Advances in Equine Health and Management: Estimating Bodyweight and Grazing Legumes

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Abstract

The role of the horse (*Equus caballus* L.) has evolved since it first appeared four million years ago (Hunt, 1995). According to a survey conducted by the United States Department of Agriculture (USDA), 45.7% of farms use horses for pleasure, 24.8% use horses for farm or ranch work, and 15.9% use horses for breeding (USDA, 2007). Within the sector of horses used as pleasure, workloads can vary drastically from minimal work (maintenance) to intense work (horses participating at the highest levels of competition). Within this range of workload, there are also horses described as hard keepers or easy keepers. The range of energy output of horses varies drastically; therefore, there is not a single ratio or feedstuff that applies to all horses. These different categories of horses have led to two different management problems; how to keep bodyweight (BW) off easy keepers and maintenance horses, and how to keep BW on hard keepers and performance horses. The objectives of the following studies were: 1. to determine the forage nutritive value, yield, and preference of legumes when grazed by adult horses and 2. to assess the accuracy of previously derived BW estimation equations, and if warranted, develop new BW estimation equations for adult draft and warmblood horse breeds using morphometric measurements.

To determine objective 1, research was conducted in 2014 and 2015 in St. Paul, MN. Legumes were established as monocultures and in binary mixtures with cool-season grasses in a randomized complete block design with four replicates. Stands were established on May 16, 2014 and April 27, 2015. Adult horses grazed eight alfalfa (*Medicago sativa* L.) varieties, one red clover (*Trifolium pratense* L.), and one white

clover (*Trifolium repens* L) when legumes reached the pre-bud stage. Legumes were measured for yield and samples to determine forage nutritive values were harvested prior to grazing. Plots were visually assessed for the percentage of forage removal on a scale of 0 to 100 to determine horse preference. White clover had the greatest amount of equine digestible energy (DE; 2.58 to 2.75 Mcal/kg) in monocultures and mixtures in 2014 and in monoculture in 2015. Digestible energy of all legumes exceeded equine DE requirements for adult horses at maintenance. In both years, alfalfa varieties yielded more compared to white clover ($P < 0.0001$). The top alfalfa variety yielded 17.4 and 12.9 Mt/ha in 2014 and 2015, respectively. In both years, horses had similar preference for all legumes and removed between 72 to 99% of available forage. This research helps to confirm that legumes are a nutrient dense, high yielding and preferred forage when grazed by adult horses.

To determine objective 2, morphometric measurements were collected on adult (≥3 yr), non-pregnant draft (n = 138) and warmblood (n = 89) horse breeds at two separate shows in Minnesota in 2014. Trained personnel assessed body condition score (BCS) on a scale of 1 to 9, measured wither height at the third thoracic vertebra, body length from the point of the shoulder to the point of the buttock (BL wrap), body length from the point of the shoulder to a line perpendicular to the point of the buttock (BL straight), neck circumference at the midway point between the poll and the withers, and girth circumference at the third thoracic vertebra. Each horse was weighed using a portable livestock scale. Individuals were grouped into breed types using multivariate ANOVA analysis of morphometric measurements. Bodyweight estimations equations

were developed using linear regression modeling. For estimated BW, the model was fit using all individuals and all morphometric measurements, except BL wrap. For ideal BW, the model was fit using individuals with a BCS of 5 and morphometric measurements not affected by adiposity; BL straight and height. Mean (± SD) BCS was 6.3 (± 0.9) and 5.2 (± 0.6) for draft and warmblood horses, respectively. BW (kg) was estimated by taking [girth (cm)$^{1.528}$ x BL straight (cm)$^{0.524}$ x height (cm)$^{0.246}$ x neck (cm)$^{0.261}$] / 1,181 (draft) or 1,209 (warmblood)] (R^2 = 0.96; rMSE = 28 kg). This is an improvement over the previous BW estimation equation for light-breed horses, which utilized BL wrap and girth circumference to estimate BW (R^2 = 0.94; rMSE = 34 kg). Ideal BW (kg) was estimated by [(4.92 x BL straight (cm)) + (4.64 x height (cm)) – 951 (draft) or 1,016 (WB)] (R^2= 0.90 and rMSE = 33 kg). Morphometric measurements were successfully used to develop new and improved BW-related equations for draft and warmblood horses. The equations will assist draft and warmblood horse owners and professionals with managing horse BW, nutrition and health.

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CHAPTER ONE: LITERATURE REVIEW

Introduction

The role of the horse (*Equus caballus*) has evolved since it first appeared four million years ago (Hunt, 1995). Horses are hindgut fermenters, designed to eat high fiber forage continuously throughout the day (Janis, 1976). Microbial fermentation in the cecum of the large colon produces volatile fatty acids, which are thought to contribute to 60 to 70% of the horse’s total energy needs (Vermorel and Martin-Rosset, 1997). Historically, horses were nomadic animals and could cover an average of 20 miles each day while grazing. As a domesticated animal, the horse was instrumental to both economic development and the success of large-scale invasions and the settling of the land (Mills and McDonnel, 2005).

Today, however, the life of a horse is vastly different from that of wild horses (Przewalski’s horse) and even from the first domesticated horses. Although the horse is still legally classified as a livestock (American Horse Council, N.D.), the job of the majority of today’s horses has transitioned from a work animal to a companion animal. According to a survey conducted by the United States Department of Agriculture (USDA), 45.7% of farms use horses for pleasure, 24.8% use horses for farm/ranch work, and 15.9% use horses for breeding (USDA, 2007). Within the sector of horses used as pleasure, workloads can vary drastically from minimal work (maintenance) to intense work, such as horses participating at the highest levels of competition. The majority of horses are kept at maintenance or in light work; however there is a large population of performance horses and breeding stock of which have high energy needs.

Current Equine Management Challenges

The range of energy output of horses varies drastically; therefore, there is not a single ratio of feedstuff that applies to all horses. Horses can be kept at maintenance, where they are seldom (or never) asked to exert energy beyond their free will. These horses have digestible energy (DE) demands ranging from 1.52 to 2.00 Mcal/kg bodyweight (BW) consequently, horses can also be Olympic level athletes, competing in strenuous events including three day eventing and racing. These horses competing at the upper echelons of their discipline are often referred to as elite or performance horses (Pratt-Phillips, 2016).

Within this range of workload, there are also horses described as hard keepers or easy keepers. Both types can present management challenges. Hard keepers are horses that are prone to weight loss regardless of quantity and quality of the ration (Becvarova et al., 2009). Other classifications of horses with high-energy demands include growing horses, lactating broodmares and breeding stallions. Digestible energy needs for these horses range from 2.18 Mcal/kg bodyweight (BW) for a 500 kg breeding stallion, between 2.66 and 3.45 Mcal/kg BW for a 500 kg horse in heavy to intense work, and up to 4.15 Mcal/kg BW for a 3 month old foal, which is the age a foal will start consuming forage and concentrates (Nutrient Requirements of Horses, 2007). In contrast, easy keepers are horses that easily gain weight and are thought to be metabolically efficient (Becvarova et al., 2009). These different categories of horses have led to two different management problems; how to keep BW off easy keepers and maintenance horses, and how to keep BW on hard keepers and performance horses.

Management of the Hard Keeper and Performance Horse

Horses are grazing animals, and given the choice will spend about 60% of their time eating, whether it is on fresh pasture or hay fed *ad libitum* (Mills and McDonnel, 2005). However, not all horse and farm owners have adequate pasture to maintain horses on pasture while consuming sufficient levels of nutrients to maintain body condition and BW. Instead of pasture, many farms utilize dry lots (i.e. dirt lots) for turn out and rely on hay as a forage source. In these scenarios, horses with elevated nutritional needs are supplemented with grain concentrates (Hoffman et al., 2009), typically fed in 1 to 2 meals throughout the day (Santos et al., 2011). However, this feeding program is not what the horse evolved to eat (Janis, 1976) and as a result, there are many negative effects associated with feeding high quantities of concentrates. After consuming meals of grain concentrates, horses have large fluctuations in plasma glucose and insulin, causing peaks and valleys of energy throughout the day (Stull and Rodiek; 1988, Hothersall and Nicol, 2009). Pratt-Phillips et al. (2010) concluded that diets consisting of nonstructural carbohydrate (NSC)-high rations led to significant diminishment of insulin sensitivity, which may over time lead to insulin resistance, even in non-obese horses. It has also been observed that horses fed hay and grain spend much less time chewing compared to horses on pasture, resulting in less saliva present to moisten the food. This affects gut acidity and may lead to dysfermentation and colic, as well as ulceration in the hindgut (Harris et al.; 2006, Ralston; 2007). Decreased access to pasture also increases the risk factor for colic (Hudson et al., 2001).

Benefits to Grazing Fresh Forage

There are many benefits from allowing horses to participate in grazing behavior. Research has demonstrated that a diet high in forage content, whether as hay or fresh pasture, helps to reduce negative behaviors including coprophagy, bedding-eating, cribbing, and chewing (Pell and McGreevy; 1999, Hothersall and Nicol; 2009). Although keeping horses on pasture mimics their ancestral grazing behavior, performance horses in heavy work may not be able to maintain BW and body condition on grass pasture alone. Grass pastures average 2.26 digestible energy (DE) Mcal/kg, 15.5% CP, 12.1% NSC, and a 1.74:1 Ca:P (Dairy One Labs, 2015). Most horses' needs will be met by a productive grass pasture (Bott et al., 2013); however growing horses, performance horses in heavy work, and lactating mares all have energy and nutrient needs greater than what can be met by grass pasture alone (NRC, 2007). Because of this, these horses are commonly fed large amounts of grain concentrates in one or two meals each day. However, the increased DE and crude protein (CP) content of alfalfa (*Medicago sativa* L.) and other legumes may be able to fill the caloric gap for these horses when grazing pastures. Legume pastures average 3.08 DE Mcal/kg, 25.9% CP, 12.9% nonstructural carbohydrates (NSC), and have a 3.5:1 Ca:P (Dairy One Labs, 2015). By grazing horses on pastures containing alfalfa and other legumes, horse owners may be able to eliminate the need for concentrates in the diet.

Benefits to Grazing Alfalfa

Alfalfa and other legumes have a distinct physiology that offers many benefits in terms of nutritional content and pasture health. A unique feature of alfalfa growth is the crown development. Crown development occurs through contractile growth and begins as early as one week after emergence (Mueller and Teuber, 2007). As the seedling stem elongates, secondary shoots form off of the primary stem in alternating trifoliate or multifoliate leaves and the hypocotyl shortens and thickens. This contraction of the main root pulls the stems slightly below the surface of the soil and becomes the area of the plant known as the crown. Crown development benefits the health of the plant by providing protection from cold temperatures and mechanical damage (Mueller and Teuber, 2007). The deep root and crown system also make it more drought resistant compared to other legumes and cool-season grasses (Lacefield et al., 2002). This evolutionary mechanism has resulted in legumes that are more persistent, compared to some grasses, and may lead to a longer life span of a grazing area.

The most notable benefit of legumes compared to grasses is the overall increased quality and nutrient content. CP levels have been reported at averages of 17 to 21.9% (Buxton; 1996, Sleugh et al.; 2000, and Martinson et al.; 2012) in non-grazing trials. In a 2012 study looking at beef steers grazing alfalfa and tall fescue, CP levels averaged 22.1 to 26.7% CP (Boland et al., 2012). Legume-cool season grass mixture plots have been previously reported with CP levels of 19% (Sleugh et al., 2000). NDF levels have been previously reported at averages of 35.7% (Kura Clover), 41.1 to 42.5% (alfalfa monoculture), and 48.7% in alfalfa-cool season grass mixtures (Sleugh et al.; 2000, and Martinson et al.; 2012). Results published by Boland et al. (2012) in a grazing trial reported 31.4to38.1% NDF. There are limited reports of equine DE in legume pasture, however alfalfa hay has values averaging 2.45 to 2.50 Mcal/kg (Martinson et al.; 2012, Rodiek and Stull; 2007). NSC values are also rarely reported in cattle and sheep grazing.

