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THOROUGHBRED GROWTH AND FUTURE RACING PERFORMANCE

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Introduction

The success of a Thoroughbred racehorse is determined by a multitude of factors, many of which are impossible to evaluate. Thoroughbreds are commonly selected for racing ability by pedigree and conformation analysis. There have been few studies associating growth and body size with racing performance (Pagan, 1998a; Cain, 2006; Smith et al., 2006).

The genetic make-up, or genotype, contributes to a horse's racing ability by influencing physical characteristics including conformation, lung capacity, and growth potential, and mental attributes including the "will to win." Environmental factors such as nutrition, exercise, and conditioning are difficult to quantify, and management during growth and development as well as trainer variation all influence the horse's potential for success. Many methods of anatomical or pre-competitive performance assessment are employed by Thoroughbred breeders, trainers, bloodstock agents, and owners. However, these methods are subjective and there have been no established and fail-proof methods for predicting potential success.

A large retrospective study conducted by Cecil Seaman of Thoroughbred Analysts using body measurements taken at Thoroughbred sales concluded that horses in the "underweight" to "ideal weight" (±2% optimum weight) range earned significantly more than those in the "overweight" to "obese" categories (Pagan, 1998a; Cain, 2006). However, body weights in this study were estimated and not actually measured.

A study of 260 Thoroughbreds born in 1981 and 1982 described associations between yearling body measurements and racing performance (Smith et al., 2006). It was reported that hip height, body length, and heart girth were positively correlated with win percentage (number of wins/number of starts). There were no significant correlations between any body measurement and lifetime earnings; however, the study reported a trend linking taller fillies and greater earnings. Horses that won or placed in a stakes race tended to be taller as yearlings.

Mature size and the pattern of growth are influenced by the genetic make-up of the horse and the environment, but it is inconclusive if growth plays a role in the success of a racehorse. It is known that heavier foals have a greater incidence of osteochondrosis (Pagan, 1998b). Foals that developed hock and stifle OCD tended to be heavier at birth and fast-growing between 3 and 8 months. Furthermore, it is reported that heavier but not taller yearlings command higher prices at public auction (Pagan et al., 2005).

The purpose of this study in Thoroughbreds was to make objective measurements of a horse's growth to determine if certain characteristics affect the odds of its success as a racehorse.

Materials and Method

Racing performance data were collected from 3,734 Thoroughbreds raised in the USA between 1996 and 2002 and their growth records were retrospectively examined to determine if various growth characteristics could be associated with success as a racehorse.

The population consisted of 1,850 fillies and 1,884 colts raised on 55 commercial and private farms in the states of Kentucky (n=3,199), California (n=183), and Virginia (n=352). The population was represented by 456 sires.

Growth measurements (body weight using an electronic scale and wither height) were taken approximately every 30 days; however, the number of records per horse ranged from 1 to 18. Growth variables were converted into percentiles and quartiles for analysis. Percentiles and quartiles provided a standard unit of measurement to compare an individual horse to the population. Percentiles rank the relative position of an individual in the population by indicating what percent of the reference population that individual will equal or exceed. The 50th percentile is the median. Percentiles take into account the spread of data around the mean. The reference growth population used was the USA Thoroughbred separated for fillies and colts. This reference population was created by Kentucky Equine Research using data from approximately 7000 Thoroughbreds.

Racing results were collected from the American Produce Records (Bloodstock Research Information Services Inc, Lexington, Kentucky, USA, 2006) and are complete up to October 2005. Variables recorded for each horse included registered name, total years raced and country(s) raced in, total number of starts, wins, shows and placings, total number of starts as a two-year-old, wins as a two-year-old, starts and wins on a turf track, dirt-sprint starts and wins, dirt-distance (> one mile) starts and wins, starts and wins on a muddy or sloppy track, and stakes wins and places (classified as either listed or graded stakes). Each horse's standard starts index (SSI), also known as the racing index (RI), was recorded. The SSI indicates the earning power of an individual based on average earnings per start and enables comparison of racing performance of horses regardless of year of birth or gender. An SSI of 1.00 represents the average for each crop.

