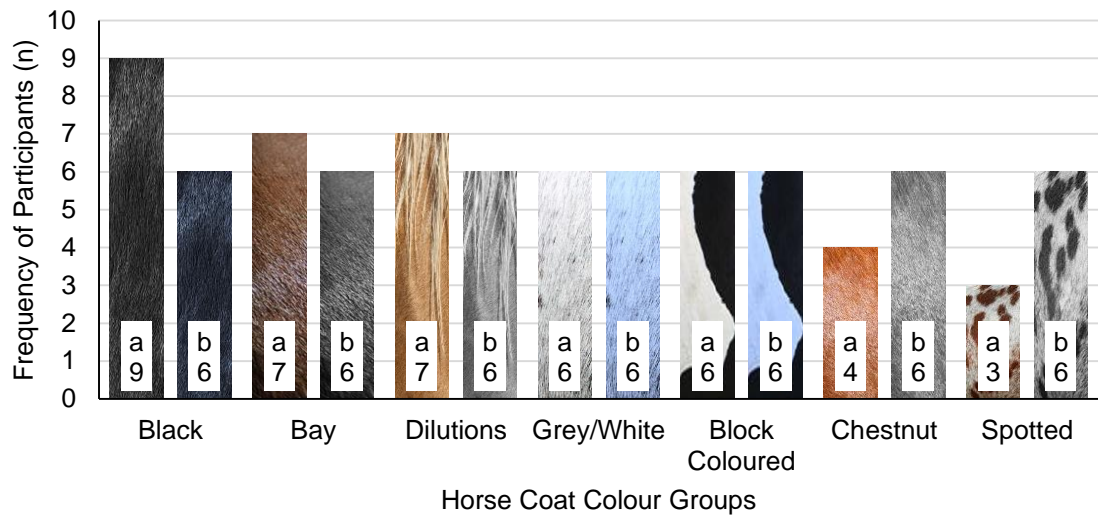


Figure 46 Participants' grouped favourite horse colours (a) (n=42) compared to a hypothesised equal spread of favourite horse colours (b) (N divided by the 7 grouped horse coat colours=6).

No participants choose black as their least favourite horse colour. Most participants selected spotted horses as their least favourite. This trend was observable both in grouped colours (41%, 16 out of 39) and ungrouped colours (28%, 11 out of 39) (see Table 17). The second most selected 'least favourite' horse colour was piebald (18%, 7 out of 39). Piebald was grouped with the similar phenotype skewbald (n=2) (as described in section 4.2.3 Table 18) this horse colour group (i.e. block coloured) was the least favourite of 28% of participants (9 out of 39).

Participants' least favourite horse colours were indicated with probabilities that were significantly different (n=39, df=9, p=0.004). When least favourite horse colours were grouped according to similar phenotypes this probability showed to be even higher (n=39, df=5, p=0.001). However, only the data of the grouped

colours meet the assumptions of minimum expected values of over five (see Figure 47).

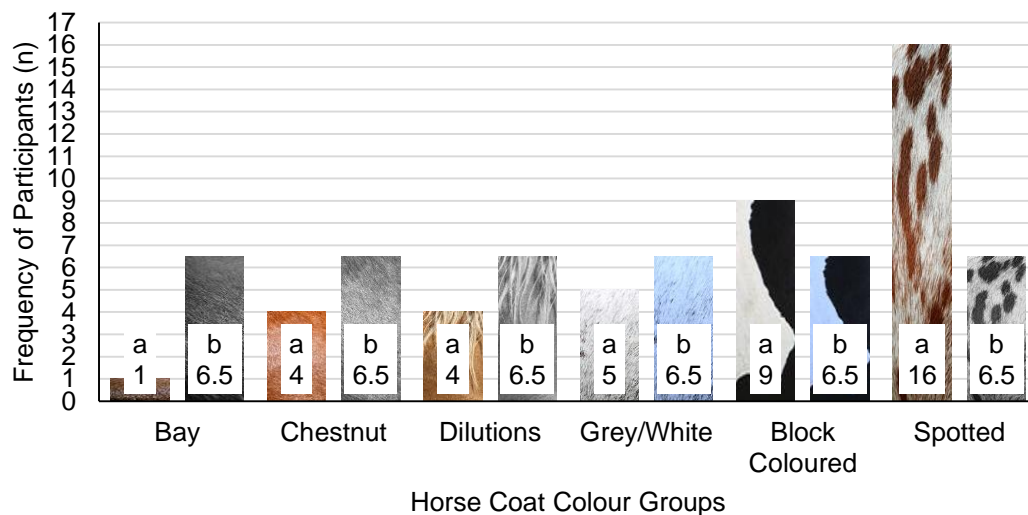


Figure 47 Participants' grouped least favourite horse colours (a) (n=39) compared to a hypothesised equal spread of least favourite horse colours (b) (N divided by the 6 grouped horse coat colours=6.5)

Comparison of favourite/least favourite horse colours split by participants sex can be seen in Figure 48. One male participant did not have a favourite horse colour and the remaining six's favourite colours were divided between black (n=4), block coloured (n=1) and dilutions (n=1). A more varied range of horse colours were selected by the larger number of female participants (n=32). In consequence spotted (n=9), bay (n=4) and chestnut (n=3), were also selected as favourites. A similar distribution was apparent for least favourite horse colours e.g. spotted was selected as the least favourite horse colour by most male (44%, 4 out of 9) and female participants (51%, 15 out of 29).

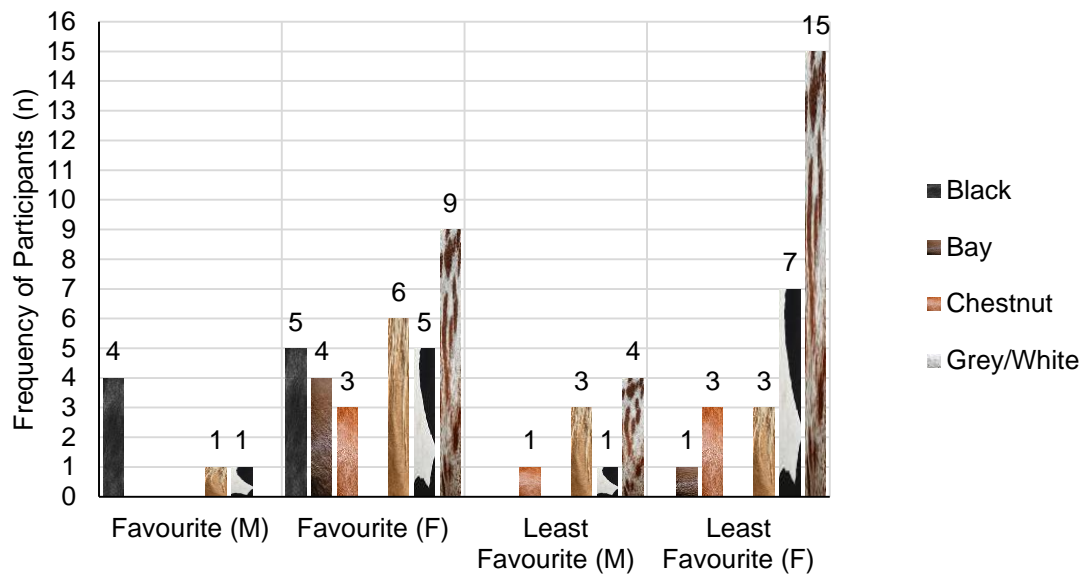


Figure 48 Surveyed equestrians' favourite (n=41) and least favourite (n=39) horse colours divided between male (M) and female (F) participants.

4.2.11.1 Conclusion

A significant amount of participants indicated having a favourite horse colour, which suggest that British equestrians' do have horse colour preferences. Although a relative higher proportion of participants selected black as their favourite horse colour (29%, 9 out of 42), statistical analysis suggested that this apparent trend could have happened by chance. Therefore, any apparent trend in favourite horse colours amongst British equestrians cannot be concluded and the alternative hypothesis, stating that surveyed British equestrians' favourite horse colours occur with equal probability, amongst the selected colours can be supported.

However, 60% of participants (39 out of 65) indicated having a least favourite horse colour. Therefore, the alternative hypothesis that least favourite horse colours are selected with equal probability can be rejected. Spotted and block coloured horses were the least favourite horse colour for both male and female participants. This suggests that a current fashion in horse colours amongst British equestrians cannot be demonstrated by favouritism of some horse colours, but more due to unpopularity of other colours i.e. spotted and block coloured.

4.2.12 Horse Colour Bias in the BEF Futurity

4.2.12.1 Judges Preferred Horse Colours

Twenty-seven participants (45%, 27 out of 60) expressed a perceived horse colour bias in the BBF by ranking horse colours from 1-10 according to BBF judges' favourite horse colours (as described in section 4.3.1.6 Table 23). Colours were ranked: bay > black > chestnut > grey/white > dun/buckskin > palomino > roan > skewbald > piebald > spotted. Participants ranked spotted, piebald, skewbald and roan horses the lowest, implying that these are the horse colours perceived as the least favourite by BBF judges. Bay, black, chestnut and grey were the highest ranked implying that these are more favoured by BBF judges. This indicated a trend in perceived preference for 'solid' horse colours compared to 'coloured' horses.

4.2.12.2 Bias in Performance versus Veterinarian Phase

Participants' opinion on whether there was horse coat colour bias within the Futurity process differed between the veterinarian evaluation phase and the potential performance evaluation phase (see figure 49).

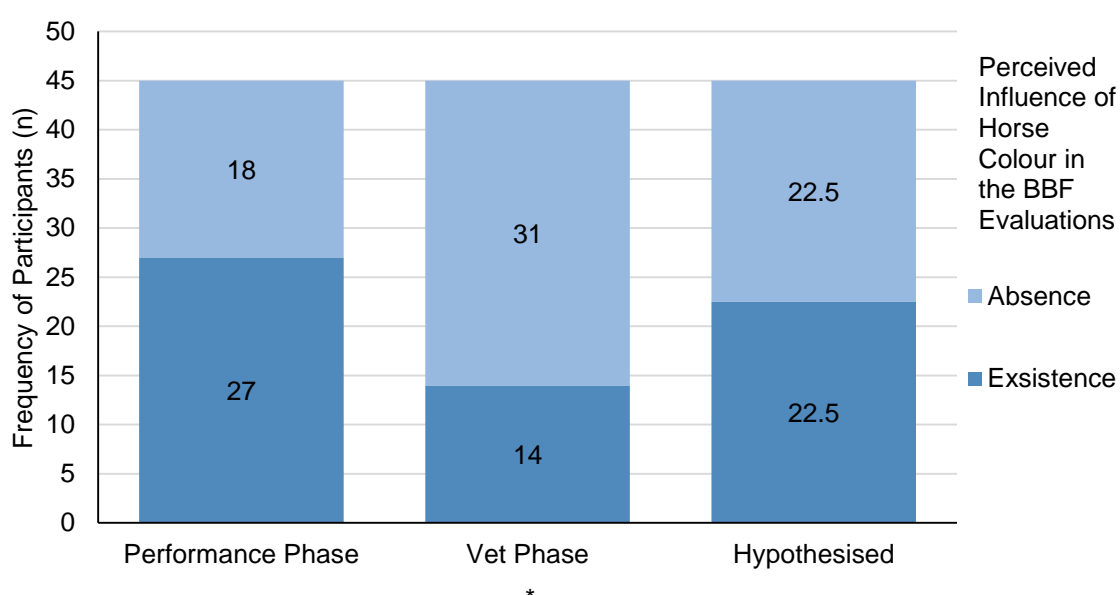


Figure 49 Observed frequency of participants (N=45) perception of existence or absence horse colour bias in the veterinarian and performance evaluation phase of the BBF evaluations, compared to a hypothesised equal probability (N divided by the 2 answers=22.5). *Statistical significant.

Forty-two percent of participants (27 out of 64) thought the performance evaluation phase could be biased according to horse colour, compared to only 22% (14 out of 64) for the veterinarian assessment. Frequency of participants perception of horse colour influence in the veterinarian assessment decreased with severity i.e. Not influential: n=31, slightly influential: n=10, moderately influential: n=3, very influential: n=1. This diverse perception of bias was

significant compared to an equal probability of opinions ($n=45$, $df=3$, $p<0.0001$). Participants perception on the existence or absence of bias in the veterinarian assessment phase, was also significant compared to an expected equal spread of bias perception ($n=45$, $se=3.35$, $p=0.017$). Similarly, the different (degrees of horse colour influence in the performance evaluation phase (i.e. not influential: $n=18$, slightly influential: $n=12$, moderately influential: $n=13$, very influential: $n=2$) was significant compared to an expected equal occurrence ($n=45$, $df=3$, $p=0.007$). However, when comparing participants perception of absence or existence of horse colour bias in the performance evaluation phase, the difference was not statistically significant compared to equal probability ($n=45$, $se=3.35$, $p=0.23$).