Previously reported NSC values for alfalfa hay average 8.2 to 9.3% (Martinson et al.; 2012 and Rodiek and Stull; 2007).

The increased CP found in legumes over grass species is the result of the nitrogen-fixing bacteria *Rhizobium*, which is able to convert atmospheric nitrogen (N_2) into a form (ammonium nitrogen, NH_3) that is usable by plants (Mueller and Teuber, 2007). There are many strains of rhizobia that work on different legumes. White clover (*Trifolium repens* L.) and red clover (*Trifolium pratense* L.) commonly utilize one strain (*Rhizobium leguminosarum trifolii*) while alfalfa commonly utilizes *Sinorhizobium meliloti* or *Rhizobium mongolense* (Phillips; 1980, NRCS; 2008). All strains function by infecting the root hairs of the main taproot and forming nodules, which is where the conversion of atmospheric to ammonium nitrogen occurs (Mueller and Teuber, 2007). This nitrogen-fixing bacteria forms a symbiotic relationship with the plant; in exchange for providing the plant with nitrogen, the plants provide the bacteria with carbohydrates that serve as an energy source (Texas A&M AgriLife Research & Extension Center, N.D.).

In addition to the increased CP and DE content, legumes also offer an increased level of calcium (Ca). Lewis and Sparrow (1991) looked at mineral content of varying soil types and varying pasture species and reported a Ca:P ratio for monoculture alfalfa of 2.14:1. Martinson et al. (2012) reported a higher Ca:P ratio of 5:1 in bud stage alfalfa hay. Grace et al. (2002) grazed Thoroughbred yearlings on a pasture consisting of a Ryegrass-white clover mixture and reported a Ca:P ratios of 1.06:1. Calcium is particularly important for pregnant and lactating broodmares (Nutrient Requirements of Horses, 2007). Both pregnant and lactating broodmares can be challenging to manage nutritionally. For example, Ca consumption at marginal levels during pregnancy has been shown to slow fetal growth (Harris; 2003, Frape; 2004) and an imbalance of minerals, including Ca and phosphorous (P) can adversely affect the foal at birth and result in reduced milk yield for the mare (Frape, 2004). Not only are macro- and micro-nutrient levels critical, but also overall energy balance is important for broodmares. Digestible energy requirements for broodmares in the last trimester are 20% higher than requirements for early pregnancy (Nutrient Requirements of Horses, 2007). The increased Ca, CP, and DE content of grazing legumes may offer pregnant and lactating broodmares high levels of nutrition without the need for grain concentrates.

Economic benefits of alfalfa and of grazing

Utilizing legumes in a pasture setting has benefits beyond horse health. There are many economic benefits as well. Grazing horses on pasture may reduce the amount of hay and grain concentrates that are necessary. During the growing season, feeding costs for horses on pasture can be negligible with the exception of pasture maintenance. In an alfalfa grazing system, cost is further reduced because of the lessened need for nitrogen fertilizer. For horses that are already being maintained on alfalfa hay, it’s been estimated that 40% of the cost of producing alfalfa hay is machinery and equipment (Lacefield et al., 2002). In a grazing system, this cost is reduced, and offers further savings to the horse owner.

Additionally, the duration of use for grazing alfalfa can also be longer in a pasture system. The critical fall harvest period for alfalfa hay is the six-week period that precedes the average date of the first killing frost (Bagg, 2009). Harvesting for hay during this period removes all leaf growth, and regrowth energy must come from stored carbohydrates in the root system (Bagg, 2009), which can lead to plant damage. When used for grazing, horses can be managed to graze alfalfa down to a taller height (15 to 20 cm), therefore, only removing a portion of the leaf area. This reduces the use of carbohydrates that have been stored for regrowth and helps to limit damage and negative impacts on the yield in the following spring (Volesky and Anderson, 2010).

The most frequent concern for beef and dairy producers who keep animals on alfalfa is that of bloat, a painful condition involving the inability to release a large amount of gas built up in the rumen (Majak et al., 2003). Because horses are hindgut fermenters, they do not experience bloat. Another potential downfall to grazing horses or other livestock on alfalfa is the risk of crown damage and long-term impacts on stand productivity (Lacefield et al.; 2002, Volesky and Anderson; 2010). Rotationally grazing, allowing the forage to regrow and limiting turn out during wet or muddy periods can manage this.

In the Midwest, climate plays a large role in yield potential of alfalfa. Typically, only varieties that can withstand the severe winters are planted. This limits the yield potential as varieties with higher winter survival ratings often have lower fall dormancy ratings. Fall dormancy is defined as the reduction in shoot growth in response to shortening day length and decreasing temperatures (Xianglin and Liqiang, 2005). The two factors are not necessarily tied together directly; however they both have an effect on yield (Miller, 2011). Lower fall dormancy ratings may contribute to lower total season yield; however, these varieties may be more persistent over time. Alfalfa is a high yielding and productive crop. Yields are typically lower in the establishment year than subsequent years (Pecetti et al., 2008). First year yields have been reported between 8.7

(Berdahl et al., 2001) and 13.5 MT/ha (Sleugh et al., 2000). Clover yields are also respectable at 8.4 MT/ha (Sleugh et al., 2000) and 8.6 MT/ha (Peterson et al., 1994). Binary mixture yields range between 8.5 MT/ha (Orchardgrass, White Clover) and 12.6 MT/ha (Bromegrass, Alfalfa; Sleugh et al., 2000). This is in contrast to second year yields of 13.6 to 19.9 MT/ha (Pecetti et al., 2008).

Along with yield and persistence, livestock preference is a major component of pasture productivity (Allen et al., 2013). The animal makes a marked contribution to overall pasture management by selecting plant species and plant parts, which in turn determines its own nutritional level in terms of both quality and quantity (Gesshe and Walton, 1981). It is thought that NSC level may impact animal selection, with preference being given to plant species with higher levels (Mayland et al., 2000). Gesshe and Walton (1981) observed that alfalfa was a highly preferred forage compared to grasses and other legumes when grazed by steers. Horses are selective and aggressive grazers, which may limit the productivity and survival of some pasture species (Archer; 1973, Archer; 1978, Allen et al.; 2013). Horses are also very social animals and will typicallly travel in herds or groups. Houpt (2001) reported that when two horses were eating together, if one started or stopped eating, the other would follow.

Management of the Easy Keeper

In contrast to the horses that require high caloric rations, there is a growing trend towards obesity of horses in the United States and Europe. Most instances of obesity are the result of an imbalance between energy intake and expenditure (Geor and Harris, 2009). Johnson et al. (2009) observed husbandry practices including feeding of high-energy rations to physically inactive horses. These horses are receiving more calories than they are exerting and as a result, weight gain and fat deposition occurs. Excess BW can lead to health issues including insulin resistance (IR) and Equine Metabolic Syndrome (EMS); both of which can lead to laminitis (Treiber et al.; 2006, Geor and Harris; 2009), poor thermoregulation (Cymbaluk and Christison; 1990, Webb et al.; 1990) and decreased athletic ability (Thorton et al., 1987).

Horses prepare for the winter by increasing their forage intake and growing a thick coat of hair. This stimulated appetite and subsequent increased adipogenesis are in response to the increased secretion of proopiomelanocortin (POMC) peptides from the hypothalamic-pituitary axis (Ssewannyana et al.;1990, Donaldson el al.; 2005) These changes allow the horse to store energy, which carries them through the winter months when food is scarcer and conditions are harsh, (Johnson et al., 2009). Most adipose stores are been depleted when spring arrives. This cycle has led to the inheritance of what is known as the “thrifty gene” (Prentice, 2005) and it is thought that thriftiness is related to insulin resistance (Johnson et al., 2009). In a study investigating a specific line of swine (*Sus scrofa domesticus*) who had evolved to have a thrifty genotype due to cycles of feasting and famine found that when these animal were allowed to consume excess food in captivity, they developed excessive adiposity, IR, hypertriglyceridemia, and hypercholesterolemia in comparison to domestic swine (Martin et al.; 1973, Buhlringer et al.; 1978, Dyson et al.; 2005). Horses with the thrifty gene are able to withstand harsher environmental conditions more easily than horses lacking the gene. However, today’s horses rarely have to endure the same conditions their wild ancestors did. Although horses still live in cold climates, they are provided shelter, consistent and high quality feed stuffs, and are often blanketed to aid in body temperature maintenance. Under these modern conditions, the thriftiness gene manifests itself as weight gain. Certain breeds including Morgans, and pony breeds appear to be "thriftier" and are more prone to IR and obesity (Treiber et al., 2006).

While it has been extensively studied that excess BW leads to numerous health issues, most owners are maintaining their horses at a higher bodyweight. The 2005 National Animal Health Monitoring System (NAHMS) study estimated that 4.5% of the United States equine population was overweight or obese (USDA, 2005). This number is based on owner-reported assessment of horse body condition. Several studies have indicated that the number of overweight or obese horses is actually much higher. Wyse et al. (2008) determined that horse owners could not accurately assess body condition score (BCS; Henneke et al., 1983) and that owners of obese horses were more likely to underestimate their horse's BCS. Thatcher et al. (2012) found that 45% of 319 horses assessed were found to be overweight or obese. Other studies have also determined that greater than 14% of horses are overweight or obese (Donaldson et al.; 2004, Pratt-Phillips et al.; 2010, Harker et al.; 2011, Martinson et al.; 2014). These results are similar to a study of companion animals that showed 26% of cats and 25% of dogs were obese (Allan et al., 2000). It has also determined that horse owners lacked the ability to detect changes in adiposity over time (Mottet et al., 2009).

Detecting changes in adiposity is key to owner management of horse obesity. The most common method to tracking weight change is to look at body condition, as a measure of fat deposition. Similarly to humans, horses tend to deposit adipose tissue in specific areas. The six areas of interest on the horse include the crest of the neck, the withers, along the topline, behind the shoulder, over the ribs, and the tail head area

(Henneke et al., 1983). The BCS system was developed as a way to assess adiposity and places horses on a scale that ranges from one (emaciated) to nine (obese; Henneke et al., 1983). This is a subjective score and is best used by the owner or a trained professional to track changes over time. The cresty neck score is a similar tool, however it assesses the neck. Increased fat deposits along the neck of horses and ponies have been shown to be associated with IR and EMS (Carter et al., 2009). Both of these systems look specifically at adipose tissue and it is important to note that accuracy largely depends on knowledge of the scoring system, and repeated assessment of the horse by the same, trained person.

Determining a horse's BW is important for horse health and nutrient management; however, few owners have access to a scale or can accurately estimate horse BW or BCS. Although it was been reported that owners tend to underestimate BCS (Harker et al., 2011), there is limited information regarding horse owners ability to accurately estimate horse BW. To estimate BW, horse owners frequently use BW tapes or equations. Bodyweight estimation equations exist for adult light horse breeds (Hall, 1971), ponies (Owen et al., 2008) and miniature horses (Bruce et al., 2010) utilizing heart girth circumference and body length measurements. Recently, new equations were developed that improved existing BW estimation equations by adding breed type, neck circumference and height (Martinson et al., 2014). Martinson et al. (2014) also developed ideal BW estimation equations for ponies, Arabian and stock horses to better equip horse owners and professionals with tools to manage horse BW. The ideal weight estimations give owners a tool to use in addition to BCS in determining if their horse is overweight. However, these new equations are not available for al breed-types.