To account for genetic variation, the sire index (SI), also known as the sire production index (SPI), was collected for each horse. The SI indicates the average racing class of foals sired by a stallion and is calculated by averaging the SSI of all the stallion's foals that have started three or more times in North America or Europe.

DATA ANALYSIS

Growth data were divided into four age groups: foal (1 month or 0-30 d), suckling (2-6 months or 31-180 d), weanling (7-12 months or 181-360 d), and yearling (13-18 months or 361-555 d). Within each age group, individuals had between 1 and 6 measurements. The averages of the growth percentiles were calculated so that each individual had 4 percentiles for weight and height over the study.

Percentile data were then grouped into quartiles, so that instead of dividing the data into 100 even divisions, the data were divided into 4 divisions. Animals could then be described in the first quartile (percentile of 0-25), the second quartile (percentile of 26-50), the third quartile (percentile of 51-75), and the fourth quartile (percentile of 76-100) for weight or height.

Using the racing performance data, observations were made regarding each horse's status as a racehorse. First, horses were catalogued as being "raced" or "unraced." Unraced horses were unnamed, named with no race record, or named and unraced. All the horses in the population were then classified as having started or not started as two-year-olds. Win percentage was calculated for horses that raced by dividing total number of wins by total number of starts.

The data were presented in two different ways. First, in each age group the average growth percentiles were compared between the two groups within each performance measure (raced vs. unraced, winners vs. non-winners, raced at two years old vs. not raced at two years old, stakes winners vs. not stakes winners, graded stakes winners vs. not graded stakes winners, and G1 winners vs. not G1 winners).

Second, for each age group (foal, suckling, weanling, and yearling) the percentage of raced, raced at two years old, winners, stakes winners, graded stakes winners, or G1 winners in each growth quartile (both weight and height) was calculated.

STATISTICAL ANALYSIS

Data for weight and height quartile (as the response variable) for each factor (raced, raced at two years old, winner, stakes winner, graded stakes winner, G1 winner) were analyzed using an analysis of variance with respect to age category. When a significant ($p<0.05$) main effect or interaction was found, multiple comparisons were made using the least significant difference method. Data for earnings, sire index, and number of starts for each quartile (weight and height as the factor) for each age group were also analyzed using an analysis of variance.

In each age group, the percentages of raced vs. unraced, winners vs. non-winners, raced at two years old vs. not raced at two years old, stakes winners vs. not stakes winners, graded stakes winners vs. not graded stakes winners, and G1 winners vs. not G1 winners were compared for the four quartiles using Pearson's Chi Square test statistics. P-values less than 0.05 indicate that the percentage of yes was significantly different among the four quartiles.

A logistic regression model was applied in each age group to predict the probability of being a stakes winner based on sire index, exact weight percentile, exact height percentile, and their various interactions.

Results are expressed as mean ± standard error of the mean (sem) unless otherwise indicated. Computations were done using JMP 6.0 (SAS, Inc., Cary, NC) and NCSS (Number Crunching Statistical Systems, Kaysville, UT).

Results

STUDY POPULATION AND RACING PERFORMANCE

Of the 3,734 foals, 79% (2,940) started in a race and 71% (2,088) of those won at least one race. More colts raced than fillies (82% vs. 74%) and of those, more colts than fillies won at least one race (73% vs. 69%). However, of those that raced, fewer colts started as two-year-olds than fillies (44% vs. 51%). There was no difference in the percentage of two-year-old winners (36% vs. 34% for colts and fillies respectively), but more colts than fillies won two-year-old stakes (9.2% vs. 4.6%) and G1 races at any age (1.2% vs. 0.9%) (Table 1).

Table 1. Summary of the study population.