4.2.12.3 Free Text Answers

Thirty-one percent ($n=8$) of participants who expressed a free text answer, indicated that they did not believe that judging bias, according to the colour of the horse, within the BBF evaluations existed (as discussed in section 4.3.1.10). However, the remaining 18 participants expressed some form of horse colour bias although not necessarily attributed to BBF evaluations (see Figure 50). Perceived preferences for considered 'solid' horse colours (i.e. bay, black and chestnut) was recurring, and considered "traditional", "in favour of judges", "flashy", "most common" and that "they stand out more". A perceived negative bias against spotted and coloured/block coloured horses was also apparent with comments such as; "not disposed to athletic performance types", "markings are distracting to the judges", "chopped off by the changes of colour", "highlight some

poorer conformational aspects”, and breeders “perceived to have gone for colour not quality or type”.

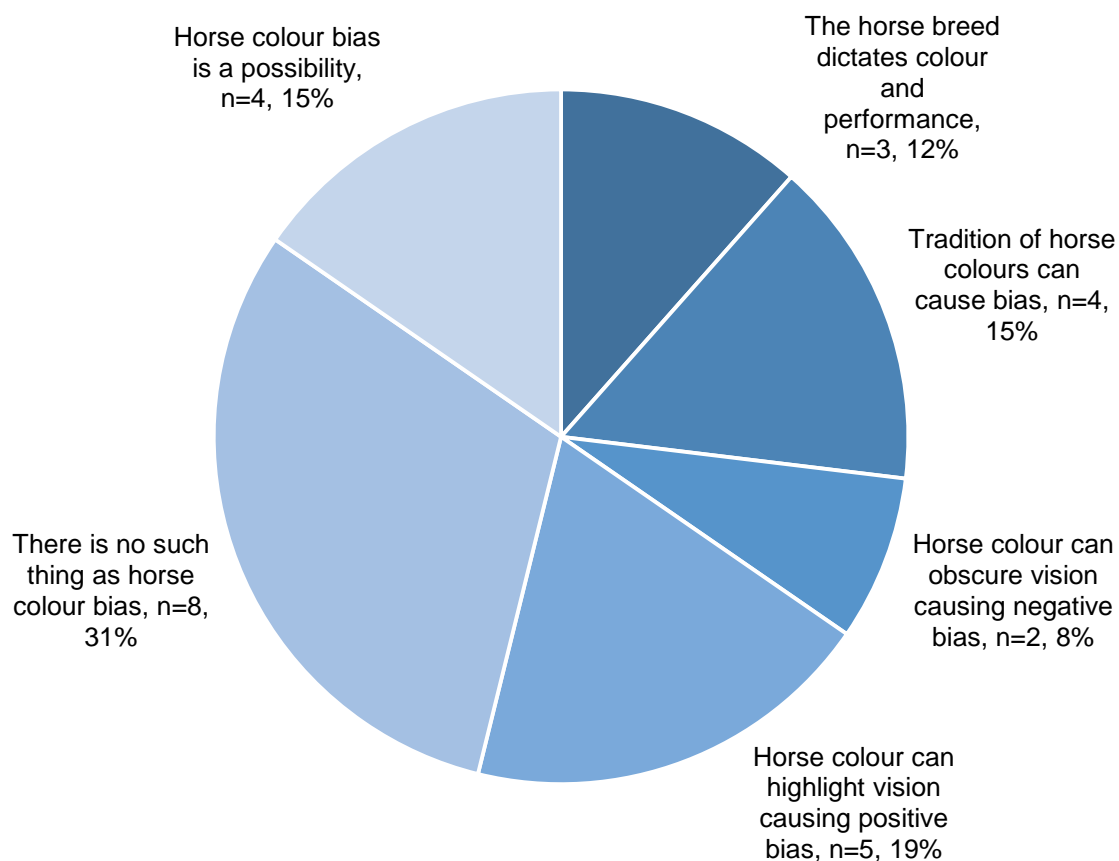


Figure 50 Frequencies of trends in free texts answers (n=26)

4.2.12.4 Conclusion

A minority of the surveyed equestrians indicated that horse colour (in variable degrees) influences the BBF evaluations, showing a ranking of the perceived favourite horse colours from the favourite ‘solids’ to block coloured and spotted as the least favourite. The performance phase of the BBF evaluations, were

perceived to be more likely to be biased according to horse colour compared to the veterinarian evaluation. However, the amount of people who indicated perceived horse colour bias in the performance evaluation phase was not significant compared to participants who did not indicate a bias perception. Furthermore, a significant amount of participants did not indicate perception of horse colour bias in the veterinarian evaluation phase.

Free text attitude statements from participants supports the apparent negative bias of spotted and block coloured horses, and the preference of 'solid' coloured horses both in the BBF evaluations, and in the general equine industry. However, a large proportion of the participants also suggested that they do not believe horse colour influences BBF evaluations. These participants indicated that apparent horse colour preferences may not be a result of bias, but breeding quality, population size and the "deceptive" nature of a spotted or block coloured horse's coat. It can therefore be concluded that only a minority of the surveyed equestrians has an assumption that the BBF is biased by horse coat colour, and the alternative hypothesis can be supported.

4.2.13 BBF Experience versus Horse Colour Bias Perception

4.2.13.1 Participants' Own Bias Experience

Twenty participants had a horse evaluated in the BBF evaluations (as described in section 4.3.1.8). However, only 16% (n=3) of these thought that their horse had been favourably scored because of coat colour, and 5% (n=1) that their horse had been unfavourably scored because of its colour. The perception of

unfavourable bias according to horse colour, compared to an expected equal spread between all three answer options (i.e. no bias experience: n=13, undecided: n=6, bias experience: n=1) was significant (n=20, df=2, p=0.004) (see Figures 51). However, the perception of favourable horse colour bias was not significant (n=20, df=2, p=0.23) compared to an expected equal spread of bias perceptions (i.e. no bias experience: n=7, undecided: n=9, bias experience: n=3).

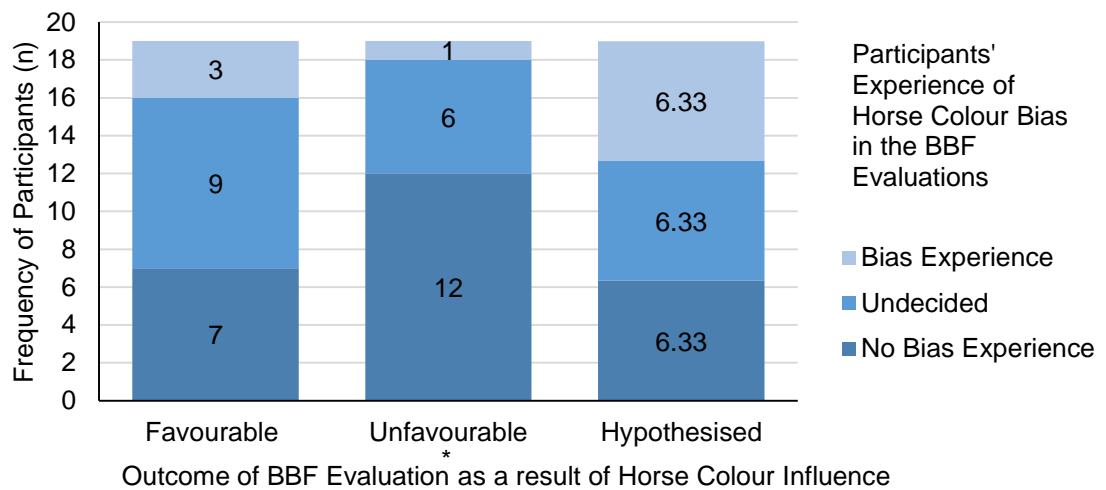


Figure 51 Observed frequency of participants (n=19) own experience of favourable or unfavourable horse colour bias in the BBF, compared to a hypothesised equal occurrence of answers (n divided by the 3 answers=6.33). *Statistical significant different.

4.2.13.2 BBF Experience versus Bias Perception

Thirty-nine percent of participants (25 out of 64) indicated having previous experience with the BBF evaluations (as described in section 4.2.5). Sixty percent of these participants (15 out of 25) were spectators of an event. The BBF participation was a multiple answer question, and although in total all answer

options were selected, the majority of participants only had one type of experience with the evaluations (as described in section 4.2.5). Despite 39 participants indicating not having any experience with the BBF (Q5), perception of bias within the BBF evaluations were indicated by 45 participants (Q6, described in 4.2.6). Among the respondents were two performance evaluation judges and one veterinarian judge of the BBF events. One of the performance judges and the veterinarian indicated that the performance evaluation phase of the BBF could be moderately influenced by horse colour, and the other performance judge indicated horse colour could “slightly” influence performance evaluation. One performance judge also indicated the veterinarian evaluation phase could be moderately influenced by horse colour, whilst the remaining two judges agreed it was not. Generally, participants with previous experience of the BBF evaluations were less likely to perceive colour bias in the performance evaluation and veterinarian phase, compared to participants without BBF experience. However, this difference was not statistically significant ($p>0.05$). Furthermore, participants with experience as spectators of a BBF evaluation were significantly more likely not to perceive the performance evaluation phase bias, according to horse colour, compared to participants without spectator experience ($n=45$, $df=1$, $p=0.044$). Likewise, participants who indicated being breeders ($p=0.016$) and handlers ($p=0.010$) of evaluated horses were significantly less likely to perceive the veterinarian evaluation phase of the BBF bias according to horse colour, compared to survey participants without this experience. No other BBF experience had a significant relationship to perception of bias in the evaluations. There was also no significant difference between the amount of

different BBF experiences, and the participants' perceived horse colour bias of the two different evaluation phases ($p=0.87$ and $p=0.23$).

4.2.13.3 Free Text Answers

No respondents stated any personal experience of horse colour bias in the BBF, in the free text answers (Q10). One participant stated "Have no experience of Futurity evaluations but I assume they are judged in an unbiased manner". In contrast, another participant stated "I have had experience of colours being influential in the show ring".

4.2.13.4 Conclusion

The degree of previous BBF experience had no significance on participants' perception of horse colour bias within the evaluations. Free text answers highlighted one participant with no BBF experience who nevertheless assumed the evaluations unbiased. However, the minority of the respondents who did indicate a perception of horse colour bias within the BBF evaluations were those with no previous experience of Futurity events. However, actual judges of the BBF event did indicate that horse colour bias could influence the evaluations, in both the performance and veterinarian evaluation phase. Nevertheless, the 60% of participants who had spectated at a BBF evaluation were less likely to perceive any horse coat colour bias in the performance evaluation phase. Furthermore, participants who had breed an evaluated horse or who handled a horse during an evaluation, were significantly less likely to perceive horse colour bias in the veterinarian phase.

In conclusion, the alternative hypothesis can be rejected, as handling or breeding a BBF horse or being a spectator at an event makes a participant significant less likely to perceive bias in the BBF.

4.3 Discussion and Conclusion

The majority of respondents expressed a favourite horse colour, which suggests that specific horse coat colours are preferred by equestrians. This might be comparable to human preference of object colours (e.g. (He *et al.*, 2011; Hurlbert and Ling, 2007)). Human preference for object colours has also been found to vary according to sex ((He *et al.*, 2011; Hurlbert and Ling, 2007)). However, gender differences in horse colour preferences were not apparent amongst the surveyed equestrians. This could be due to the small number of male participants indicating a favourite horse colour (n=7), compared to female (n=55), resulting in an under representation of male favourite horse colours. Nevertheless, the distribution of male to female equestrians is in accordance with gender distribution within British equestrianism (British Horse Society, 2015, BETA National Equestrian Survey 2010-2011). Furthermore, the non-existence of sex differences in horse colour preferences is in agreement with a previous study on judging bias in European western riding competitions (Hansen, 2012).

This could suggest that horse colour preferences do not follow the same psychological and physiological rules as object colour bias (e.g. male dominance associated with red). In addition, no horse colour was significantly favoured by surveyed equestrians. However, participants' least favourite horse colours were selected with statistical significance; suggesting that distinct preferences for

horse colours, amongst British equestrians, do exist. Nevertheless, horse colour preferences are most likely a result of other mechanisms than those of object colour preference.