CHAPTER TWO: FORAGE NUTRITIVE VALUE, YIELD, AND PREFERENCE OF LEGUMES UNDER HORSE GRAZING DURING THE ESTABLISHMENT YEAR

Introduction

Horses have evolved as hindgut fermenters, designed to continuously eat small meals of forage (Janis, 1976). However, the role of the horse has evolved and many horses have higher nutritional needs than grass pasture can provide. Legumes are commonly fed to horses as hay to provide a higher level of nutrients and digestible energy (DE) compared to grass hay, but are rarely grazed as fresh forage in monoculture. Although most horses' nutritional needs can be met by grass pastures (Bott et al., 2013), growing horses, horses in heavy work, and lactating mares all have greater energy and nutrient needs than can be met by grass pasture alone (NRC, 2007). The increased DE and crude protein (CP) content of alfalfa and other legumes may be able to fill the nutritional gap for these horses when grazing.

Legumes average 3.08 DE Mcal/kg, 22.1 to 26.7% (Boland et al., 2012), 31.4 to 41.4% NDF (Boland et al.; 2012, Sleugh et al.; 2000), 8.2 to 9.3% non-structural carbohydrates (NSC) (Rodiek and Stull; 2007 and Martinson et al.; 2012), and a 2.14:1 calcium to phosphorus (Ca:P) ratio (Lewis and Sparrow, 1991). In contrast, grass pastures average 2.26 DE Mcal/Kg, 15.5% CP, 12.1% NSC, and a 1.7:1 Ca:P ratio (Dairy One Labs, 2015). Along with being nutrient dense, alfalfa is also a high yielding forage species. Establishment year yields have been reported between 8.7 (Berdahl et al., 2001) and 13.5 MT/ha (Sleugh et al., 2000), while clover yields range from 8.4 MT/ha (Sleugh et al., 2000) to 8.6 MT/ha (Peterson et al., 1994). Binary mixture yields range between 8.5 MT/ha (Orchardgrass (*Dactylis glomerata* L.), and white clover (*Trifolium repens* L.)) and 12.6 MT/ha (Smooth bromegrass (*Bromus inermiss* L.) and Alfalfa; Sleugh et al., 2000).

Differences in livestock preference affects not only utilization of a species, but ultimately forage persistence if preferred pasture species are repeatedly grazed (Allen et al.; 2013, Marten et al.; 1987). Legumes tend to be highly preferred by both sheep and cattle compared to grass species (Rutter et al.; 2006, Boland et al.; 2010, Boland et al.; 2012). Horses are known to be selective grazer, but most research has focused preference among grass pasture species (Archer; 1973a, 1973b, Hunt and Hay; 1990, Allen et al.; 2013). Although alfalfa is widely used as both a fresh and conserved forage source for ruminants, there is limited research investigating alfalfa as a fresh forage source for horses. The objectives of this research were to evaluate forage nutritive value, yield, and preference of legumes under horse grazing in the establishment year.

Materials and Methods:

Research was conducted in Saint Paul, Minnesota. Seed beds were prepared from an existing pasture dominated by Kentucky bluegrass with multiple disking and field cultivation passes during the summers of 2014 and 2015. Alfalfa stands were established on May 16, 2014 and April 27, 2015 on a Waukegan silt loam (a fine-silty over sandy or sandy-skeletal, mixed, superactive, mesic Typic Hapludoll) with a pH of 6.5. No soil amendments were required based on Minnesota pasture fertility guidelines. Stands were established in a randomized complete block design with four replicates. Plots were 1.8 m x 6.1 m. Eight alfalfa varieties, one red clover (*Trifolium pretense* L.), and one white clover were planted as a monoculture and in a binary mixture with a cool-season grass mixture comprised of tall fescue (*Schedonorus arundinaceus*), orchardgrass, perennial ryegrass (*Lolium perenne* L). Legumes were planted at a rate of 20.3 kg/acre and grasses were planted at a rate of 16.8, 11.1 and 24.7 kg/acre for tall fescue, orchardgrass and perennial ryegrass, respectively. Alfalfa varieties include '401Z+', 'BlueJay HR', 'Cutting Edge', 'Red Falcon', and experimental alfalfa populations with varying fall dormancies (FD) designated as FD 2, FD3, FD 4, and FD 5. The red and white clover varieties were 'Freedom MR' and 'Kopu II', respectively. In 2015, '403T' was used in place of '401Z+'.

Prior to the first harvest, weeds were removed by hand. After first harvest, a broadleaf herbicide [imazamox (2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1*H*-imisazol-2-yl]-5-(methoxymethyl)-3-pyridinecabroxylic acid); 0.29 L/ha] was applied to the monoculture plots to control broadleaf weeds. To encourage legume and mixture establishment, horses began grazing after the first harvest when legume re-growth reached the pre-bud stage. No horse grazing occurred during the first harvest.

Stands were measured for yield on July 1, August 5, and September 15, 2014 and on June 29, July 23, August 24, and October 12, 2015 by mechanically harvesting a 0.91 x 5.18 m strip using a flail harvester (Carter Manufacturing Company, Inc., Brookston, IN). Samples to determine forage nutritive values and plant maturity were taken in triplicate by hand sampling a small area to a 5 cm height from each plot prior to grazing. Plant height and stem counts were measured in two rows along a 0.3-meter line prior to horse grazing. Hand samples were assessed for maturity using the mean stage count method (Kalu and Fick, 1983). The binary mixture samples were separated into grass and legume components and weighed to determine composition, then recombined. All samples were dried at 60°C for 48 hours to determine dry matter (DM). After drying, stems and leaves were separated to determine the leaf to stem ratio for alfalfa grown in monoculture (Lamb et al., 2003). After weighing stems and leaves individually, alfalfa samples were recombined and all samples were ground through a 6-mm screen in a Wiley mill (Thomas Scientific, Swedesboro, NJ) followed by a 1-mm screen in a Cyclotec (Foss, Eden Prairie, MN). Samples were homogenized and submitted for analysis at a commercial forage testing laboratory (Equi-analytical; Ithaca, NY).

Crude protein was calculated as the percentage of N multiplied by 6.25 (Method 990.03; AOAC, 2010). Neutral detergent fiber was measured using filter bag techniques (Ankom Technology, 2013). Starch and water soluble carbohydrates (WSC) were measured using techniques described by Hall et al. (1999). Non-structural carbohydrates were estimated by added WSC and starch (Longland and Byrd, 2006). Mineral concentrations were determined (Thermo Jarrell Ash IRIS Advantage HX Inductively Coupled Plasma Radial Spectrometer, Thermo Instrument Systems Inc., Waltham, MA) after microwave digestion (Microwave Accelerated Reaction System, CEM, Mathews, NC). Equine DE was calculated using an equation developed by Pagan (1998).

Four stock type horses (519 kg ± 24, 5.4 BCS ± 0.5) grazed in 2014 for 4 hours each day for four consecutive days in August and September. In 2015, six stock type horses (513 kg ± 45, 6.0 BCS ± 0.8) grazed for an average of 6 hours each day for four days in June, July, August and October. In both years, horses grazed the first and second replicate on days one and two and the third and fourth replicates on days three and four. Preference was taken after 4 (day 1) and 8 hours (day 2) post-grazing and was measured by visually assessing the percentage of forage removal on a scale of 0 (no grazing activity) to 100 (100% of available forage grazed; Marten et al., 1987; Allen et al, 2013). Manure was manually removed at the end of each day and stands were mowed to a stubble height of 5 cm and allowed to regrow.

When not grazing, horses were kept in a dry lot, offered *ad libitum* access to water, and fed 2% total herd BW of grass hay and 1 kg each of ration balancer (Nutrena Empower Balance, Elk River, MN) daily to ensure a balanced ration (NRC, 2007). All experimental procedures were conducted according to those approved by the University of Minnesota Committee on Animal Use and Care.

Data were analyzed using the Mixed procedure of SAS (version 9.4; SAS institute; Cary, NC). Statistical significance was set at $P \leq 0.05$ and means separations were determined using Tukey HSD. Replicate was considered a random effect while all other variables were considered fixed effects. Monoculture and binary mixture plots were analyzed separately. Environmental interactions prevented the combination of years. Forage nutritive values are reported for the final cutting of 2014 and as a season average of the four cuttings in 2015.

3.0 Results and Discussion:

Temperature and Precipitation

During the 2014 and 2015 grazing seasons (May through October), average monthly air temperatures were near historical averages (Figure 1). More rainfall was recorded during June 2014 and for most of the 2015 grazing season compared to the historical averages (Figure 1).

Maturity

In 2014 and 2015, there was no difference in plant maturity among alfalfa and clover varieties at the time of grazing ($P \geq 0.05$). In 2014, all legumes were in the late vegetative to early bud stage, ranging from a maturity of 2.17 to 2.49 (Kalu and Fick, 1983). In 2015, legumes were grazed at a vegetative stage which ranged from 1.66 to 1.88 (Kalu and Fick, 1983). Throughout the grazing season, horses grazed the legumes and mixture plots every 23 to 28 days. A cutting schedule ranging from 24-28 days tends to result in maturities ranging from late vegetative to early bud in seeding year alfalfa (Sheaffer et al., 1992), agreeing with the maturities observed in the current trial. Cool-season grass maturities were not assessed.

Forage Nutritive Values

Forage nutritive values for each year, legume monoculture, legume grass mixture and corresponding treatment x year interactions were different ($P \leq 0.05$) and are presented separately.

Among the eight monoculture and mixture alfalfa varieties in both years, there were no differences between forage nutrient values measured except for 'Cutting Edge' in 2014 which had a lower CP value compared to '401Z+' (Table 1 and 2). In general, red clover ('Freedom MR') had lower DE and NSC contents and higher CP and NDF contents compared to the alfalfa varieties in both years and in both monoculture and mixtures. In comparison, white clover ('Kopu II') was similar to alfalfa but tended to have higher DE and NSC contents and lower NDF contents compared to red clover in both years and in monoculture and mixtures. For all monocultures and mixtures, forage nutrient values met or exceeded requirements for adult horses at maintenance and CP exceed requirements (NRC, 2007).

There are limited reports of equine DE in legume pasture; however, current results are similar to alfalfa hay reported by Martinson et al. (2012) and Rodiek and Stull (2007) that ranged from 2.45 to 2.5 Mcal/kg. One potential drawback to grazing pure legumes is the increased DE compared to grass pastures. For example, a 500 kg adult horse at light work requires 19.98 Mcals per day (NRC, 2007). If an adult horse at light work consumed 2.0% bodyweight of a pure legume pasture for five months, they would have an excess of 6.22 Mcals per day, resulting in weight gains leading to a 1 score change in BCS over 60 days (NRC, 2007). Therefore, grazing of a pure legume pasture should be reserved for horses with elevated caloric needs, including horses in heavy work and breeding stock (NRC, 2007).

Crude protein content of legumes in monoculture in the current study were higher than previously reported averages of 17 to 22% (Buxton; 1996, Sleugh et al.; 2000, and Martinson et al.; 2012). Crude protein of legume grass mixture plots observed in the current study were greater than the previously reported CP level of 19% (Sleugh et al., 2000). However, CP was similar to Boland et al. (2012) who observed 22 to 27% CP when beef steers grazed alfalfa and tall fescue. Differences observed between the current results and past results were likely influenced by local weather conditions, maturity at the time of grazing or harvest (Martinson et al., 2012; Popp et al., 1999) and percent legume in mixture plots.