The free text answers from participants gave indications of these possible mechanisms i.e. horse colours are perceived as “un-balanced” and stigmatised for being of lesser quality (‘coloured’) compared to “traditional” and “flashy” colours (black, bay, chestnut). Tradition of horse colour preferences has been apparent through the ages e.g. spotted horses were popular in the Baroque period in Europe but went out of fashion by the Victorian age (Kathman, 2014b). The Thoroughbred studbook was started in Britain at this time, and the preference for ‘solid’ coloured horses was apparent in the breed description (Kathman, 2014b). Later a similar preference for ‘solid’ coloured horses was also apparent in warmblood horses’ studbooks. There has been little recent change in horse colour regulations which could suggest survey participants’ apparent negative bias towards spotted and block coloured horses, is a result of this historic horse colour fashion still being applied. Correspondingly, free text answers stated spotted and “coloured” horses were “not disposed to athletic performance types” and “perceived to have gone for colour not quality or type”. These statements imply that ‘solid’ horse colours are associated with sports horses of e.g. warmblood and Thoroughbred breeding. The perception that spotted and ‘coloured’ horses are of lesser quality might also relate to newer studbooks where horse colour and not performance is the main entry criteria e.g. The British Palomino Society.

Survey participants' perception that BBF judges least prefer spotted and block coloured horses agrees with anecdotal feedback from BBF participants (Dixon, pers. com, Rogers, pers. Com, 2013). However, the majority of survey participants did not think that the BBF evaluations were biased according to horse colour, and expressed this in their free text statements: "Futurity judges are judging on conformation and pedigree and coat colour does not come into the equation", "judges are qualified to judge on basis of recognised criteria and unbiased by colour" and "A good horse is never a bad colour!". Generally, experience with the Futurity did not have a bearing on this bias perception, apart from a significant lack of horse colour bias perception from participants who had spectated the BBF events, or had handled or bred an evaluated horse.

The minority of survey participants who did indicate a bias perception in the Futurity, were more likely to perceive the performance evaluation phase influenced by horse colour. This could be due to this phase's more subjective evaluation process. In the free text answers participants expressed how horse colour can give an "optical illusion", "trick the eye", be "deceptive" and "may highlight some poorer conformational aspects", but also "catch judges eye more making them stand out and more likeable" and "hide conformation faults". Participants' perception of horse colour influence in equine sports performance competition judging also varied between disciplines. A significant amount of survey participants perceived dressage to be more biased according to horse colour. A free text answer stated, "In both pure dressage and in the dressage phase of eventing subjective aesthetic factors come into play so coat colour can have a subliminal effect here". Another participant stated, "all judges could bias either positively or negatively with respect to colour. Whether this is conscious or

subconscious is debatable". Judging bias according to colour in non-equine sports has been suggested to be due to the human brains limitations in memory recall and decision making, and more often than not out of the conscious control (LeMaire and Short, 2007; Cornelissen and Greenlee, 2000). However, only three participants who had entered a horse in the BBF evaluations indicated having an experience of positive bias, and only one of negative bias according to their horses' coat colour.

In conclusion, the majority of survey participants did not believe in horse colour bias, regardless of previous horse experience or specific experience within the BBF, however, significantly disliked spotted and block coloured horses. This is interesting because British equestrians have a history of these horse colours being unfashionable, and bias in general is a subliminal effect. Furthermore, participants indicated a distinct difference of horse colour bias perception between equestrian disciplines, i.e. more influence of horse colour in the subjective equestrian disciplines dressage, the dressage part of eventing and the performance evaluation phase of the BBF, and less in show jumping, endurance riding and the veterinarian evaluation phase of the BBF. This hereby suggests that British equestrians subconsciously bias spotted and block coloured horses negatively, which could be affecting subjective equine performance evaluations. However, this conclusion might not be representative of the wider British equestrian population due to a relatively small sample size of this study (n=65).

5 Discussion and Conclusion (Complete Thesis)

Bias in judging, as a result of uniform colour, has been suggested in a variety of subjectively judged sports (Balmer *et al.*, 2003; Bar-Eli *et al.*, 2006; Findlay and Ste-marie, 2004; Ste-Marie and Lee, 1991), but colour bias has not previously been examined in equine performance evaluations. This study investigated the potential of horse coat colour bias by 1) comparing differences in BBF component and premium scores using ANOVA, 2) analysing the effect of different disciplines (dressage, eventing, show jumping), years (2008-2014) and regions on BBF scores using PRIMER, 3) evaluating BBF horses' breed registration and assessing genetic potential using the WBFSH top 100 stallion lists, and 4) investigating British equestrians perception of horse colour bias by questionnaire and subsequent analysis.

Previous anecdotal feedback from participants of BBF evaluations suggested that a negative bias exists towards 'coloured' horses i.e. horses with excessive white markings (Dixon, pers. com, Rogers, pers. Com, 2013). This is supported in this study by 1) significantly lower mean component and premium scores of block coloured (piebald and skewbald) and spotted (spotted, appaloosa and roan) horses compared to all other horse coat colours, 2) continued relative lower premium scores of block coloured and spotted horses over time, despite an overall trend of increasing premiums with each subsequent year, 3) block coloured horses receiving below average scores even within breed registers with relatively high mean BBF scores, and significantly lower premium scores of block coloured/grey horses compared to bay horses with similar genetic potential, and

4) block coloured and spotted horses were considered the least favourite horse colours by a significant amount of survey participants, who also thought BBF evaluators disfavour those colours.

However, contrary to the anecdotal feedback, from BBF participants, the majority of survey participants did not believe that horse colour bias the BBF evaluations. Which was significant for participants who had spectated an event, bred or handled an evaluated horse. In addition, one 'free text' comment was "Have no experience of Futurity evaluations but I assume they are judged in an unbiased manner". Bias is a result of the human brains limitation in decision-making and memory recall, hence bias is often out of conscious control. Therefore, both participants and evaluators are probably not aware of any bias. Nevertheless, all three BBF evaluators who completed the questionnaire thought that the BBF could be slightly biased by horse colour. The performance phase of the BBF was thought more likely to be biased than the veterinarian phase. However, component scores showed the same significant differences between horse colours for both phases.

The jump score was the only component without significant differences between horse colours. Show jumping scores obtained in young horse evaluations have been connected to longevity (Wallin *et al.*, 2001) therefore it is important that jumping ability is not biased. Survey participants suggested that only dressage, and the dressage part of eventing, have bias suggesting that show jumping is more objectively judged and therefore have no possibility of horse colour bias. Colour bias has been previously suggested in subjectively judged sports e.g. Taekwondo (Hagemann *et al.*, 2008), therefore also suggested for subjectively

equestrian sports. The total number of show jumping scores was relatively small which might have influenced the results. Nevertheless, the show jumping discipline in BBF evaluations showed colour bias that was different to that seen in the dressage and eventing disciplines e.g. show jumping did not negatively bias grey horses. This further suggests the score differences according to horse colour is a result of bias in the subjective judging

Grey horses had significantly lower component and premium scores than other 'solid' coat colours, but were not significantly biased for or against by survey participants. However, one participant commented on the associated health risks of greys e.g. grey horses are more prone to melanomas (Rosengren Pielberg *et al.*, 2008), and white horses in general have through history been associated with lethal factors, due to genetic disorders of some white haired genotypes e.g. Frame Overo (Vrotsos *et al.*, 2001; Sponenberg, 2009) and SW2 (Kathman, 2014b). However, advances in equine coat colour genetics has proved that these lethal genotypes are not associated with greys. The lethal genetic conditions are associated with some block coloured and spotted genotypes. Many breed organisations and studbooks have not modernised with genetic developments in terms of horse coat colour recognition. Consequently, a historic negative bias against white marked horses could explain the lower scores of grey, block coloured and spotted horses in the BBF. However, such bias would also manifest throughout the wider equine community.

Furthermore, analysis showed that the apparent bias, according to horse coat colour, could not be directly compared to bias in object and athletes uniform colour i.e. no sex preference or comparable rank order of colours was found. This

could suggest that bias of horse colour is a result of other mechanisms than those found in non-equine sports e.g. a historic negative bias such as when spotted horses went out of fashion in the Victorian age (Anonymous, 1838). It could also suggest that the significantly lower scores of white marked horses was not a result of bias. One survey participant suggested that white marked horses were “not disposed to athletic performance types”. However, spotted horses from the Knapstrupper breed were amongst the top ten scoring breed registers of the BBF, which suggests that white marked horses can have significant sporting potential. However, no spotted horses were evaluated for dressage (in 2014) and all the dressage horses with WBFSH stallion influence in the immediate bloodline were bay, black or chestnut. This reflects that stallions making the WBFSH lists are solid coloured, and when primarily solid coloured horses are being competed in top equestrian sports this would further result in a positive bias of these colours amongst equestrians, which in turn could manifest in bias in evaluations such as the BBF. Further analysis showed that block coloured and grey horses did not receive mean scores below a premium value, but scores were significantly lower compared to bay horses of the same genetic potential. Therefore, the apparent bias is unlikely to be because of differences in breed quality but perhaps reflects the underrepresentation of white marked horses amongst the top breeding stallions. Black, bay and chestnut are the most common horse coat colours, which is partly due to genetic inheritance. Survey participants described black, bay and chestnut horses as “traditional” and “flashy”, and since the Victorian age, they have been favoured in thoroughbred and warmblood horse breeding. Therefore, it is suggested that these horse colours are still favoured amongst sport horse breeders, which could support any unconscious bias even before

entering the BBF evaluations. Subsequently, the apparent negative bias of white marked horses appear to be deeper rooted in the British equestrian community. The horse colour has possibly been given a bad stigma because of the over breeding of low value “Gypsy” Irish Cobs which commonly are white marked.

Furthermore, the colour white has been suggested to cause bias in sport performances because it increases visual attention, whilst patterns have been found to increase recollection and involuntary attention. Furthermore, zebra stripes compared to a ‘solid’ horse coat have been shown to cause motion camouflage. Therefore, it is likely that in addition to historic bias, white marked horses are more prone to bias than darker and ‘solid’ colours because of the nature of the coat patterns and the higher proportion of white. Survey participants also commented that “markings are distracting to the judges”, conformation is “chopped off by the changes of colour”, and that white marks can “highlight some poorer conformational aspects”.

In conclusion, horse coat colour bias is suggested to influence the BBF evaluations; indicated by significantly lower scores of block coloured, spotted (and in part grey) horses. This is attributed to the prominent nature of the colours and a historic negative bias amongst British equestrians. Horse coat colour and BBF premium scores can both influence the value of a horse. Therefore, breeders are cautioned to consider horse colour inheritance in any breeding decisions e.g. overproduction of block coloured and spotted horses could be contributing to the increased numbers of low value equines, which is currently the largest welfare concern in Great Britain. However, advances in knowledge of equine coat colour genetics has shown that most white mutations are not lethal, although this stigma

may have contributed to a negative historic bias. Moreover, mutations responsible for white markings are already part of the genepool of British sports horses, and more mutations are likely to occur. Therefore, breed organisations are encouraged to modernise their coat colour regulations to include more white marked horses, so in future potentially good sports horses would not be discriminated because of coat colour.

Horse colour cannot be easily obscured to minimise the bias in judging, as e.g. bloodline and owner records can. Since bias is more prominent when judging is subjective the ultimate goal is therefore to make judging more objective, to minimise the occurrence of bias. By making the judging process easier for the judge, the mental 'short cuts' made, such as judging a horse by its colour, would be made redundant. The scoring system in the BBF has at time of writing been altered to a linear system which makes scoring of components more transparent for horse owners, and judges are required to have more practical competition experience (Rogers, 2015). However, to make judging more objective measurable attributes such as back and neck length can be recorded and technology can be used to aid the judges' decisions, e.g. gait analysis software, which is already used in other equine sectors, or life play back of horse movements as used in rugby competitions. The ideal way to eliminate horse colour bias would be to alter horse colour electronically and have evaluations on computerised systems. However, this approach might be too futuristic for the traditional equine community, but can be recommended for future research into equine coat colour bias.

6 Limitations and Future Work

Although the overall dataset for this study was significant in size ($n=4001$), data for particular groups were sometimes still limited e.g. endurance horses, 3 year old show jumping horses and horses with WBFSH stallion influence. This resulted in some limitations in the conclusions. Future work should focus on these groups and look at ways to increase the numbers evaluated in the Futurity.

The sample size of survey participants was also limited ($n=65$) and opinions gained may therefore not represent the wider British equine community. Future work should aim to reach a larger proportion of the equine sector; possibly focussed more on BBF participants.

Future work investigating horse coat colour bias could include a computerised horse evaluation programme where horse coat colours are digitally altered in a way that the same horse can be evaluated having a different coloured coat, or all horses evaluated have the same colour. In that way, 'true' colour bias in judging can be analysed.

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1 Appendix i: Equine Coat Colour Genetics

1.1 Base Coat Colours

Coat colour and white spotting patterns in horses are determined during embryonic development (Hauswirth *et al.*, 2013). Genes at 12 different loci are responsible for most equine coat colours. Besides, from spontaneous mutations, infections or faults in development, equine coat colours are therefore inherited from both parents.

Black pigmentation (eumelanin) and red pigmentation (phaeomelanin) are the basis of all horse colours. The expression between the two are controlled by two genetic loci called extension and agouti (Thiruvankadan *et al.*, 2008).

1.1.1 Extension (E/e, ea)

The extension locus (MC1R) has two alleles ("a pair...of genes occupying alternatively the same locus"(p. 16 Boden, 2007)) i.e. E and e, where E extends the amount of eumelanin and reduces phaeomelanin and the e allele has the opposite effect. Thus, ee is the genotype of chestnut horses and EE and Ee creates black or bay/brown coloured horses (Kathman, 2014b).

E is dominant over e, hence a horse with the genotype EE could never produce a chestnut foal, and two chestnut parents could never produce a black, brown or bay foal. Chestnut coloured horses are however common in most breeds, despite the genotype being homozygous recessive (Thiruvankadan *et al.*, 2008).

1.1.2 Agouti (A, A^t/a)

The agouti locus controls the distribution of eumelanin and phaeomelanin pigments, by restricting black to the points of a horse (i.e. legs, tail and mane)

thereby creating the bay or brown coat colour (see Figure 52). The agouti allele (A) is dominant, consequently the genotype AA or Aa is that of a bay horse, while a black horse has the genotype aa (Thiruvankadan et al., 2008).

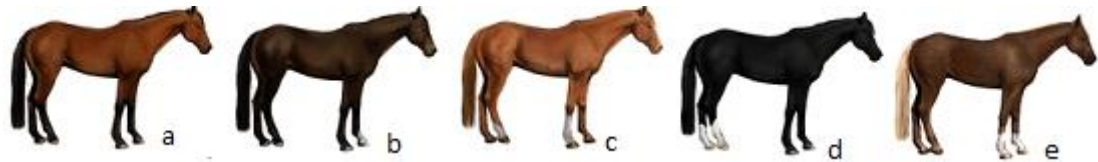


Figure 52 a) Bay E_A_, b) Dark Bay/Brown E_At_, c) Chestnut ee__, d) Black E_aa, e) Dark Chestnut/Liver Chestnut aa__ No other genetic mutation has been identified as the cause of this shade (Slater, 2014).

A dominant black gene, created by a mutation in the extension locus (E to ED), has been suggested by some authors, although other authors have not found a genetic link between agouti and extension loci controlling eumelanin production (Thiruvankadan et al., 2008; Sponenberg, 2009). Recent research has on the contrary found new mutations on the agouti locus. The A^t allele has a “milder” restriction effect of black than A, creating dark brown horses instead of bays. The A⁺ allele, called wild bay, restricts black further than on ordinary bays, leaving very little black on the legs. The wild bay allele has however not been genetically identified yet, hence remains theoretical (Kathman, 2014a).

The dominant (E) extension allele has to be present for the agouti allele to be expressed. As a result, recessive epistasis can occur when a chestnut horse masks the dominant (A), but passes the gene to its offspring. Friesians, Fjord, Percheron, Haflinger and Suffolk Punch breeds have eliminated the agouti (A) allele, whilst the Cleveland Bay exclusively comprises of bay horses (Kathman, 2012).

1.2 Shading

Complex multifactorial genetics are behind variations in shades of the basic equine coat colours (Sponenberg, 2009). Shades are most obvious in bay and chestnut horses, and rarely noticeable in black horses (Thiruvankadan *et al.*, 2008). ‘Sooty’ is an example of pigment seemingly having switched from red to black, creating dark often dappling marking on the cranial part of the horse. The genotype of heavily sooty horses can be difficult to distinguish phenotypically e.g. palominos can be mistaken for buckskins, buckskins for bays and even chestnut horses can look like wild bays, although sootiness in chestnuts is often not expressed as dramatically as in other colours (Kathman, 2014b).

In the Futurity, different shades of the basic coat colours are recognised as follows; bay horses are categorised by the shades; light bay, bay and dark bay, and chestnut horses by; chestnut and dark chestnut. The recent genetic research theorising the three different colours of bay i.e. bay, wild bay and brown, might be the genetic background of some of these shade categories, which are often used by stud books and breed registers (Kathman, 2012). Brown is characterised by a limited restriction of black, in such a way only the muzzle, the area surrounding the eyes and the dorsal side of the body is left light (see Figure 52).

Brown, dark bay and black can therefore be difficult to distinguish between phenotypically, but can now be genetically tested for (A^t) (Kathman, 2012). However, the terms of colour categories are often used inconsistently in stud books, and assumingly in the Futurity where colour is mostly phenotypically characterised by the owner (Kathman, 2012).

The genetic mechanisms behind dark chestnut, often referred to as ‘liver chestnut’ by stud books (see Figure 52), have not been identified (Kathman,

2014b). However, several genetic modifiers creating lighter shades of chestnut have been recognised. These include the dominant Mealy (PA+) which produces the lightest shade of chestnut with pale red or yellowish areas on the muzzle, over the eyes, inside the legs and on the flanks and abdomen (Thiruvenkadan, Kandasamy and Panneerselvam, 2008). Mealy also affects bay, which gives the characteristic colour of the cave painted horses, and have therefore been thought to reflect the colour of early domesticated horses (Kathman, 2014b). The pre-domesticated horse was also thought to be dun coloured, and an association between Mealy and dun might be why there is not a category for “light chestnut” in the Futurity evaluations, as these could be considered dun coloured because of its similar phenotypic look. However, dun is a result of dilution gene not shading.

1.3 Dilutions

Dilution alleles work by clumping together pigment granules, leading to decreased light absorption. This differs from the albino allele which decreases the number of granules, true albinism is in fact not present in equines (Thiruvenkadan, Kandasamy and Panneerselvam, 2008; Kathman, 2014b). Several new mutations responsible for diluted equine coat colours are being discovered e.g. champaign, pearl and mushroom but these are not yet categorised in the BBF (Kathman, 2014a; Cook et al., 2008).

1.3.1 Dun (D)

Dun has been used to describe a variation of genotypes with a similar phenotype. The dominant allele D has been suggested to be responsible for the colour, although the linked locus M is responsible for the primitive markings characterising the colour (i.e. dorsal stripe, shoulder stripe and leg bars). The dun mutation was only very recently identified (Animal Genetics, 2014). Previously nearby markers on the dun chromosome were used to identify homozygous duns with the zygosity test. This test was unreliable for certain breeds, now hypothesised to carry a different mutation to the common dun (Ludwig et al., 2009; Kathman, 2012, 2014b).

Dun acts upon both eumelanin and phaeomelanin (excluding the points), and has a similar effect both homozygous and heterozygous. Red dun horses are chestnut horses with the dun factor, phenotypically pinkish red horses with dark red points (see Figure 53). Bay horses with the dun factor have a yellowy body with black points, suitably called yellow duns (see Figure 53) (Stachurska, 1999).

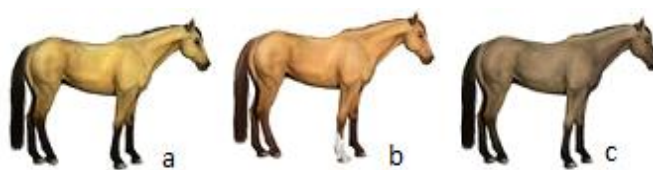


Figure 53 a) Yellow Dun E_A_D_, b) Red Dun ee__D_, c) Mouse/Gruella E_aaD_ (Slater, 2014).

In Britain, buckskins (a cream diluted bay) are often mistaken for duns. This is apparent in stud books where “dun” seem to hide in generations of black horses,

and this is not possible as dun will always be expressed in the phenotype (Kathman, 2014b). Black horses with the dun factors are thus grey with black points, termed grulla in America or mouse coloured in Europe (see Figure 53) (Kathman, 2012).

Dun is commonly found in breeds where cremello dilutions are also present, thus common in Spanish influenced breeds from North and South America (Bowling and Ruvinsky, 2000). Dun is also found in primitive breeds where outcrosses to Arabians and Thoroughbreds were uncommon, e.g. the Shetland Pony, Highland Pony and uniformly in Norwegian Fjords. Dun is very uncommon in European warmbloods and Thoroughbreds (Kathman, 2014b). The BBF has a coat colour category for registered dun horses, there are however no difference in classification of chestnut, bay, brown or black based duns. The cream diluted horses in the BBF, on the other hand, have this categorisation.

1.3.2 Cream (Cr)

The mutation responsible for the cream dilution is present on the MATH-locus, it was however previously assigned to the C-locus associated with red-eyed albinos, and the tradition of using the symbol C has not changed (Kathman, 2012; Locke *et al.*, 2001).

Cream has an effect on phaeomelanin and brown (bay) eumelanin but has little visual effect on black eumelanin. Heterozygous cream produces buckskin (yellow body with black points) on bay horses, or palomino (golden body with whitish mane and tail) on chestnut (see Figure 54) (Locke *et al.*, 2001). A black horse with a cream gene is called smoky black, yet the phenotype would most often be

that of a non-diluted black (Thiruvankadan *et al.*, 2008). The partial expression of the gene is a result of incomplete dominance (Locke *et al.*, 2001). In the occurrence of homozygous cream the base colour is diluted completely to perlino (bay), cremello (chestnut) and smokey cream (black) (see Figure 54). A double diluted cream has pink skin, white coat and blue often slightly greenish eyes (Kathman, 2012; Thiruvankadan *et al.*, 2008).

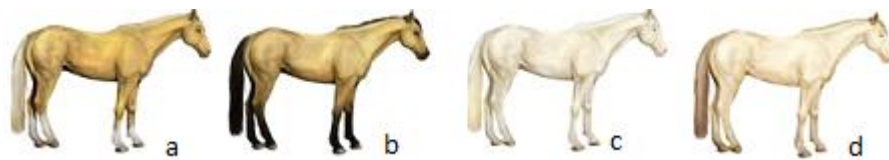


Figure 54 a) Palomino $ee_CrNonCr$, b) Buckskin $E_A_CrNonCr$, c) Cremello ee_CrCr , d) Perlino E_A_CrCr or Smokey Cream E_eeCrCr (Slater, 2014).

The shade of palomino horses varies from very light to “sooty” palomino (Thiruvankadan *et al.*, 2008). Billington and McEwan (2009) suggested the preferred shade to be a golden yellow, most likely created by using a cremello and chestnut parent, moreover the guaranteed way to create palomino coloured offspring.

In Britain, cream dilutions are common amongst the Welsh and Connemara pony breeds (Kathman, 2012). In the BBF evaluations there are separate coat colour categories for palominos and buckskins, but not for perlino, cremello or smokey cream horses. This exclusion of homozygous diluted horses was until recently also present in the British Palomino Society. However, the demise of the Cremello Society forced the Palomino Society to register cremello, perlino and smokey

cream horses (British Palomino Society, 2014). Although there is an obvious phenotypic difference between heterozygous and homozygous creams, when breeding for the heterozygous combination (e.g. palomino) using a homozygous cream (e.g. cremello) with a non-cream horse (i.e. chestnut) is the only way to guarantee the desired colour. Phenotypically white horses, not only cream dilutes, have a history of having associated restrictions against breeding or not being allowed registration in certain breed registers. This has been due to associated skin disorders and lethality (Rieder *et al.*, 2008; Mau *et al.*, 2004). However, no health risks are associated with Cream, and restrictions in registration must therefore be more due to unpopularity of the colour. Multiple dilutions e.g. Dun and Cream are possible because of the different loci of inheritance (Kathman, 2014b). However, these are not recorded in the BBF and without looking through the pedigree of all horses evaluated it is, not possible to identify cremello, perlino, dunskin or dunalino horse colours entered. It must be assumed that if these horses entered the evaluation, they would have been registered as palomino, buckskin, dun or even as a grey horses, as phenotypical identification of colours can be misleading (Mau *et al.*, 2004).

1.3.3 Other Dilutions

Newly discovered dilution are not categorised in the BBF evaluations, but not likely to be represented there either. These include the champagne (CH) gene which is dominant like the other dilutions but dilutes both eumelanin and phaeomelanin, hence the phenotype of heterozygous and homozygous champagne is almost identical (see Figure 55) (Cook *et al.*, 2008). Pearl is

another newly discovered recessive dilution mutation, found on the MATH-locus like cream. However the amount of recognised pearl horses worldwide are not yet large enough to exclude the possibility that still undiscovered colour genes are responsible for the phenotype. Additional dilution genes are currently being discovered, e.g. the mushroom dilution in Shetland ponies (Kathman, 2014b).