Non-structural carbohydrate contents are rarely reported in cattle and sheep grazing legumes or binary mixtures. However, NSC are of great interest in horse nutrition as they have been shown to affect horses diagnosed with certain diseases. Muscle pain in horses diagnosed with Polysaccharide Storage Myopathy (PSSM) was exacerbated by feeding diets high in NSC (Firshman et al., 2003) and Borgia et al. (2009) recommended only hay containing ≤10% NSC should be fed to horses affected by PSSM. Frank (2009) recommended a maximum of 12% NSC for obese, laminitic and insulin-resistant horses. Because legumes tend to be lower in NSC compared to cool-season grasses (Martinson et al. 2012), legumes offer a potentially lower NSC forage for diseased horses. However, 2014 NSC values of legume monocultures were higher than previous reports. Martinson et al (2012) and Rodiek and Stull (2007) reported alfalfa hay ranged from 9.3 to 7.7% NSC which is lower than values observed in 2014, but similar to values observed in 2015. Time of day and weather conditions are known to impact NSC (McIntosh et al., 2007). All forage samples were collected early to mid-morning. However, in 2014, samples were held in a freezer for one to two days before drying. Pelletier et al. (2010) has shown that freezing can lead to an increase in NSC compared to samples placed directly into the dryer. This may help explain the higher than expected NSC values observed in 2014.

Although horses have no daily requirement for NDF (NRC, 2007), it was evaluated as an indicator of forage quality. For both monoculture and mixture plots, NDF levels were lower than previously reported (Sleugh et al.; 2000, and Martinson et al.; 2012). However, the current results were similar to Boland et al. (2012) who reported NDF ranged from 31.4to38.1% in a beef grazing system. Similar to other forage components, NDF is affected by maturity (Martinson et al., 2012; Popp et al., 1999) and local weather conditions.

The NRC (2007) recommends most adult horses have a Ca:P between 2:1 to 3:1. All of the legume monoculture and mixtures in the current study were within this range which agreed with past results observed in pasture (Lewis and Sparrow, 1991) and hay (Martinson et al., 2012). However, Ca:P observed in the current study were greater than 1.06:1 that Grace et al. (2002) reported for ryegrass and white clover mixtures.

Legume Yield, Plant Height, Legume:Grass and Legume Stem:Leaf

Total yields (MT/ha) for legumes and legume cool-season grass binary mixtures are presented in Figure 2. There was no difference ($P \geq 0.05$) in total yield between legume monocultures in either year except in 2015 when 'BlueJay HR' yielded less compared to FD5. In 2014, 'Freedom MR" yielded less compared to some alfalfa varieties; however, in 2015, there were no difference in yield between red clover and alfalfa. In both years, white clover ('Kopu II') yielded less compared to the alfalfa varieties and less compared to red clover in 2015.

In 2014 mixtures with grasses, both red and white clovers yielded less compared to alfalfa grass mixtures. All alfalfa varieties resulted in a similar total yield when mixed with grasses ($P \leq 0.05$). In 2015, no differences in yield were observed among the legume grass mixtures.

Legume monoculture and legume grass mixture yields observed in both years are comparable to results previously published. Previously reported legume monoculture and legume grass mixture yields ranged from 6.7 to 13.5 MT/ha under grazing (Berdahl et al., 2001; Meyer et al., 1957; Sleugh et al., 2000). Red and white clover yields are similar to establishment year yields of 8.6 MT/ha observed for Kura clover (*Trifolium ambiguum* B.) when grazed by sheep (Peterson et al., 1994).

Legume height and stem counts were positively correlated with total yield (height; R ≥ 0.66, stem count; R ≥ 0.32) in both years. In both years, 'Cutting Edge' was the tallest alfalfa variety with heights ranging between 52 and 47 cm. 'Freedom MR' red clover height ranged from 33 to 32 cm while 'Kopu II' white clover was the shortest legume ranging from 23 to 22 cm ($P \leq 0.05$). In both years, 'Kopu II' white clover and 'Freedom MR' red clover had 71 to 86 and 50 to 77 stems within a 0.3-meter row, respectively. Clover stem counts were greater compared to all alfalfa varieties which ranged from 22 to 43 stems ($P \leq 0.05$).

After observing a visual difference in legume:grass in 2014, the binary mixture samples were separated into grass and legume components and weighed to determine composition in 2015. In 2015, there was an effect of both grazing ($P = 0.0003$) and grazing x variety ($P = 0.003$) for legume:grass; therefore, results are reported individually for each grazing (Table 3). There was no difference in legume:grass at the start of the first grazing ($P = 0.5856$) with ratios ranging from 12.5:1 to 3.5:1. For subsequent grazing, a similar trend was observed. FD 3 had the greatest (P ≤ 0.0087) legume:grass that ranged from 31.6:1 to 13.4:1. In comparison, 'Kopu II' white clover and '403T' had the lowest legume:grass and ranged from 5.0:1 to 2.3:1.

These results are similar to previous researchers who reported legume:grass that ranged from 4:1 to 1:1 (Sheaffer et al.; 1990, Berdahl; 2001).

Alfalfa leaf to stem ratio was only determined in 2015. No differences in leaf:stem were observed across grazings ($P = 0.4794$); however, differences between monoculture and mixtures were observed ($P < 0.0001$). However, in mixtures, grasses were classified as leaves, thus contributing to the higher leaf:stem observed in mixtures.

Within monocultures, all varieties were similar and ranged from 1.5:1 to 1.7:1. The same results were observed within mixtures; however, the ratio increased to 3.3:1 to 2.2:1. Monoculture results observed in the current study are consistent with previously reported studies that demonstrated legume leaf:stem were between 1:1 and 1:5:1 (Luckett and Klopfenstein, 1970; Sheaffer et al.; 2000; Lamb et al,; 2007).

Horse Preference

In both years, there were no differences among preference between legume and clover varieties in either the monoculture and binary mixtures ($P > 0.05$). In 2014, percent removal ranged from 91%to 71%, and in 2015, removal from 99 to 98% removal. Although other studies have investigated horse preference of cool-season grasses in a pasture system (Allen et al., 2013; Wilson and Hoormann, 2004), this appears to be the first study investigating horse preference of legumes. While there is limited data for equine preference among legumes, several studies have reported cattle and sheep grazing preference. In a legume grass mixture, beef cattle prefer alfalfa and other legumes to cool-season grass species, and spent 60 to 65% of time consuming alfalfa, regardless of the proportion offered (Boland et al.; 2010, Boland et al.; 2012). Rutter et al. (2006) also reported that in cool-season grass-white clover mixtures both dairy and beef heifers and dairy and beef sheep spent the majority of time (60 to 92%) consuming white clover over grass. Rutter et al. (2006) also observed that any remaining available forage in binary mixture plots was almost exclusively grass.

4.0 Conclusions

Forage nutrient values were similar among the eight alfalfa varieties. In general, red clover was lower in quality while white clover was similar to superior in quality to alfalfa. All equine DE and CP values exceeded daily requirements for horses in maintenance to light work. There was no difference in total yield between alfalfa varieties in monocultures or mixtures. White clover yielded less compared to the alfalfa varieties in monoculture and both red and white clovers yielded less compared to alfalfa mixtures. There were no differences among preference between legumes in monoculture and binary mixtures, nor were there differences in the leaf to stem ratio. Legumes in a grazing system offer a high yielding, nutrient dense and preferred alternative for horses with increased energy needs. However, horses grazing legume or legume grass mixed pastures should be monitored to avoid excessive bodyweight gain.

CHAPTER III: ESTIMATION OF ACTUAL AND IDEAL BODYWEIGHT USING MORPHOMETRIC MEASUREMENTS AND OWNER GUESSED BODYWEIGHT OF ADULT DRAFT AND WARMBLOOD HORSES

1. Introduction

There is a growing problem of overweight and obese horses in the United States and Europe. Many researchers have estimated that ≥14% of horses are overweight as indicated by a body condition score (BCS) of ≥7 (Donaldson et al.; 2004, Brooks et al.; 2010, Pratt-Phillips et al.; 2010, Harker et al.; 2011, Thatcher et al.; 2012 and Martinson et al.; 2014). Most instances of obesity are the result of an imbalance between energy intake and expenditure (Geor and Harris, 2009). Excess bodyweight (BW) can lead to health issues including insulin resistance and Equine Metabolic Syndrome, both of which can lead to laminitis (Geor and Harris, 2009), poor thermoregulation (Cymbaluk and Christison; 1990 and Webb et al.; 1990), and decreased athletic ability (Thorton et al., 1987).

Determining a horse's BW is important for horse health and nutrient management; however, few owners have access to a scale or can accurately estimate horse BW or BCS. Wyse et al (2008) determined that horse owners could not accurately assess BCS and that owners of obese horses were more likely to underestimate their horse's BCS. Thatcher et al (2012) found similar results and determined that owners frequently underestimated the BCS of their horses. Mottet et al (2009) also determined that horse owners lacked the ability to detect changes in adiposity over time. Although it has been reported that owners tend to underestimate BCS, there is limited information regarding horse owners ability to accurately estimate horse BW.

To estimate BW, horse owners frequently use BW tapes or equations. Bodyweight estimation equations exist for adult light horse breeds (Hall, 1971), ponies (Owen et al., 2008), and miniature horses (Bruce et al., 2010) using heart girth circumference and body length (BL) measurements. Recently, new equations were developed for ponies, Arabians, and stock-type horses that improved existing BW estimation equations by adding breed type, neck circumference, and height (Martinson et al., 2014). Martinson et al (2014) also developed ideal BW estimation equations for ponies, Arabian, and stock horses to better equip horse owners and professionals with tools to manage horse BW.

Although BW estimation equations exist for light-breed horses, ponies, and miniature horses, equations have not been developed for draft and warmblood horses. The objectives of this study were to develop BW estimation equations using morphometric measurements for adult draft and warmblood horses and investigate horse owner's ability to estimate BW of these breed types.

2. Materials and Methods

All experimental procedures were conducted according to those approved by the University of Minnesota Institutional Animal Care and Use Committee. All statistical analyses were conducted in R (R Core Team 2012, Vienna, Austria; version 2.15.1) unless otherwise noted.

Morphometric Measurements and Demographics

Morphometric measurements were taken on 227 adult draft and warmblood horses at the Scott County Fair Draft Horse Show (Jordan, Minnesota) (n = 138) and the Fall Harvest Horse Show (St. Paul, Minnesota) (n = 89), respectively, in 2014. The Scott County Fair Draft Horse Show was primarily draft horse hitch teams, whereas the Fall Harvest Horse Show was mostly hunters and jumpers. The Fall Harvest Horse Show was not breed specific, but most horses present were warmblood horses or warmblood crosses; only warmblood and warmblood crosses were used to develop BW estimation equations.

Data were collected on adult horses that were ≥3 years old and nonpregnant. The same six trained personal in teams of two collected the following measurements: BCS on a scale of 1 (poor) to 9 (extremely fat; Henneke et al.,1983) and height at the third thoracic vertebra (team 1); neck circumference at the midway point between the poll and the third thoracic vertebra (Carter et al., 2009) and girth circumference at the third thoracic vertebra (team 2); and BL from the point of the shoulder to the point of the buttock (BL wrap) (Wagner and Tyler, 2011) and BL from the point of the shoulder to a line perpendicular to the point of the buttock (BL straight; Martinson et al., 2014) (team 3; Fig. 3). The two-person team assessing BCS mutually agreed on the horse's BCS. Body length wrap was collected for use with the Hall equation (1971), whereas BL straight was collected for use in developing new equations and for use in the Martinson et al (2014) equation. Each horse was weighed using a calibrated portable livestock scale (Weigh-Tronix, Fairmount MN, PS2000 [warmblood horses] and PS5000 [draft horses]). Age, gender, breed, and discipline were also recorded. For draft horses only, shoe height was measured and actual height (wither height minus shoe height) was used in developing equations. Owners or the horse's exhibitor were also asked to estimate the horse's BW before weighing horses on the livestock scale. The owner estimated BW was later compared with actual BW using Student's *t* test with significance set at $P \leq .05$ and PROC CORR in SAS (SAS Inst. Inc., Cary, NC; version 9.3).

Determination of Breed Types

Horses were grouped by type (draft or warmblood), and this grouping was confirmed using multivariate analysis of variance (ANOVA) analyses. Means (± standard deviation [SD]) of age, BCS, neck circumference, girth circumference, height, and both BL (BL straight and BL wrap) measurements were calculated. Breeds were divided into two breed types: draft and warmblood.

Estimation of BW

All individuals were used to develop a linear model to predict scale BW using height, BL straight, girth circumference, neck circumference, and breed type. Models based on a log transformation were also considered, and the best model was selected on model diagnostics and the Aikeke information criterion (AIC). Leave-one-out cross-validation was used to ensure the data were not over fit. The final model, using log-transformed data, was used for all horses and compared to existing BW estimation equations (Martinson et al., 2014 and Hall, 1971) using root mean square error (rMSE). The rMSE was computed using leave-one-out cross-validation to ensure a more valid comparison with existing equations.

Estimation of Ideal BW

Only horses with a BCS of 5 were used to develop ideal BW equations as these individuals were assumed to have an ideal BW (Harker et al., 2011 and Martinson et al., 2014). This assumption has also been made in dogs (Mawby et al., 2014), which have a similar BCS scale. Only measurements that were not affected by adiposity were included in the model and included height, BL straight, and breed type (Martinson et al., 2014). Other morphometric measurements including girth and neck circumference tend to fluctuate with changes in adipose tissue (Carter et al., 2009) and, therefore, were not included when developing ideal BW equations. Models based on log-transformed values were also considered, but model diagnostics showed that variance was more constant on the original scale. The best model was selected based on model diagnostics and AIC. The average difference between ideal and actual BW was also calculated for each BCS within a breed type.

Development of a BW Score

Horses with a BCS ≥7 and <4 were considered to be overweight and underweight, respectively (Harker et al.; 2011, Thatcher et al.; 2012, Martinson et al.; 2014 and Henneke et al.; 1983). To assess the likelihood of being overweight or underweight, an ordinal logistic regression was developed on the basis of BCS, using the difference between estimated actual BW and ideal BW and breed type. A model was selected on the basis of AIC. The linear predictor from the selected model was considered the BW score and was standardized to a 0 to 100 scale by finding the percentile of each score among horses with a BCS of 5, assuming normal distribution. Values were chosen by picking the point on the receiver operating characteristic (ROC) curve closest to perfect classification. Cutoff values were established for overweight horses, as there were insufficient horses with a BCS <4.

3. Results and Discussion

Determination of Breed Types

Differences between breed types were confirmed using multivariate ANOVA analysis (*P* < .0001). Previous researchers have also shown a clear distinction in the morphometric measurements of different breeds (Pratt-Phillips et al.; 2010 and Martinson et al.; 2014). As expected, draft and warmblood horse morphometric measurements were greater compared with previously published light horse breeds and ponies (Table 4) (Brooks et al.; 2010, Martinson et al.; 2014, Owen et al.; 2008 and Sadek et al.; 2006).

Demographics and Morphometric Measurements

Data were collected from 138 draft horses and 89 warmblood horses (Table 4). Draft horse breeds included Percheron (61%), Belgian (25%), Clydesdale (11%), and Shire (3%). Most draft horses were geldings (75%), used for driving (97%), with an average age ± SD of 6.7 ± 2.9 years and an average BW ± SD of 853 ± 78 kg. Body condition scores ranged from 5 to 8 with a mean ± SD of 6.3 ± 0.9. Almost half (42%) of draft horses were considered overweight with a BCS of ≥7. Warmblood horse breeds included warmblood horses and crosses (36%); Dutch Warmblood and crosses (19%); Holsteiner and crosses (17%); Hanoverian and crosses (14%); Oldenburg and crosses (8%); Westphalian (3%); and 1% each Irish Sport Horse, Mecklenburg, and Trakehner. Warmblood and warmblood crosses were identified by owners, and information on specific warmblood breeds was not given for these individuals. Most warmblood horses were geldings (74%), used as hunters (51%) or jumpers (43%), or both (6%), with an average age ± SD of 9.7 ± 3.5 years, BW ± SD of 604 ± 51 kg, and BCS ± SD of 5.3 ± 0.6. Only 2% of warmblood horses were considered overweight with a BCS of ≥7. Warmblood horses had lower BW ($P < .0001$) and BCS ($P < .001$) compared with draft horses.

The mean BCS of warmblood horses observed in the present study was similar to previous reports for adult horses that ranged from 5.4 to 5.8 (Brooks et al.; 2010, Pratt-Phillips et al.; 2010, Martinson et al.; 2014 and Owen et al.; 2008). The mean draft horse BCS observed in the present study was similar to previously reported values for draft breeds (Brooks et al.; 2010 and Pratt-Phillips et al.; 2010) and ponies (Martinson et al.; 2014). The difference between draft and warmblood BCS may be related to show ring standards and requirements for performance. When pulling a hitch, greater size may be beneficial. In contrast, warmblood horses in the hunter and jumper disciplines likely require a more ideal BCS to complete a jump course in a timely manner. However, the BCS system (Henneke et al.; 1983) was developed using stock-type broodmares to determine the minimum body condition for conception and pregnancy. With documented differences in breed-type morphology (Brooks et al.; 2010, Pratt-Phillips et al.; 2010, Martinson et al.; 2014, Owen et al.; 2008 and Sadek et al.; 2006), future research should focus on determining how different breed types accumulate adipose tissue and how that impacts the ideal BCS for different horse breeds, including draft and warmblood horses. Further research is also needed to examine the rates of obesity in draft horses and the effect of show ring standards on horse management and welfare.

Estimation of Actual BW

Girth and neck circumferences, height, and BL (BL straight) were used from all individuals (n = 227) to develop BW estimation equations. Breed types were initially combined into one model; however, the model was improved by separating each breed type into individual equations. The resulting equation for estimating BW was [girth $(\text{cm})^{1.528}$ × BL straight $(\text{cm})^{0.574}$ × height $(\text{cm})^{0.246}$ × neck $(\text{cm})^{0.261}$]/1,181 (draft) or 1,209 (warmblood)] (R^2 = 0.96; rMSE = 28 kg).

This equation is an improvement over the equations developed by Hall (1971) (R^2 = 0.94; rMSE = 33 kg) and Martinson et al (2014) (R^2 = 0.95; rMSE = 30 kg). These results demonstrate that draft and warmblood horse BW estimation is improved when breed type, height, and neck circumference are added to BW estimation equations (Fig. 4). Adding additional morphometric measurements and breed type should lead to more accurate BW estimation equations. Including breed type was also shown to improve accuracy in estimating the BW of Criollo horses (Neder et al., 2009), miniature horses (Bruce et al., 2010), as well as Arabians, ponies, and stock horses (Martinson et al., 2014).

Estimation of Ideal BW

Ideal BW was estimated by taking {[4.92 × BL straight (cm)] + [4.64 × height (cm)] − 951 (draft) or 1,016 (WB)} (R^2 = 0.90; rMSE = 33 kg). The rMSE of 33 kg translates to approximately 132 kg (at the 95% confidence level) or 15% and 22% of an average adult draft (851 kg) and warmblood (603 kg) horse BW, respectively. The ideal BW range for both draft and warmblood horses is similar to past research using other horse breeds and humans. Martinson et al (2014) determined that the ideal BW range for adult light horse breeds and ponies was 20% and 30%, respectively. In the model used for humans, the ideal BW range increases with height and is approximately 27% (Willet et al., 1999).Table 5 lists horse scale BW, ideal BW, and the difference between the two based on BCS for the two breed types. As BCS increases, the difference between scale and ideal BW also increases due to additional adipose tissue found on horses with higher BCS. The estimated ideal BW reflects the need for BW loss in horses with higher BCS. Conversely, the estimated ideal BW can help confirm the necessity for BW gain in horses with lower BCS.

The amount of BW loss or gain necessary to achieve a change in BCS has not been well studied. Researchers have suggested that the amount of BW gain (or loss) necessary to change a BCS likely depends on the mature BW of the equine (Nutrient Requirements of Horses, 2007). Heusner (1993) estimated an increase in one unit of BCS required 16 to 20 kg of BW gain for mature horses. More recently, Martinson et al (2014) determined that the differences between each BCS averaged 15 (3.5% of BW), 10 (3.0% of BW), and 17 (3.3% of BW) kg for Arabians, ponies, and stock horses, respectively. In the present study, when ideal BW was estimated for each equine and subtracted from the scale BW, the differences between each BCS averaged 39 (4.6% of BW) and 17 kg (2.8% of BW) for draft and warmblood horses, respectively (Table 5). By taking the difference between scale and ideal BW, the physical size (i.e., height and BL) of the equine is taken into consideration. The amount of BW necessary to change one BCS for warmblood horses is similar to previous research (Martinson et al.; 2014 and Huesner; 1993), whereas the value is greater for draft horses. This is expected as draft horses have larger BW and morphometric measurements compared previously studied horse breeds

(Martinson et al.; 2014). Owners and professionals can use the calculated ideal BW and amounts of BW necessary to change BCS as target values when designing diets for overweight or underweight horses. However, additional research into the amount of BW necessary to change one BCS is warranted. It has been suggested that the amount of BW necessary to observe a 1-U change in BCS may not be linear and may differ when increasing or decreasing BCS (Dugdale et al., 2012).

Development of a BW Score

To assess the likelihood that an individual is overweight based on morphometric measurements, an ordinal logistic regression was fit on BCS. This resulted in the following equation (without intercept): 0.028 (estimated ideal BW − estimated BW). To obtain a score between 0 and 100%, scores were converted to a percentile by standardizing the mean (9.86) and SD (42) of the score for equines in the same breed type with a BCS of 5 and finding the normal percentile. For example, an equine that is in the 80th percentile has a BW score that is greater than 80% of normal individuals. A ROC curve analysis was used to determine cutoff values for overweight (BCS ≥7) individuals; the cutoff value was the 87th percentile. Based on this cutoff value, the sensitivity was 0.74 and the specificity was 0.68 for detecting overweight horses (Fig. 5). The cutoff value for overweight draft and warmblood horses (87th percentile) is similar to the value found by Martinson et al (2014) for lightweight horses and ponies (83rd percentile).

Owner Estimated BWs

Horse owners and handlers at both the draft and warmblood horse show accurately estimated horse BW (R^2 = 0.87). Although there was no difference between mean guessed and actual BW, there was a wide range in the difference between these values (−348 to +614 kg). On average, horse owners and handlers were 52 kg off the actual BW (rMSE: 52.2 kg; Fig. 4). Misjudging horse BW by 52 kg could have serious implications for nutrition and health management.