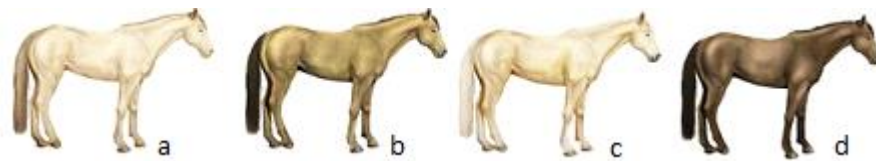


Figure 55 a) Amber Champaign E_A_CH_ b) Classic Champaign E_aaCH_, c) Gold Champaign ee__CH_, d) Sable Champaign E_A^t_CH_ (Slater, 2014).

1.4 White Coat Colour

In recent years, many new mutations creating white markings in horses have been discovered (Kathman, 2014b). Several of the white based colours are mutations on the loci KIT, as this loci is especially sensitive to mutations (Haase *et al.*, 2009). Other coat colour mutations are extremely rare, however, the white spotting mutations on the KIT loci has resulted in 19 (W1-W19) identified white spotted families in the last 100 years. Most of these mutations have been discovered in the last thirty years, and results in a white or white spotted foal born from unpatterned i.e. solid coloured parents (Kathman, 2014b; Hauswirth *et al.* 2013; Haase *et al.*, 2009).

KIT is also the loci for extension and certain proteins (e.g. the blood-typing proteins esterase and albumin) all genes at this loci are collectively passed onto

offspring by the linkage group LG II (Haase *et al.*, 2009; Andersson, 1982). This means that the base colour of the horse is often inherited with the white pattern, although horses are limited to two of the KIT white markings, one inherited from each parent. However, many of the white spotting mutations compromise the function of the KIT gene when inherited homozygous, resulting in non-viable foals (Haase *et al.*, 2007). Nevertheless, the patterns are dominant and will therefore always produce some extent of white spotting when inherited heterozygous (Kathman, 2014b).

The terminology of phenotypic classifications of white based colours amongst horse breed associations have not followed the recent genetic discoveries (Mau *et al.*, 2004). Furthermore, classifications vary greatly between breed associations and countries (Kathman, 2014b; Mau *et al.*, 2004). However, while older mutations creating phenotypically white horses (e.g. cream, grey, sabino1) cannot be differentiated in historical records, these are to some extent categorised separately in breed registration today, and the same might be the case for the new KIT mutations in following years. Because of this inconsistency in current colour categories, the following section will primarily describe the white horse coat colours as genotypes only with reference to the traditional categorisation of the horse world e.g. using the collective term 'pinto/coloured' to mean horses with large white 'block' patterns.

1.4.1 Grey (G)

Grey (G) is a horse colour category in many breed societies and within the BBF. It is a simple dominant epistasis gene (i.e. a 4.6-kb duplication in intron 6 of

syntaxin- 17 (STX17)), therefore both heterozygous and homozygous, grey affects any base colour (Thiruvankadan, Kandasamy and Panneerselvam, 2008). Horses with the gene are born, often darker, as a non-grey horse (e.g. bay) but will progressively turn completely white, starting with the head, commonly leaving the mane and tail to last (see Figure 56) (Kathman, 2014b; Rosengren Pielberg *et al.*, 2008).



Figure 56 a) Grey horse who has progressively turned white b) Dapple Grey an early stage of the gradual greying process. The two horses could have the same genotype e.g. E_aaG_ (Slater, 2014).

The rate of greying is different, but usually the horse is completely white by age 6-8, though some breeds seem to have been bred for a faster or slower greying process e.g. individuals of the Connemara Pony breed grey particularly slowly (Kathman, 2014b; Rosengren Pielberg *et al.*, 2008).

Although grey foals could potentially look quite different to older grey horses, a grey foal from a non-grey can usually be identified by the present of a light ring around the eye (Kathman, 2014b). However, for the purpose of possible phenotypic coat colour discrimination this could cause difficulties, as grey horses, especially young ones, can look completely different from each other, and even similar to roan horses (Hintz and Van Vleck, 1979). Historically fashion for the grey coat colour has changed. The colour was never as popular in England as it was in France, and it became particularly unpopular in the Edwardian era

(Kathman, 2014b). This might be due to grey horses being prone to melanomas, with 5% being malignant (Rosengren Pielberg *et al.*, 2008). Furthermore the risk of developing melanomas seem to be higher in homozygous grey horses (Kathman, 2014b). However, the colour is closely associated with the Arabian, and many British breeds with Arabian influence therefore have the colour e.g. the Welsh Mountain Pony (Kathman, 2014b).

1.4.2 Roan (Rn)

Roan is often used to describe any colour with a mix of white hair in the coat. There are several genes responsible for different variations, some that have been identified, and some that have not. These phenotypes include; frosting, brindling, spontaneous roan, white ticking, rabicano, salpicada, frosty, bleach spots, birdcather spots, flea bitten, lacing, marbling, smears, striping and fungus spots (Kathman, 2014b). Previously roan was thought to be lethal in utero if homozygous (Hintz and Van Vleck, 1979). Owing to the many similar phenotypes, stallions producing uniformly roan offspring were thought to be just lucky or have another roan like mutation (Geurts, 1977). However, today several horses have been tested to be homozygous for the dominant “true” dark head roan, whose chromosome location has been identified (Kathman, 2014b). True roan is in the linkage group with extension and the tobiano marking, and these are therefore inherited together, making roan linked to the base colour of the horse (Kathman, 2014b).

The true roan phenotype is expressed by a 50/50 combination of white and dark hair on the body of the horse, with the head and legs having retain the base

colour. The phenotypes are further classified according to the base colour i.e. blue roan (black), bay roan (bay/brown) and red/strawberry roan (chestnut) (see Figure 57), although red roan is often used incorrectly to describe a bay roan horse (Thiruvankadan *et al.*, 2008; Kathman, 2014b). However, there is only one category for all roan coloured horses in the BBF.

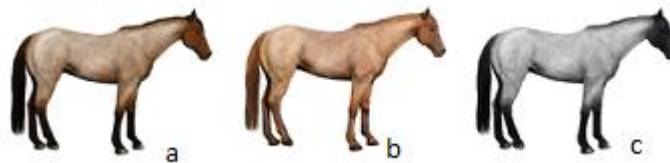


Figure 57 a) Red Roan/Bay Roan E_A_Rn_, b) Red/Strawberry Roan ee__Rn_, c) Blue Roan E_aaRn_ (Slater, 2014).

1.4.3 (Dominant) White (Spotting) (W1-W20)

The white mutations have randomly appeared in the last 100 years and are continuously being discovered (Kathman, 2014b). Some white mutations have been found to create completely white horses, whilst others create highly variable phenotypes (see figure 58) (Haase *et al.*, 2009).



Figure 58 a) A little (heterozygous) white marked/Sabino horse b) White mutations creating a completely white phenotype (Slater, 2014).

Sabino1 was the first white pattern to be identified (Kathman, 2014b). However, the researchers who discovered the additional white mutations were looking for 'dominant white', (i.e. monogenic autosomal dominant trait with the foals phenotype being white with depigmented skin and dark eyes) and therefore named the succeeding white mutations accordingly e.g. White1 (W1), White2 (W2) etc. (Haase *et al.*, 2007). The white identification continued despite the phenotypes of these new white mutations being similar to that of a sabino horse (i.e. Blue eyes, roan, white head and legs with vertically extended ragged edges when heterozygous or completely white when homozygous) (Figure 62 for common white spotting phenotypes) (Haase *et al.*, 2009; Thiruvankadan *et al.*, 2008; Vrotsos *et al.*, 2001). Since only very few individual horses have been tested, it is possible that the mutations responsible for completely white horses can also create spotted phenotypes. Some white mutations have been identified in breeds evaluated at the BBF, or breeds used in breeding of British sport horses. These include; Thoroughbreds (i.e. W2, W3, W6, W7, W12, W14), Arabians (i.e. W3, W15, W19), Holsteins (i.e. W9), Oldenburgs (i.e. W16), Quarter Horses (i.e. W10, W13), and Swiss Warmbloods (i.e. W18) (Kathman, 2014b; Hauswirth *et al.*, 2013; Haase *et al.*, 2009). Furthermore, the older W20 mutation has been identified in numerous breeds (Hauswirth *et al.*, 2013). W20 is responsible for white leg and face markings when heterozygous, and larger amount of white on homozygous horses, or in combination with other white mutations (Hauswirth *et al.*, 2013). However, heterozygous W20 white markings are not traditionally recognised as a spotting or pinto pattern, including in the BBF horse colour records (Hauswirth *et al.*, 2013). There is no testable genetic difference between horses with the W20 mutation but phenotypic differences can

be large, possibly having an effect on the observation (bias) of a horse coat colour. Depending on the degree of colour, the other white mutations could be categorised, in the BBF, as spotted, roan, piebald/skewbald or maybe even grey for phenotypically white horses.

1.4.4 Tobiano (To)

Whilst the white mutations can be hard to distinguish phenotypically, tobiano is arguably the easiest to recognise (Kathman, 2014b). This phenotype is categorised by large round areas of white patches usually crossing the dorsal line of the horse, varying in proportion of white marking on the legs and head (see Figure 59).



Figure 59 Piebald/Black Tobiano $E_{aa}To_{-}$ (Slater, 2014).

The colouring can vary greatly from nearly no white (points of origin being the legs) to almost completely white horses (see Figure 57 for typical tobiano pattern progression), but the typical ideal colouring for breeders is the classic appearance of a 50/50 white and coloured horse (Kathman, 2014b; APHA, 2007; Vrotsos *et al.*, 2001). The tobiano mutation is simple dominantly inherited, and homozygous tobiano horses do not have a consistently larger or smaller amount of white than heterozygous tobianos. It is possible that minimal marked tobianos can be

mistaken for solid coloured horses, however the mutations do not generally hide through generations (Sponenberg, 2009; Kathman, 2014b). Tobiano is one of the oldest and most common of the pinto pattern categories, located on the KIT locus, in the LGII linkage group with roan and agouti (Kathman, 2014a; Haase *et al.*, 2009; Bowling and Ruvinsky, 2000). Tobiano and the base colour is therefore inherited collectively, which might reflect on why the British term for a 'coloured' (i.e. white marked) horse is related to the base colour i.e. piebald for a black and white horse and skewbald for any other colour and white (e.g. bay tobiano). However, the terms piebald and skewbald do not discriminate what kind of pinto pattern creates the white. Nevertheless, tobiano is the most common pinto pattern amongst British breed horses, and consequently most likely to be found in the BBF evaluations.

1.4.5 Leopard Complex (Lp)

The Leopard complex gene, or varnish roan as the phenotypic colour is called, is an incomplete dominant gene (location:TRPM1) (Bellone *et al.*, 2010; Bellone *et al.*, 2008). This gene on its own creates a phenotype that is progressive, like grey, i.e. varnish roan foals are born dark, but lighten with age. Therefore, varnish roan horses (e.g. in Welsh Mountain Ponies) are commonly mistaken for being roan or grey (Kathman, 2014b). However, the Leopard complex gene is unique as it provides the fundament for the different appaloosa spotting patterns (Bellone *et al.*, 2010). Leopard (Pattern1) i.e. heterozygous leopard complex, paired with homozygous Leopard gene (PATN1), is considered the most desired pattern for breeders of spotted horses (Kathman, 2014b). It gives the phenotype of a white

horse with dark spots covering the entire body, and the colour does not 'roan out' (i.e. go lighter) with age (see Figure 60) (Kathman, 2014b).