The current results disagree with previous research. Mottet et al (2009) found that of 144 obese horses, horse owners inaccurately reported their horse as not obese 36% of the time and indicated the likelihood of owner inaccuracy in assessing BCS and BW in horses was high. In the present study, there was no difference between mean guessed and actual BW. However, draft horse owners and handlers had multiple horses that were usually weighed in pairs. As a result, it likely became easier to more accurately guess the BW of the second horse in the pair and additional horses in the hitch. Similarly, multiple warmblood horses from the same barn were weighed, and owners and handlers frequently discussed BW with other exhibitors resulting in a better estimate of horse BW.

Healthy Horse App

To remove the technical barriers that may inhibit some horse owners and professionals from using the new BW-related equations, the equations will be added to the fee-based “Healthy Horse” app available for use with Android (Google Play store) and Apple (iTunes store) operating systems. App users select a breed type (draft, warmblood, Arabian, miniature horse, pony, saddle, or stock), enter the height, girth circumference, BL straight, and neck circumference, and the app calculates the equines estimated BW and ideal BW. Bodyweight estimations for Arabian, ponies, and stock horses were developed by Martinson et al (2014), saddle type equations were developed by Hall (1971), and miniature horse equations by Bruce et al (2010). Saddle and miniature horse owners are instructed to use BL wrap measurements when estimating horse BW, and these horse owners do not receive information on ideal BW, as the equations have not yet been developed for these breed types.

4.0 Conclusions

Draft and warmblood horses exhibited at two Minnesota shows had a mean BCS of 6.3 and 5.3, respectively, and 42% and 2% of draft and warmblood horses, respectively, were considered overweight based on a BCS ≥7. Draft horses had greater BW and BCS compared with warmblood horses. Dividing horses into breed types and adding height and neck circumference resulted in improved BW estimation equations. Height and BL were used to develop ideal BW equations, and differences between ideal BW and scale BW averaged 39 and 17 kg per BCS for draft and warmblood horses, respectively. A BW score was developed, and the model suggested a cutoff at the 87th percentile for overweight horses. All equations will be added to the fee-based “Healthy Horse” app. Horse owners and handlers accurately estimated horse BW but were 52 kg off the actual BW.

Development of more accurate equations to estimate equine BW and the newly developed ideal BW equations should help draft and warmblood owners and professionals manage horses, especially individuals who are overweight or underweight. Owners and professionals can use results from both equations, along with BCS, to better manage horse BW, to design diets with appropriate caloric intake, and to establish BW goals.

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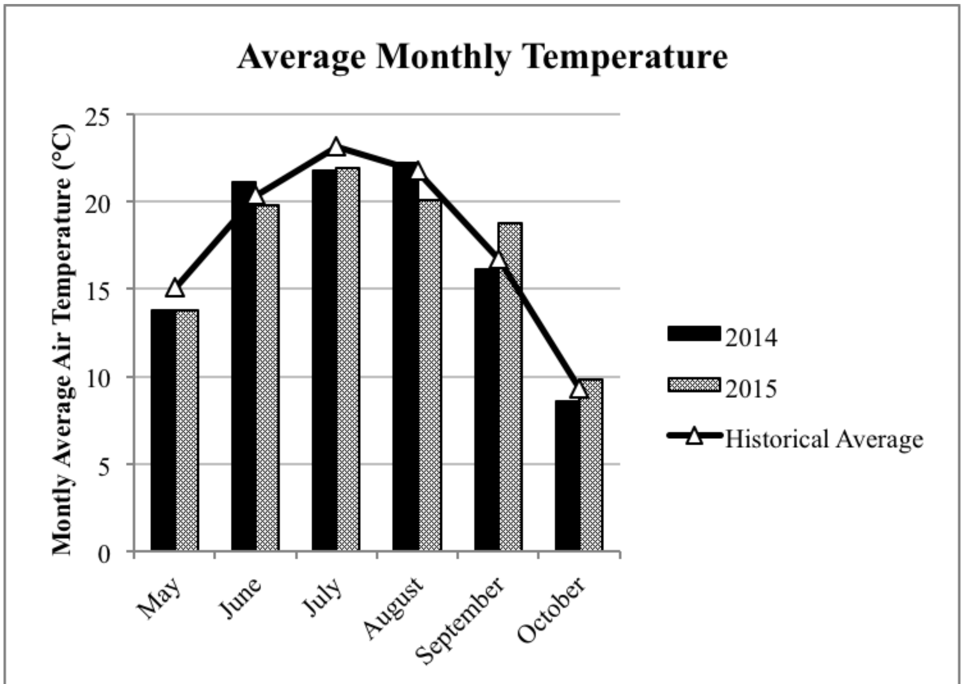
Appendix

Figure 1. Monthly air temperature (°C), precipitation (cm) and 30-year historical average for St. Paul, MN during the 2014 and 2015 grazing seasons. Weather data obtained from (http://www.dnr.state.mn.us/climate/historical/index.html)



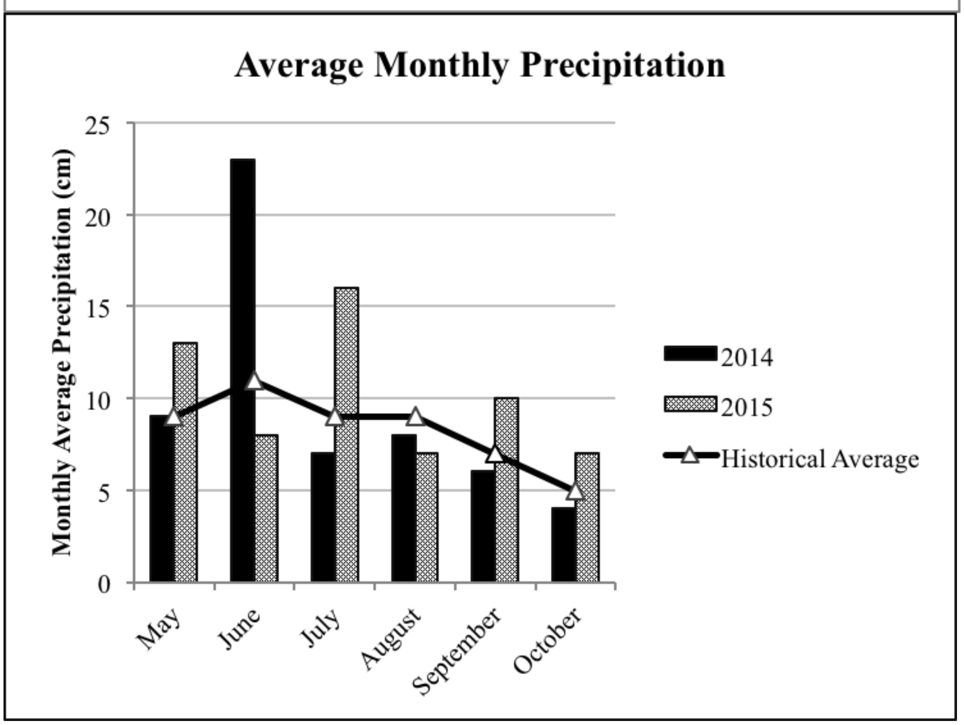


Table 1. Digestible energy (DE), crude protein (CP), nonstructural carbohydrates (NSC), neutral detergent fiber (NDF) and calcium: phosphorus ratio (Ca:P) of legume (monoculture) and legume grass binary mixtures (mix) under horse grazing in 2014 in St. Paul, MN.

	DE		CP		NSC		NDF		Ca:P	
	Mcal/kg		% DM							
Variety	Monoculture	Mix	Monoculture	Mix	Monoculture	Mix	Monoculture	Mix	Monoculture	Mix
401Z+	2.58^{b}	2.42	29.00	27.96	8.62^{b}	8.18^{b}	34.36^{ab}	41.69^{ab}	3.29:1^{a}	2.63:1^{c}
BlueJay HR	2.59^{b}	2.51	28.80	27.90	9.15^{b}	8.38^{b}	34.12^{ab}	39.23^{ab}	3.38:1^{a}	3.38:1^{ab}
Cutting Edge	2.56^{bc}	2.51	28.50	27.30	8.89^{b}	8.73^{ab}	35.35^{ab}	39.07^{ab}	3.40:1^{a}	3.36:1^{ab}
FD 2	2.60^{b}	2.51	29.60	28.43	8.47^{b}	8.80^{ab}	33.45^{b}	38.88^{ab}	3.24:1^{a}	2.88:1^{bc}
FD 3	2.55^{bc}	2.58	28.53	28.75	8.19^{b}	7.73^{b}	35.47^{ab}	36.01^{b}	3.34:1^{a}	3.32:1^{ab}
FD 4	2.58^{b}	2.50	28.49	27.49	9.20^{b}	8.58^{ab}	34.66^{ab}	39.41^{ab}	3.39:1^{a}	3.22:1^{ab}
FD 5	2.58^{b}	2.56	28.75	27.93	9.14^{b}	8.87^{ab}	34.46^{ab}	37.06^{ab}	3.43:1^{a}	3.65:1^{a}
Freedom MR†	2.48^{c}	2.42	28.72	27.51	9.53^{b}	9.53^{ab}	38.37^{a}	42.71^{ab}	3.55:1^{a}	2.97:1^{bc}
Kopu II‡	2.75^{a}	2.41	30.93	26.10	11.07^{a}	11.08^{a}	27.75^{c}	43.92^{a}	2.69:1^{b}	3.01:1^{bc}
Red Falcon	2.61^{b}	2.53	29.48	28.30	9.08^{b}	8.54^{ab}	32.67^{bc}	38.30^{ab}	3.43:1^{a}	1.96:1^{d}
P-Value	*<0.0001*	*0.0561*	*0.1637*	*0.2893*	*<0.0001*	*0.0078*	*<0.0001*	*0.0074*	*<0.0001*	*<0.0001*

^{abcd} Means without a common superscript within each column differ ($P < 0.05$)

†Denotes red clover variety

‡Denotes white clover variety

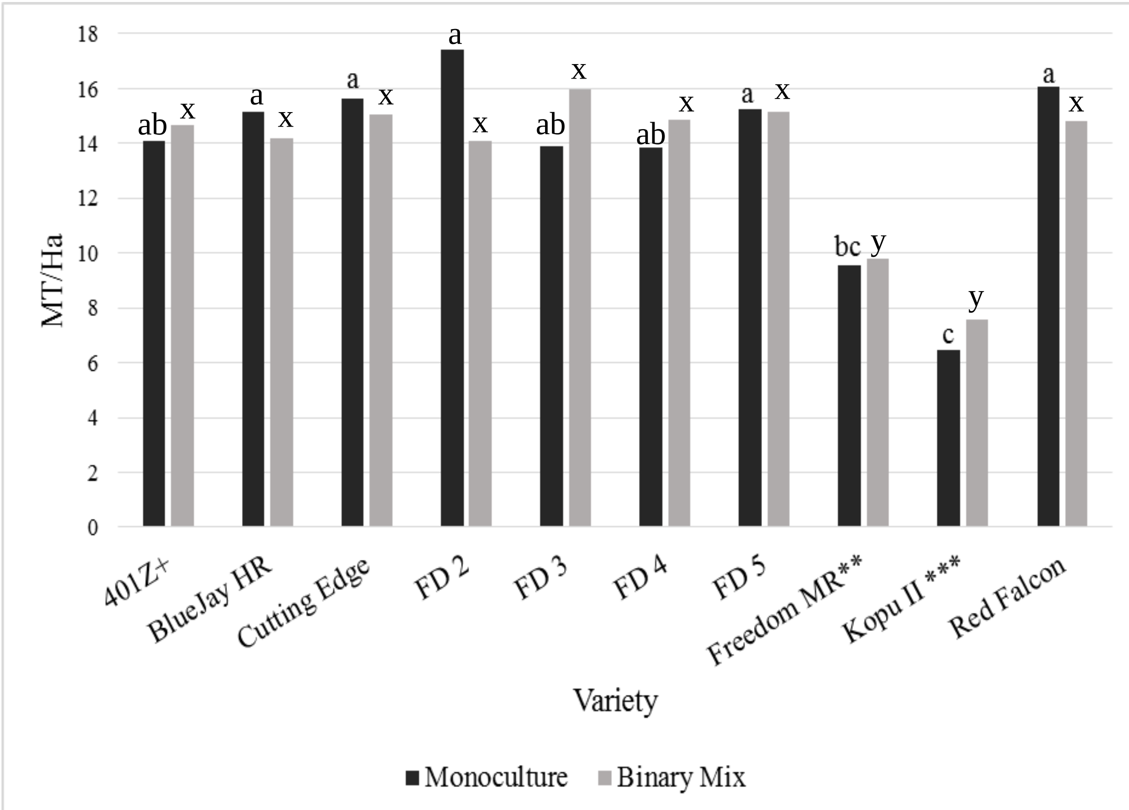
Table 2. Digestible energy (DE), crude protein (CP), nonstructural carbohydrates (NSC), neutral detergent fiber (NDF) and calcium: phosphorus ratio (Ca:P) of legume (monoculture) and legume grass binary mixtures (mix) under horse grazing in 2015 in St. Paul, MN

	DE		CP		NSC		NDF		Ca:P	
	Mcal/kg		% DM							
Variety	Monoculture	Mix	Monoculture	Mix	Monoculture	Mix	Monoculture	Mix	Monoculture	Mix
401Z+	2.66^{a}	2.63^{a}	26.53^{a}	24.43	15.40^{abc}	15.80^{ab}	32.25^{b}	34.26^{b}	2.66:1^{a}	2.63:1^{a}
BlueJay HR	2.65^{a}	2.57^{ab}	25.03^{abc}	24.43	15.08^{bc}	15.08^{ab}	33.15^{ab}	36.05^{ab}	2.65:1^{a}	2.57:1^{ab}
Cutting Edge	2.59^{ab}	2.52^{ab}	23.43^{c}	23.13	15.85^{abc}	15.33^{ab}	35.63^{ab}	38.53^{ab}	2.59:1^{ab}	2.52:1^{ab}
FD 2	2.64^{ab}	2.56^{ab}	24.09^{abc}	25.18	17.00^{abc}	15.50^{ab}	33.74^{ab}	36.43^{ab}	2.64:1^{ab}	2.56:1^{ab}
FD 3	2.59^{ab}	2.63^{a}	23.85^{bc}	24.20	15.30^{abc}	16.40^{ab}	35.78^{ab}	34.13^{b}	2.59:1^{ab}	2.63:1^{a}
FD 4	2.62^{ab}	2.53^{ab}	24.78^{abc}	23.60	14.43^{bc}	14.05^{ab}	34.35^{ab}	38.00^{ab}	2.62:1^{ab}	2.53:1^{ab}
FD 5	2.59^{ab}	2.64^{a}	24.23^{abc}	24.28	18.60^{ab}	16.80^{a}	35.40^{ab}	33.56^{b}	2.59:1^{ab}	2.64:1^{a}
Freedom MR†	2.49^{b}	2.42^{b}	26.75^{a}	25.40	13.50^{c}	13.30^{b}	38.75^{a}	41.53^{a}	2.49:1^{b}	2.42:1^{b}
Kopu II‡	2.71^{a}	2.58^{a}	26.25^{ab}	25.60	19.65^{a}	17.08^{a}	31.45^{b}	37.53^{ab}	2.71:1^{a}	2.58:1^{a}
Red Falcon	2.56^{ab}	2.53^{ab}	23.13^{c}	23.03	15.80^{abc}	15.48^{ab}	36.28^{ab}	37.93^{ab}	2.58:1^{ab}	2.53:1^{ab}
P-Value	*0.0033*	*0.0020*	*<0.0001*	*0.0533*	*0.0023*	*0.0078*	*0.0086*	*0.0092*	*0.0041*	*0.0076*

^{abcd} Means without a common superscript within each column differ ($P < 0.05$)
†Denotes red clover variety
‡Denotes white clover variety

Figure 2. Total yield for legumes and legume cool-season grass mixtures during the 2014 (A) and 2015 (B) grazing seasons in St. Paul, MN.

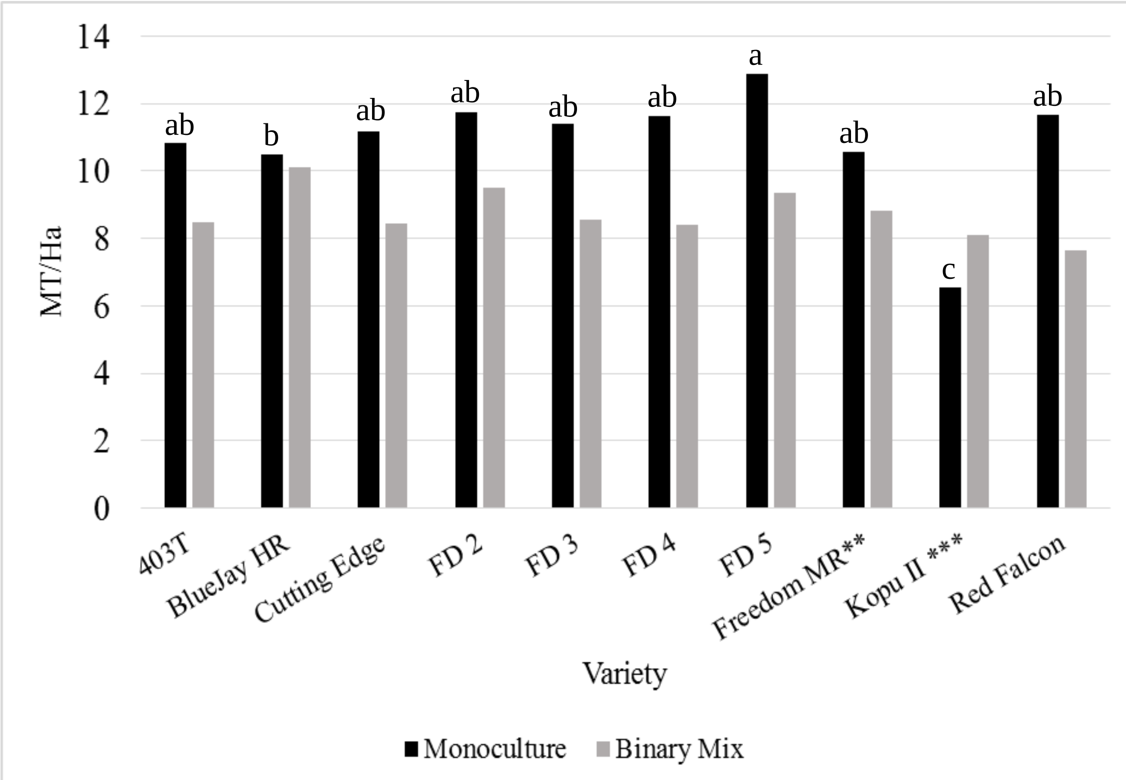
A.



abc Means without a common superscript differ ($P \leq 0.05$)

xy Means without a common superscript differ ($P \leq 0.05$)

B.



abc means without a common superscript differ ($P \leq 0.05$)

Figure 3. Morphometric measurements collected on 227 adult draft and Warmblood horses in Minnesota, including neck circumference located halfway between the poll and the withers (A), height at the third thoracic vertebra (B), girth circumference at the third thoracic vertebra (C), body length (straight) from the point of the shoulder to a point perpendicular to the point of the buttock (D), and body length (wrap) from the point of the shoulder to the point of the buttock (E).

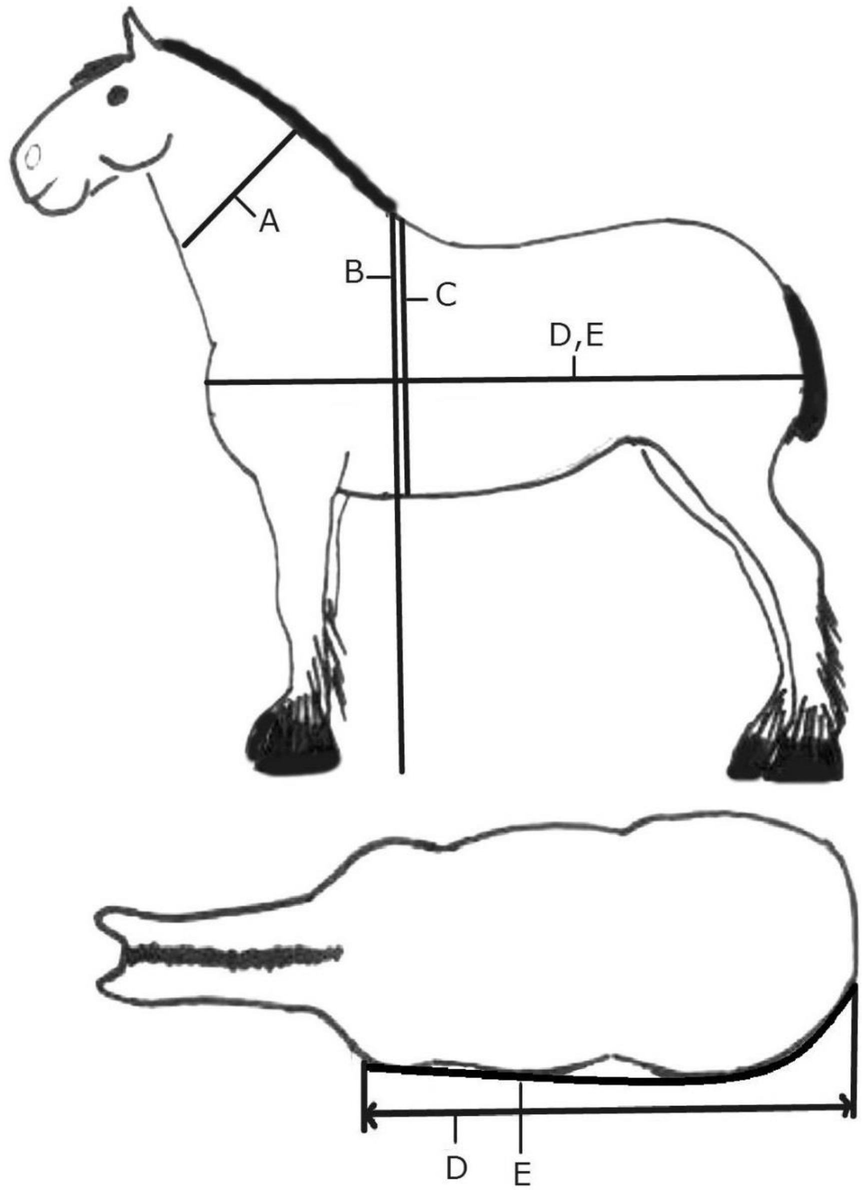


Table 3. Legume to cool-season grass ratio immediately prior to each grazing in 2015 (represented as Legume:Grass) in St. Paul, MN.