Figure 60 a) Leopard spotted black horse E_aaLpNonLpPATN1PATN1, b) Blanket spotted bay horse E_A_LPNonLpPATN1NonPATN1 (Slater, 2014)

Heterozygous PATN1 horses have less spots, further suppressed in mares and black based horses (Kathman, 2014b). The phenotype is called suppressed leopard, near-leopard or blanket, according to which other minor genes contribute to the genotype. The blanket pattern (see Figure 60) is most often found in the Appaloosa breed, but can also be found in other spotted breeds like the British Spotted Pony (Bellone *et al.*, 2010). Other variations of the pattern are called snowcap, snowflake and snowball. Within the BBF horses with spotting patterns are simply categorised as 'spotted' or 'appaloosa', although the distinction between the two is not clear. Even though most of the multifunctional genes causing the phenotypes have not yet been identified (see Figure 64 for non-leopard patterns in Appaloosas) (Bellone *et al.*, 2008). Homozygous leopard complex (Lp) and homozygous Pattern1 (PATN1) horses are called 'few spots' as the double leopard complex gene 'erases' the spots created by Pattern1 (see Figure 65 for leopard patterns in Appaloosas). A more serious concern resulting from a homozygous Lp horse is Congenital Stationary Night Blindness (CSNB), were homozygous leopard complex horses have night blindness, and can

therefore be hard to train in low light situations (Bellone et al., 2008). Appaloosa horses are also eight times more likely to develop insidious Equine recurrent uveitis (ERU), which is the leading cause of blindness in horses, and are therefore nearly four times more likely to develop blindness compared to other breeds. The cause is thought to be related to the unknown genes associated with the spotting patterns (Fritz *et al.*, 2014). Breeding Appaloosas and spotted horses therefore have ethical considerations, which is complicated by the means of inheritance of the spotting patterns. Where Pattern1 is dominant and inherited separately, it needs the leopard complex gene to be activated, and solid horses without Lp can therefore hide the gene (Kathman, 2014b).

1.4.6 Other White Markings

American Paint Horses (APH) have the additional white spotting mutation patterns Splashed White (SW1, SW2, SW3, SW4, SW5) and Frame Overo (O) (see Figure 61).



Figure 61 a) Splashed White marked horse b) Heterozygous Frame Overo marked horse c) Homozygous Frame Overo horse (lethal). A) and b) would be considered Skewbald (Slater, 2014).

APH have risen in popularity in Europe and crossbreeding has often led to the spread of these patterns outside the breed. For example, Louella Stud (2014)

imported the first APH to Britain in 1992 to support their sport horse breeding programme (the overo stallion Blue Bayou). Frame overo is dominantly inherited, so will always result in some amount of white marking even when heterozygous (for frame overo pattern progression see Figure 656) (Kathman, 2014b). However, homozygous frame causes Lethal White Overo Syndrome (LWOS), where the white foals die a few days after birth as a result of an undeveloped colon (Vrotsos *et al.*, 2001; Sponenberg, 2009). Only white horses which are homozygous for frame overo will have LWOS. However, white spotting patterns (with no documented heterozygous occurrences to date (e.g. SW2) are thought to have a similar lethality, but in early gestation (Kathman, 2014b). The splashed white pattern SW1 has been identified in the oldest strain of Welsh Mountain ponies, and is therefore also present in the British horse population (see Figure 67 for homozygous SW1 phenotypes) (Kathman, 2014b). SW1 is not lethal, but associated with deafness (Kathman, 2014b; Hauswirth *et al.*, 2012). Therefore, breeding of some types of white marked horses can have ethical considerations, but it is difficult to distinguish based on phenotype alone (APHA, 2007; Vrotsos *et al.*, 2001). Frame overo or splashed white horses would be categorised as a skewbald or piebald in BBF evaluations, depending on the base coat colour. However, if only minimally marked, splashed or frame, horses could also be considered solid (Kathman, 2014b). Additionally, a new splash mutation has been found in combination with the leopard complex in some appaloosa horses (SW5), so even spotted and pinto patterns can sometimes be hard to distinguish (Hauswirth *et al.*, 2013).

Figure has been removed due to Copyright restrictions.

Figure 62 Common white spotting phenotypes (Kathman, 2014b)

Figure has been removed due to Copyright restrictions.

Figure 63 Typical Tobiano patterns in progression (Kathman, 2014b)

Figure has been removed due to Copyright restrictions.

Figure 64 Non-Leopard patterning in Appaloosas (Kathman, 2014b)

Figure has been removed due to Copyright restrictions.

Figure 65 Leopard patterning in Appaloosas (Kathman, 2014b)

Figure has been removed due to Copyright restrictions.

Figure 66 Frame Overo pattern progression (Kathman, 2014b)

Figure has been removed due to Copyright restrictions.

Figure 67 Homozygous classic Splashed White patterns (Kathman, 2014b)

2 Appendix ii: BBF Score Sheets

a) BBF Dressage Score Sheet (British Equestrian Federation, 2013b)



Futurity DRESSAGE Score and Feedback Sheet 2013

Name _____ Number _____

Criteria	1	2	Av	
Veterinary mark (V) 10 (increments on scale of .25) For limbs, hooves and musculoskeletal frame. The vet's mark will be an average (Av) of the score they attribute today and the score they believe the horse would obtain when competing at maturity provided any veterinary advice is followed (1 & 2). Vet score explanation: Below 4 Some serious compromising features, 4 - 6 Some compromising features which will require management 7 Mainly good features, minor management may be required 8 Good features 9 Very good features, 10 Excellent features	Comments:			
Frame (F) and build for DRESSAGE 10 Should have a rectangular build with horizontal back and proportional leg length. Supple poll and head/neck connection with clean throat latch. Longer, well set, arched neck, with muscling to top line rather than underneath. Appropriately but not over-muscled back and loin with well defined wither, sloping shoulder and excellent saddle position. The horse as a whole should give a proportional, balanced, harmonious impression with limbs well positioned underneath. Some warmblood horses which are very well developed at three may be heavy at maturity.	1	2	3	Av
Correctness of paces Walk for DRESSAGE (CPW) 10 Should show an active 4 time marching straight gait with no tendency to become lateral, should have rhythm, considerable impulsion and purpose. Suppleness through the back and body, a swinging stride, freedom and reach in the shoulder, movement through all joints - elbow, hip and stifle with considerable but not excessive over track (it is possible for a walk to be "too big"). Allowances are made for a foal under 21 weeks	Comments:			
Correctness of paces Trot for DRESSAGE (CPT) 10 Should show a 2-time gait which is active, straight, elastic, rhythmical and has impulsion and purpose. Should be supple through the body with balance and self carriage on the straight and on the turns. There should be considerable lightness of footfall and a rounder action in preference to straight. Engagement of the hindquarter should give a noticeable uphill direction.	Comments:			
Correctness of paces Canter for DRESSAGE (CPC) 10 Shows a 3-time gait which is active, straight, rhythmical, balanced and has impulsion and purpose. Shows suppleness through the back and body with well placed limbs and engagement of the hindquarter demonstrating an uphill direction, balance and self carriage on the straight and on the turns/direction changes/transitions. Should be able to lengthen and shorten its stride without loss of rhythm or balance. There should be a considerable lightness of footfall.	Comments:			
Athleticism (A) for DRESSAGE 20 Should show good joint flexion in shoulder, knee and hock. Should have a good muscular and coordinated connection through the body enabling the thrust of the hindquarter to result in a lift in front and effective balance and carriage on the turns, direction changes and transitions. Desire to move forward and upward in all paces without excessive encouragement. Suppleness through the topline, without inversion or tension impairing suppleness.	Comments:			
PREMIUM = Av of V + F + CPW + CPT + CPC + A divided by 7 Scores out of ten using increments of .25 and the following range of scores: Below 4 Serious compromising features, 4 - 6 Some compromising features, 7+ Average/acceptable features, 8+ Good features, 9+ Very good features, 10 Excellent features				

b) BBF Show Jumping Score Sheet (British Equestrian Federation, 2013e)




Futurity SHOWJUMPING Score and Feedback Sheet 2013

Name _____ Number _____

Criteria	1	2	Av	
Veterinary mark (V) 10 (increments on scale of .25) For limbs, hooves and musculoskeletal frame. The vet's mark will be an average (Av) of the score they attribute today and the score they believe the horse would obtain when competing at maturity provided any veterinary advice is followed (1 & 2). Vet score explanation: Below 4 Some serious compromising features, 4 - 6 Some compromising features which will require management 7 Mainly good features, minor management may be required 8 Good features 9 Very good features, 10 Excellent features	Comments:			
Frame (F) and build for SHOWJUMPING 10 Should have a rectangular build with horizontal back and proportional leg length. Good poll and head/neck connection with clean throat latch. Longer neck length ideal, arched, neither set too high nor too low, with muscling to top line rather than underneath. Appropriately but not over-muscled back and loin with good wither, shoulder and saddle position. Should give a proportional, balanced impression with well positioned limbs.	1	2	3	Av
Correctness of paces Walk for SHOWJUMPING (CPW) 10 Should show an active marching straight walk with impulsion and purpose. Suppleness through the back and body, a swinging stride, freedom in the shoulder, elbow, hip and stifle and some over track but need not have excessive reach. Allowances are made for a foal under 21 weeks	Comments:			
Correctness of paces Trot for SHOWJUMPING (CPT) 10 Should show a 2-time gait which is active, straight, rhythmical and has impulsion and purpose. Should be supple through the body with balance on the straight and on the turns. There should be some lightness of footfall.	Comments:			
Correctness of paces Canter for SHOWJUMPING (CPC) 10 Of all paces this is of the greatest importance for a showjumper. Shows a 3-time gait which is active, rhythmical, balanced and has impulsion and purpose. Shows suppleness through the back and body and balance and self carriage on the straight and on the turns/direction changes/transitions. Should be able to lengthen and shorten its stride without loss of rhythm or balance. There should be a lightness of footfall and the body should remain horizontal or have a slight rise/lift in front. A good jumper will have a good canter.	Comments:			
Athleticism (A) for SHOWJUMPING 20 Should show good joint flexion and effective use of the body to balance and carry the horse through turns and direction changes. Desire to move forward in all paces without excessive encouragement. Suppleness through the topline, without inversion and excessive tension.	Comments:			
Jump (J) for three year olds only (10) Able to collect in the final canter stride before the jump but can also take off on a long stride when required. Places hind legs well underneath the body in preparation for take off which should have thrust. Jumps with an uplift in the wither. Quickness of reflex to draw the forearm horizontally and fold the cannon bone back under the forearm. Tucks the hindlegs and draws them up and away from the fence in the latter part of the bascule. Lands lightly and canters away easily and freely. Is careful, efficient and has real scope. If the horse makes a mistake when jumping, tackles a fence differently next time showing an ability to quickly assimilate information and self corrects if the stride is wrong. Goes forward boldly and willingly down the jumping lane, if tightness in the back or tension exist, it dissipates, horse focuses on the fences and uses energy efficiently and with purpose.	Comments:			
PREMIUM = Av of V + F + CPW + CPT + CPC + A (+J) divided by 7 (or 8) Scores out of ten using increments of .25 and the following range of scores: Below 4 Serious compromising features, 4 - 6 Some compromising features, 7+ Average/acceptable features, 8+ Good features, 9+ Very good features, 10 Excellent features				

c) BBF Eventing Score Sheet (British Equestrian Federation, 2013d)

		Futurity EVENTING Score and Feedback Sheet 2013			
		Name _____		Number _____	

Criteria	1	2	3	Av
Veterinary mark (V) 10 (increments on scale of .25) For limbs, hooves and musculoskeletal frame. The vet's mark will be an average (Av) of the score they attribute today and the score they believe the horse would obtain when competing at maturity provided any veterinary advice is followed (1 & 2). Vet score explanation: Below 4 Some serious compromising features, 4 - 6 Some compromising features which will require management 7 Mainly good features, minor management may be required 8 Good features 9 Very good features, 10 Excellent features	Comments:			
Frame (F) and build for EVENTING 10 Should have a rectangular build with horizontal back and proportional leg length. Supple poll and head/neck connection with clean throat latch. Good neck length, arched, neither set too high nor too low, with muscling to top line rather than underneath. Appropriately muscled back and loin with good wither, shoulder and saddle position. Should give a proportional, balanced impression, standing over sufficient ground with well positioned limbs.	1	2	3	Av
Correctness of paces Walk for EVENTING (CPW) 10 Should show a 4-time gait which is active, straight, rhythmical and has impulsion and purpose. Should show suppleness through the back and body, a swinging stride, freedom in the shoulder, elbow, hip and stifle and a noticeable over track. Allowances are made for a foal under 21 weeks	Comments:			
Correctness of paces Trot for EVENTING (CPT) 10 Should show a 2-time gait which is active, straight, rhythmical and has impulsion and purpose. Should be supple through the body with balance and self carriage on the straight and on the turns. A "rounder" action is preferred to a straight one and there should be a noticeable lightness of footfall.	Comments:			
Correctness of paces Canter and Gallop for Eventing (CPC) 10 Canter: Horse shows a 3-time gait which is active, straight, rhythmical and has impulsion and purpose. Shows suppleness through the back and body and balance and self carriage on the straight and on the turns/direction changes/transitions. Should be able to lengthen and shorten its stride without loss of rhythm or balance. There should be a lightness of footfall and the body should remain horizontal or have a slight rise/lift in front. A good jumper will have a good canter. Gallop: This should be free, light, forward-going and ground covering. Should be a noticeable difference in pace between the canter and the gallop and balanced upward and downward transitions, the body should be lowered when travelling at speed but footfall should not be excessively heavy.	Comments:			
Athleticism (A) for EVENTING 20 Should show good joint flexion and effective use of the body to balance and carry the horse through turns and direction changes. Desire to move forward in all paces without excessive encouragement. Suppleness through the topline, without inversion and excessive tension.	Comments:			
Jump (J) for three year olds only (10) Able to collect in the final canter stride before the jump but can also take off on a long stride when required. Places hind legs well underneath the body in preparation for take off which should have thrust. Jumps with an uplift in the wither but may show a flatter bascule than a showjumper. Quickness of reflex to draw the forearm horizontally and fold the cannon bone back under the forearm. Tucks the hindlegs and draws them up and away from the fence in the latter part of the bascule. Lands lightly and canters away easily and freely. Is careful, efficient and has real scope. If the horse makes a mistake when jumping, tackles a fence differently next time showing an ability to quickly assimilate information and self corrects if the stride is wrong. Goes forward boldly and willingly down the jumping lane, if tightness in the back or tension exist, it dissipates, horse focuses on the fences and uses energy efficiently and with purpose.	Comments:			
PREMIUM = Av of V + F + CPW + CPT + CPC + A (+J) divided by 7 (or 8) Scores out of ten using increments of .25 and the following range of scores: Below 4 Serious compromising features, 4 - 6 Some compromising features, 7+ Average/acceptable features, 8+ Good features, 9+ Very good features, 10 Excellent features				

d) BBF Endurance Score Sheet (British Equestrian Federation, 2013c)



Futurity ENDURANCE Score and Feedback Sheet 2013

Name _____ Number _____

Criteria	1	2	Av		
Veterinary mark (V) 10 (increments on scale of .25) For limbs, hooves and musculoskeletal frame. The vet's mark will be an average (Av) of the score they attribute today and the score they believe the horse would obtain when competing at maturity provided any veterinary advice is followed (1 & 2). Vet score explanation: Below 4 Some serious compromising features, 4 - 6 Some compromising features which will require management 7 Mainly good features, minor management may be required 8 Good features 9 Very good features, 10 Excellent features	Comments:				
Frame (F) and build for ENDURANCE 10 Should have limbs and frame in proportion. Good poll and head/neck connection with clean throat latch. Well set neck. Balanced or uphill in skeletal structure. Appropriately but not over-muscled back and loin. Defined wither and saddle position. Powerful hindquarters, well formed forearm and second thigh, sloping shoulder, horizontal back. Neither base narrow nor base wide. Should give a proportional, balanced, harmonious impression with limbs well positioned underneath. Neither elbows nor stifles to hug the body.	Comments:	1	2	3	Av
Correctness of paces Walk for ENDURANCE (CPW) 10 Should show an active, marching, straight and supple gait. Should have rhythm, considerable impulsion and purpose. Limb travel should be straight. Suppleness through the back and body, a swinging stride, freedom and reach in the shoulder, movement through all joints - elbow, hip and stifle with over track. Allowances are made for a foal under 21 weeks	Comments:				
Correctness of paces Trot for ENDURANCE (CPT) 10 Should show a gait which is active, straight, light footed, ground covering and energy efficient. It should have enough balance to be maintained over distance, engaging the hindquarter sufficiently. Any efficient gait permissible including jog and pace. A straighter leg action is preferable to high knee action. The trot should appear easy, fluid and rhythmical.	Comments:				
Correctness of paces Canter for ENDURANCE (CPC) 10 Shows a 3-time gait which rises, not falls, in front, is active, straight, rhythmical, balanced and light footed. It should be ground covering and show impulsion and enough purpose to be maintained over distance. Should be able to maintain rhythm during transitions and changes of direction. Body should remain horizontal.	Comments:				
Athleticism (A) for ENDURANCE 20 An overall ability to maintain economical paces over distance without undue effort. Light footed paces and a slight lift in front is favoured to minimise the impact to the forelimbs means that the thrust from the hindquarter should be evident. Should show good shoulder flexion and have a good muscular and coordinated connection through the body. Suppleness through the topline, without inversion or tension which consumes unnecessary energy.	Comments:				
PREMIUM = Av of V + F + CPW + CPT + CPC + A divided by 7 Scores out of ten using increments of .25 and the following range of scores: Below 4 Serious compromising features, 4 - 6 Some compromising features, 7+ Average/acceptable features, 8+ Good features, 9+ Very good features, 10 Excellent features					

3 Appendix iii: Attitudinal Free Text Answers

Why do you think horse coat colour does/does not influence Futurity judging?

I would like to think that judges are qualified to judge on basis of recognised criteria and unbiased by colour

7/8/2014 9:37 PM

I'm not sure if it does or if the well bred horses have those colours through their genes. I have had experience of colours being influential in the show ring.

5/8/2014 8:44 PM

Especially with foals the colour can alter the image presented although not their conformation but some colours make a horse stand out more ie chestnut

5/8/2014 10:09 AM

The Horsecworld in general tend to be traditional in their preferences; although in mitigation I think that a beautifully put together horse with fab' movement would still score highly regardless of colour. BUT, if two very similar animals were difficult to decide on the traditional bay horse would probably come out on top!

4/8/2014 2:18 PM

Why should it - a good horse cannot be a bad colour.

3/8/2014 12:47 PM

Have no experience of Futurity evaluations but I assume they are judged in an unbiased manner considering conformation, movement etc as colour has no relevance to a horses performance or potential. Any other competitive discipline should not really take colour into consideration, however you do not tend to see spotted or coloureds in general showing classes and not so many spotted in performance classes/SJ/BD/BE probably because the origins of the breed are not disposed to athletic performance types. But as the breed develops and is refined I expect we will see more of them performing well as has happened with coloured horses

2/8/2014 6:51 PM

If they like the horse then they are more likely to score higher

2/8/2014 2:40 PM

I believe that there is a possibility that all judges could bias either positively or negatively with respect to colour. Whether this is conscious or subconscious is debatable.

2/8/2014 2:37 PM

I believe Futurity judges are judging on conformation and pedigree and coat colour does not come into the equation

1/8/2014 11:12 PM

In sj the only factor is whether they can clear the fence or not and in endurance it is whether they can go fast enough for long enough. In both pure dressage and in the dressage phase of eventing subjective aesthetic factors come into play so coat colour can have a subliminal effect here

1/8/2014 10:29 PM

Na

1/8/2014 10:22 PM

Colour has no bearing on performance

1/8/2014 8:39 PM

a good horse is a good horse regardless to colour

1/8/2014 8:18 PM

If a judge is dressage trained I don't think they are as biased against any color in the USA but others might disagree with me vehemently. The Hunter/Jumper Judges I do believe are color biased in the US. The only part where I think color comes into play is in un-balanced chrome in facial markings and un-balanced white on the legs; it gives an optical illusion for the viewer/judge especially in dressage.

1/8/2014 4:34 PM

A good horse is never a bad colour!

1/8/2014 4:07 PM

I think you find that Bays, Chestnuts, Blacks and Greys tend to be the most common, but coloured horses are becoming more so too these days. You see less palomino, buck, roan etc colourings. Think it's just due to what's being shown to evaluate each as presented.

1/8/2014 3:48 PM

Traditionally through the bloodlines the majority of top quality performance equines as warmbloods or thoroughbreds were solid colours. Bay, black and chestnut seem more predominant for horses bred for their bloodlines, particularly in dressage, the variations in colour suggest more crosses with other breeds to possibly make them more rideable temperaments for amateur riders so perhaps don't score as highly as purebred, flashy but less rideable warmbloods or thoroughbreds.

1/8/2014 3:28 PM

Colour can be unfortunate at times (particularly for piebald/skewbald horses) as the changes in coat colour from dark to light in different patches can be deceptive. The colour may highlight some poorer conformational aspects, or may trick the

eye into seeing something which isn't actually there because of the pattern i.e. A coloured horse with a black patch across it's back may give the illusion of a long back, when in actual fact the back is of normal length, it is just the contours and shape of the horse are 'chopped up' by the changes of colour. There is also a slight stigma over coloured horses, in my experience, as those seen to 'breed for colour' may not have the conformational attributes of something none coloured, as they are perceived to have gone for colour not quality or type, which isn't always the case.

1/8/2014 3:00 PM

The colour is of no significance to the bef

1/8/2014 2:37 PM

Because in some cases at the moment the area of bias appears to be more about who bred or owns the horse as opposed to a true evaluation of it's potential performance in the sport long term or indeed colour

1/8/2014 2:32 PM

Judges perception might be affected by colouring of top horses.

1/8/2014 12:52 PM

I think some coat colours catch judges eye more making them stand out and more likeable

1/8/2014 12:48 PM

May only come into influence if the colourings / markings are distracting to the judges eye and at this level of evaluations they should not be e.g., one white sock, coloured horses with uneven markings.

31/7/2014 5:15 PM View respondent's answers

*should be 'does/does not' Is this horse racism?

30/7/2014 11:16 PM

I believe certain colours show off body structure better than others and therefore hide conformation faults.

30/7/2014 10:55 AM

Different colours/ markings can provide more aesthetically pleasing appearance in terms of: white socks may visually influence the appearance of stride length... Some certain block colours will arguably be in favour of judges at certain showing events and also some conformation traits will be more easily seen with block colours as opposed to coloured/ spotting (muscling etc)

4/6/2014 1:21 PM

Colour should only be taken into account when it is specific to breed type. Eg. you would not want a colored Dartmoor pony as the Dartmoor breed should only be solid, bay/black and sometimes chestnut. Other than that if it is being entered in for a sports type futurity, then colour should not matter.

4/6/2014 12:53 PM

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5 Copies of Publications

5.1 Proceedings of the fourth Centre for Agricultural and Rural Sustainability Symposium, 2014, p160

Fisker Hansen, A., Whitaker, T. and Dixon, J.

Does Horse Colour Influence Performance Evaluations?

The British Equestrian Federation (BEF) under the auspices of British Breeding evaluates over 800 young horses annually under the Futurity scheme. The Futurity evaluates individual horses' potential to succeed on a discipline basis (Dressage, Show Jumping, Eventing and Endurance). Anecdotal feedback from exhibitors has suggested that Evaluators may have a bias with respect to the coat colour of the horse. The premium scores awarded at the Futurity events can influence the future of the performance horses. Thus, any potential bias could have financial implications for the 'worth' of a horse and therefore financially affect the British equine sector. The research aim is to analyse Futurity data from the past 7 years (n>3500) to investigate whether equine coat colour bias exists within the Futurity evaluations.

Bias influenced by team uniform colour, has been suggested in subjective judging of sporting disciplines, thus suggesting an observational colour bias from the Futurity evaluations. Research into memory and cognitive colour perception further support the possibility of colour bias e.g. colours aid memory of separate events, further enhanced by patterns of colour.

Preliminary analysis of Futurity premium scores from 2012 (n=750) suggest a negative bias, shown by lower scores of piebald, skewbald and roan coloured horses (bottom 20% of average scores). Further statistical analysis of the wider dataset will determine if these results are statistically significant. In addition, a questionnaire is under development, which will further investigate the general attitude of British equestrians towards coat colour bias in horse performance evaluations.

5.2 Proceedings of the Postgraduate Society Conference Series, 2014, p11

Fisker Hansen, Randle, H., and Dixon, J (2014).

Are British Equestrians Influenced by Horse Coat Colour when Judging Performance?

Anecdotal feedback from exhibitors of the British Breeding Futurity (BBF) has suggested that judges exhibit bias with respect to the coat colour of horses. The BBF is part of The British Equestrian Federation (BEF) and evaluates >700 young horses per year for their potential in sport. The premium scores awarded at the BBF, can influence the 'worth' of a horse, thus any bias in scoring could have financial implications for the British equine sector.

This research project aims to (1) evaluate the perception of British equestrians towards coat colour bias in horse performance judging, and (2) investigate whether equine coat colour bias exists within the Futurity evaluations.

Preliminary analysis of premium scores from the 2012 Futurity evaluations (n=750), suggest a negative bias according to the colour of the horse, shown by significantly lower scores of horses with white block markings and spots i.e. Piebald, Skewbald and spotted coloured horses. This apparent bias is also mirrored in survey data of British equestrians (n=65) which provides further evidence that we all have some equine coat colour bias.

This coat colour bias is attributed to the human brains' limitations in memory recall and decision-making. Previous research on the uniform colour of sport teams has also suggested that colour is a non-conscious method of shortening the decision processes. Thus, horse colour fashion may be of significant influence to the subjective evaluation of sports horses.