Variety	1st Grazing	2nd Grazing	3rd Grazing
403T	3.8:1	5.0:1[b]	2.3:1[b]
BlueJay HR	6.0:1	12.5:1[ab]	5.5:1[ab]
Cutting Edge	7.6:1	9.6:1[b]	3.5:1[ab]
FD 2	5.7:1	7.7:1[b]	3.2:1[ab]
FD 3	4.1:1	31.6:1[a]	13.4:1[a]
FD 4	11.6:1	6.7:1[b]	4.6:1[ab]
FD 5	5.9:1	20.7:1[ab]	12.4:1[ab]
Freedom MR*	12.5:1	9.2:1[b]	4.8:1[ab]
Kopu II**	7.1:1	4.4:1[b]	2.6:1[b]
Red Falcon	4.3:1	8.2:1[b]	5.7:1[ab]

[ab] Means without a common superscript differ ($P < 0.05$)
*Denotes red clover variety
**Denotes white clover variety

Figure 4. Residuals of the draft and warmblood data fit to four different models: owner guessed weight (Guessed Weight), Hall (1971, Hall Equation), Martinson et al. (2014, Martinson Stock Equation), and the newly developed bodyweight estimation equation (New Equation) for adult draft and warmblood horses.

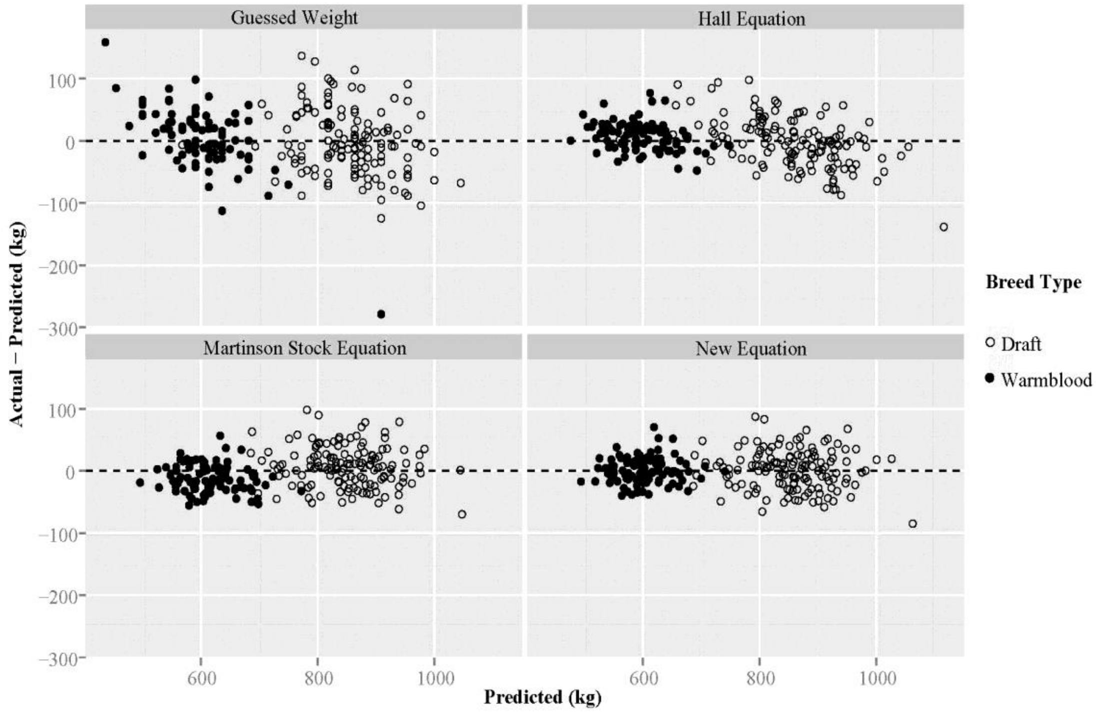


Table 4. Description of breed types, breeds, and mean age, body condition score (BCS), morphometric measurements, and bodyweights (BW) of 227 adult draft and warmblood horses obtained at two shows in Minnesota in 2014.

Type	Breed or Breed Registry	Total	BCS = 5	BCS	Age	Height	BL straight[2]	BL wrap[3]	Girth Circ.[4]	Neck Circ.[5]	Scale Weight
		n			year			cm			kg
Draft	Percheron	84	15	6.4 ± 0.9	6.9 ± 3.2	179 ± 4	188 ± 7	201 ± 7	226 ± 9	126 ± 6	862 ± 69
	Belgian	34	8	6.2 ± 1.0	6.3 ± 2.5	178 ± 7	186 ± 8	199 ± 9	226 ± 9	128 ± 6	859 ± 82
	Clydesdale	15	1	6.3 ± 0.7	6.3 ± 2.2	174 ± 4	183 ± 9	194 ± 9	221 ± 10	122 ± 6	787 ± 90
	Shire	5	0	6.6 ± 0.5	6.6 ± 1.8	176 ± 5	186 ± 6	197 ± 6	221 ± 5	124 ± 6	843 ± 75
Draft Mean		138	24	6.3 ± 0.9	6.7 ± 2.9	178 ± 5	187 ± 7	200 ± 8	225 ± 9	126 ± 6	853 ± 78
Warmblood	Warmblood and crosses[1]	32	25	5.2 ± 0.4	9.9 ± 3.4	167 ± 5	171 + 6	180 ± 7	198 ± 5	100 ± 6	602 ± 54
	Dutch Warmblood and crosses[1]	17	11	5.3 ± 0.5	8.2 ± 2.4	168 ± 5	171 ± 6	179 ± 7	199 ± 7	101 ± 4	607 ± 51
	Holsteiner and crosses[1]	15	11	5.1 ± 0.5	8.0 ± 2.5	168 ± 6	170 ± 6	178 ± 6	199 ± 6	99 ± 6	610 ± 48
	Hanoverian and crosses[1]	12	9	5.2 ± 0.5	12.4 ± 3.1	166 ± 5	172 ± 7	180 ± 7	201 ± 6	102 ± 4	612 ± 42
	Oldenburg and crosses[1]	7	3	5.3 ± 0.8	8.4 ± 2.9	165 ± 4	167 ± 3	175 ± 4	196 ± 4	100 ± 3	572 ± 31
	Westphalian	3	2	6 ± 1	16 ± 7	168 ± 13	174 ± 7	182 ± 7	201 ± 15	100 ± 12	612 ± 120
	Irish Sport Horse	1	0	7	9	157	168	177	197	97	595
	Mecklenburg	1	0	6	10	175	174	180	208	100	636
	Trakehner	1	0	6	7	166	163	173	201	103	613
Warmblood Mean		89	61	5.3 ± 0.6	9.7 ± 3.5	167 ± 5	170 ± 6	179 ± 7	199 ± 6	100 ± 5	604 ± 51

[1]Equines in these breeds included purebred equines and multiple breed crosses that included one parent from the designated breed
[2]Body length straight
[3]Body length wrap
[4]Girth circumference
[5]Neck circumference

Figure 5. Determination of cutoff values for overweight (BCS ≥ 7) horse based on ROC curve analysis of 227 adult draft and warmblood horses exhibited at two shows in Minnesota in 2014.

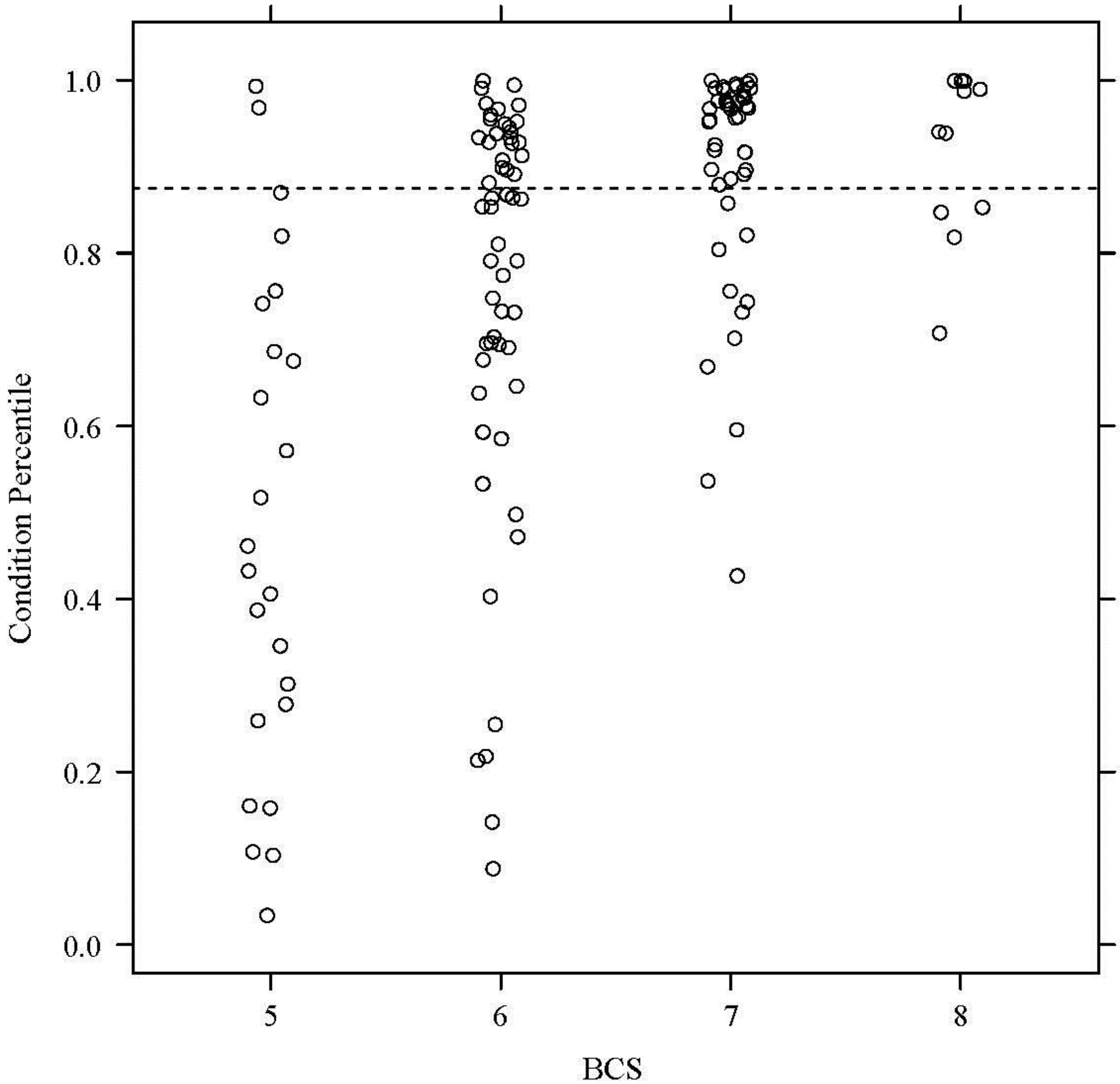


Table 5. Scale weight, ideal weight, and the difference between the two based on body condition scores (BCS) for adult draft and warmblood horses obtained from two shows in Minnesota in 2014 (mean ± SD).

	Draft			Warmblood		
	Scale Weight	Ideal[1] Weight	Difference	Scale Weight	Ideal Weight	Difference
BCS	kg					
4[2]				593 ± 58	604 ± 36	-11 ± 32
5	787 ± 81	790 ± 60	-3 ± 41	599 ± 54	603 ± 50	-4 ± 30
6	835 ± 62	789 ± 43	46 ± 28	620 ± 43	599 ± 40	21 ± 28
7	893 ± 61	809 ± 51	84 ± 41	596 ± 2	557 ± 25	39 ± 23
8[2]	926 ± 56	812 ± 53	114 ± 56			

[1]Ideal BW (kg) calculated as [(4.92 x BL straight (cm)) + (4.64 x height (cm)) – 951 (draft) or 1,016 (WB)]

[2]No draft horses received a BCS of 4 while no warmblood horses received a BCS of 8