Further statistical analysis of BBF data from 2007-2014 will investigate equine coat colour bias in futurity evaluations in more detail.

5.3 Proceedings of the Centre for Agricultural and Rural Sustainability Symposium, 2014, p9

Fisker Hansen, Randle, H., and Dixon, J (2014).

Preliminary Study of Equine Coat Colour Bias and British Equestrians Perception of this in Evaluations of Potential Sports Horses

Participant feedback from young horse evaluations in the UK (BEF Futurity) has suggested a judging bias according to the coat colour of the horse. The Futurity evaluates >700 young horses per year for their potential in sport, awarding each horse a premium score from 1-10. The scores can influence the 'worth' of a horse, thus any bias in scoring could have financial implications for the British equine sector.

This research project aims to (1) evaluate the perception of British equestrians towards coat colour bias and (2) investigate whether equine coat colour bias exists within the Futurity evaluations.

Preliminary analysis of premium scores from the 2012 Futurity evaluations (n=750), suggest a negative bias according to the colour of the horse, shown by significantly lower scores of horses with white block markings and spots i.e. Piebald, Skewbald and spotted coloured horses. This apparent bias is mirrored in survey data of British equestrians (n=65), showing a positive correlation between premium scores and favourite horse coat colours of the surveyed (R=0.63), and a negative correlation between premium scores and least favourite horse coat colours (R=-0.8).

Bias is evidenced in subjectively judged sporting events, and is a result of the human brains' limitations in memory recall and decisions making. This apparent horse coat colour bias is thus suggested to influence potential performance horse evaluations, possible due to a current 'fashion' in horse colours amongst British Equestrians.

Further statistical analysis of data from the 2007-2014 BEF Futurity will investigate equine coat colour bias in more detail.

5.4 Proceedings of the British Society of Animal Science annual conference, 2014, p42

Fisker Hansen, Randle, H., and Dixon, J

Is there a 'colour fashion' in British bred sports horses? An investigation into British equestrians preference for horse colours and perception of equine coat colour bias

Implications Survey results suggest a perceived bias in the British Equestrian Federation (BEF) Futurity according to the colour of the horses. Blocked Coloured and Spotted were the least favourite horse coat colours of the British equestrians.

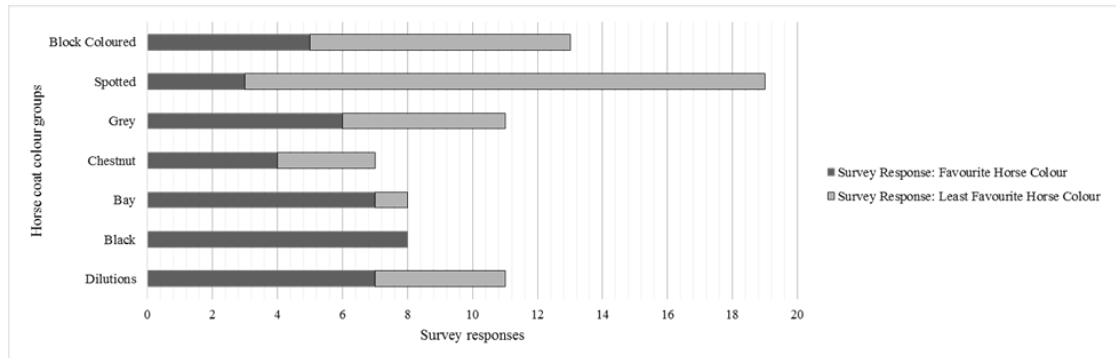
Introduction Changes in 'fashion preference' of equine coat colours is evident through history, through domestication of the horse and particular with the introduction of modern day studbooks, described by Linderholm and Larson (2013) and Cieslak *et al.* (2007). Anecdotal feedback from participants of the BEF Futurity has suggested a judging bias in the young horse evaluations according to the colour of the horse. The aim of this study was to investigate whether a current preference in horse coat colours exists amongst British equestrians, and furthermore, to investigate British equestrians' perception of equine coat colour bias in sport horse performance evaluations.

Material and methods A 10 question online survey was designed, piloted and distributed through social media (June-September 2014) targeted at British equestrians. Participants (n=65) had a varied background within the equine sector. Questions were a combination of randomised multiple choice with free text options, agreement range questions, and free text opinion. The survey was designed to obtain participants own opinion with minimal suggestion bias. Chi-square tests on survey responses were used to analyse the significance of answers to questions about favourite (n=40) and least favourite (n=37) horse colours. Responses were compared with an expected equal spread of preference responses amongst the 7 horse coat colour groups: Bay, Chestnut, Black, Grey/White, Block Coloured (piebald and skewbald), Spotted (spotted and roan) and Dilutions (palomino, dun, buckskin). Horse coat colours were grouped according to similar phenotypes, and in accordance with horse colour categories of the BEF Futurity data.

Results Although the majority of survey participants indicated a favourite horse colour (n=40/65), an overall preferred coat colour within the sample was not evident (p=0.68). The majority of survey participants also indicated having a least favourite horse colour (n=37/65), with Block Coloured and Spotted being chosen as the least favourite by a significant number of respondents (p<0.001). Favourite and least favourite horse coat colours of survey participants can be seen in Figure 1. The majority of survey participants did not think equine sports performance judging was biased according to the colour of the horse, although 45/65 did think dressage could be more susceptible. Most participants (27/45) thought the performance evaluation process of the BEF Futurity could be biased

according to the colour of the horse, whereas only 14/45 thought the same about the veterinary component.

Figure 1 Frequency of the surveyed British equestrians' favourite and least favourite horse colours



Conclusion The majority of survey participants did not think that equine sport performance judging is biased according to the colour of the horse. However, they did think that performance evaluation process of the BEF Futurity is, suggesting a cause for investigation. The significantly lower preference of Spotted and Block Coloured horses, compared to no significance of favoured horse colours, suggest the possibility of a negative bias amongst British Equestrians for these horse coat colours. Further detailed analysis of horse coat colour bias within the BEF Futurity data of the years 2008-2013 will investigate this further.

Acknowledgements The author would like to thank the ESF-CUC for the research programme bursary.

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5.5 Proceedings of the British Society of Animal Science annual conference, 2015, p281

Fisker Hansen, Randle, H., and Dixon, J

Preliminary investigation into equine coat colour bias within the British Breeding Futurity young horse evaluations

Implications ‘Blocked Coloured’ (BC) and ‘Spotted’ (Sp) horses had significantly lower Premium Scores than ‘Solid’ (S) coloured horses, suggesting a negative horse coat colour bias influencing potential performance horse evaluations.

Introduction The British Equestrian Federation (BEF), under the auspices of the British Breeding Futurity, annually evaluates >700 young horses (Foals-3yo) for their potential as future performance horses. Individual horses are evaluated on a discipline basis (Dressage, Show Jumping, Eventing or Endurance). Feedback from participants has suggested that a bias in the evaluations according to the horses coat colour exists. Since the premium scores awarded at the Futurity can influence the ‘worth’ of a horse, any bias in scoring could have financial implications for the British equine sector. Judging bias according to athletes’ uniform colour has been found in several studies e.g. that of Hageman *et al.* (2008) and changing ‘fashions’ in horse coat colour is apparent through history as described by Linderholm and Larson (2013). However, no prior research has investigated judging bias according to the coat colour of the horse. The aim of this preliminary research project was to (1) investigate whether equine coat colour bias exists within the Futurity evaluations and (2) evaluate in which discipline or part of the evaluation process this occurs.

Material and methods Premium scores awarded to horses exhibited in the 2012 BEF Futurity (n=750) were used as the dependent variable, comparing horse coat colour groups, using descriptive statistics, Oneway ANOVA and Tukey HSD post hoc analysis in IBM SPSS statistics 21. Horse colours were grouped according to phenotype similarities: Bay (n=422): light bay, bay, dark bay; Chestnut (n=126): chestnut, dark chestnut; Black (n=64); Block Coloured (BC) (n=49): piebald, skewbald; Grey (n=47); Dilutions (n=29): dun, buckskin, palomino and Spotted (Sp) (n=13): spotted, appaloosa, roan. Descriptive statistics and conditional formatting in Microsoft Excel 2013 were used to ascertain apparent changes in the mean premium scores awarded between disciplines Dressage (n=274), Show Jumping (n=151), Eventing (n=306) and Endurance (n=19), and in component scores of the different aspects of the evaluation process (veterinarian, frame & built, walk, trot, canter and athleticism).

Results BC and Sp horses had the lowest mean premium score across all disciplines (Table 1), and in all aspects of the evaluation process. Low premium scores of a few individual Sp horses however skewed the mean of this coat colour group. Not all horse coat colour groups were represented in the

Endurance evaluations. BC coloured horses had significantly lower Premium scores compared to all other 'Solid' (S) coat colour groups (Table 1). No other coat colour group had significantly different premium scores from other coat colour groups.

Table 1 Significant levels of horse coat colour group comparisons (BC to all other colour groups)

Coat Colour Group (I)	Coat Colour Group (J)	Mean Premium Score	Mean Difference (I-J)	Standard Error
Block Coloured (Mean Premium Score=8.03)	Bay	8.41	-.39*	.06
	Chestnut	8.38	-.35*	.07
	Black	8.41	-.38*	.07
	Spotted	8.13	-0.10	.12
	Grey	8.34	-.31*	.08
	Dilutions	8.43	-.40*	.09

*. The mean difference is significant at the 0.05 level.

Conclusion 'Blocked Coloured' and 'Spotted' horses had significantly lower premium scores than 'Solid' coloured horses. This did not differ according to discipline or in the different aspect of the evaluation process. Further analysis of data from multiple years of Futurity evaluations, will allow investigation of this apparent bias and its significance with a larger sample size.

Acknowledgements The author thanks the BEF for supplying data and the ESF-CUC for the research programme bursary.

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5.6 Proceedings of the 11th International Society of Equitation Science Conference, 2015, p38

Fisker Hansen, Randle, H., and Dixon, J

An investigation of equine coat colour bias in assessment of potential performance horses

Bias, a result of the human brain's limitations in memory recall and decision-making, has been extensively studied e.g. in sport with judging bias according to athletes' uniform colour. Feedback from participants of the British Equestrian Federation's (BEF) young horse evaluations, The British Breeding Futurity, has suggested evaluator bias according to horse colour. The Futurity annually evaluates foals-3yo for their potential as future performance horses on a discipline basis (Dressage, Show Jumping, Eventing or Endurance). The premium scores awarded at the Futurity can influence the worth of a horse, thus any bias in scoring could have economic implications. This is noteworthy, as unwanted horses have majorly increased in Britain, affecting equine welfare. The aims of this study were to (1) investigate whether equine coat colour bias exists within the BEF evaluations, by analysing 7 years (2008-2014) of Futurity data (n=4001 horses), and (2) investigate current preferences in horse coat colours amongst British equestrians, by online surveying. Registered horse colours were grouped according to phenotypic similarities: Bay (B) (n=2218): light bay, bay, dark bay; Chestnut (C) (n=773): chestnut, dark chestnut; Black (Bl) (n=345); Spotted (S) (n=298): spotted, appaloosa, roan, grey; Block Coloured (BC) (n=241): piebald, skewbald and Dilutions (D) (n=126): dun, buckskin, palomino. The survey was designed, piloted and distributed through social media (June-September 2014) (n=65).

One-way ANOVA and Tukey HSD post hoc analysis (IMB SPSS statistics 21) of the BEF data showed BC to have the significantly lowest mean premium score compared to all 'solid' (i.e. B, C, Bl, D) coat colour groups ($P < 0.001$). Spotted horses had the second lowest mean premium score, significantly lower than B, C and Bl horses ($P < 0.001$). Block Coloured horses also had the lowest mean premium score according to the discipline Show Jumping (n=754) and Eventing (n=1574). In Dressage evaluations (n=1608), S horses had the lowest mean score followed by BC horses. These results mirror those of the questionnaire with BC and S chosen as the least favourite horse colours by a significant number ($p < 0.001$) of respondents. This suggests a negative bias of 'Block Coloured' and 'Spotted' horses influencing subjective evaluations of potential sports horses. Thus, a new subject in equitation science, comparable to colour bias in sport, is theorised, potentially identifying horse colour bias as a discipline to be assessed in regards to welfare issues of breeding low value equines. Future analysis will include the development of a 'genetic data normalisation' method based on the world breeding federation for sports horses' top 100 sires list. LP: Negative bias of horse colour is suggested to influence the evaluation of potential performance horses, possibly due to a current fashion in horse coat colours. Knowledge of horse colour bias can contribute to welfare assessments regarding overbreeding.