Numbers	*Colts*	*Fillies*	*Total*
Born	1884	1850	3734
Starters	1544	1396	2940
Winners (horses that won at least one race)	1124	964	2088
Repeat winners	797	605	1402
Raced as two-year-old	673	714	1387
Winner as two-year-old	245	243	488
Registered names	1814	1800	3614
Named unraced	270	404	674
Unnamed	70	50	120
Total unraced	340	454	794
Two-year-old stakes winners	47	33	80
Stakes winners	143	122	265
Stakes placed	249	205	454
Graded stakes winners	67	40	107
G1 winners	18	13	31
Millionaires	13	8	21

The majority of starters (60%) had racing careers of one to two years (66% fillies and 55% colts) while 14% of fillies and 26% of colts raced for four or more years.

Only two fillies compared with 24 colts in the data set raced for more than seven years (Table 2).

Table 2. Summary of years raced in the racing careers of the study population.

Years raced in career	*Colts*	*Fillies*	*Total*
1	366	382	748 (25.4%)
2	477	544	1021 (34.7%)
3	299	299	598
4	197	114	311
5	119	45	164
6	62	10	72
7+	24	2	26
Average number of years raced ± SD	2.69 ± 1.50	2.24 ± 1.10	
Median number of years raced (range)	2 (1-10)	2 (1-7)	

The number of career starts ranged from 1 to 85 with a median of 11 and an average of 15 ± 13.4 (SD) (Table 3). Average earnings per starter were $79,384 (median = $27,187), and average career earnings for colts and fillies were $93,184 vs. $64,143 respectively. Colts also earned more per start than fillies ($5,913 vs. $4,730). The average SSI of all starters was 1.92 (1.96 vs. 1.87 for colts and fillies respectively).

A total of 2,565 (84.2%) starters in this study raced in the USA and of those, 56 also raced overseas. The most common racing destination after the USA was the UK (218 horses) followed by Japan (122 horses), France (57), UAE (29), Puerto Rico (31), Italy (16), Germany (3), and Panama (2). Brazil, Hong Kong, South Africa, and Turkey had one horse each from the data.

In contrast with the breed average, the population of horses in this study had a greater number of starters (79% vs. 70%), winners/foals (56% vs. 47%), repeat winners/foals (37.5% vs. 35.9%), stakes winners (7.1% vs. 3.5%), graded stakes winners (2.9% vs. 0.8%), and G1 winners (0.8% vs. 0.2%) (Table 4).

In addition, the horses in this study had fewer career starts compared with the breed average (15 vs. 21), but greater average earnings per start ($5,352 vs. $1,723). Although in both this study and in the breed average, fillies earned less per start than colts, the difference between these was greater in the current study with the average earnings per start for fillies at 80.0% of colts compared with 92.3% in the total population.

Table 3. Summary of racing statistics from the study population.

KER racehorse population (3734 horses born between 1996 and 2002)	
Starters/foals	78.7%
Winners/foals (starters)	55.9% (71.0%)
Repeat winners/foals (starters)	37.5% (47.6%)
Stakes winners/foals (starters)	7.1% (9.0%)
Graded SW/foals (starters)	2.9% (3.6%)
Grade 1 SW/foals (starters)	0.8% (1.1%)
Stakes-placed/foals (starters)	12.2% (15.4%)
Two-year-old starters/foals (starter)	37.1% (47.2%)
Two-year-old winners/foals (% 2yo starters)	13.1% (35.2%)
Two-year-old SW/foals (% 2yo starters)	2.1% (5.8%)
Average career starts/foals (median)	11.8 (8)
Average career starts/starter (median)	14.9 (11)
Average earnings/starter (median)	$79,384 ($27,187)
Average earnings/starter male (female)	$93,164 ($64,143)
Average earnings/start (median)	$5,352 ($2,254)
Average earnings/start male (female)	$5,913 ($4,730)
Average racing index of sires	1.48
Average SSI of all starters	1.92

Table 4. Summary of racing statistics from the USA average for the breed.

Thoroughbred Times averages for the breed (all registered Thoroughbreds born between 1987 and 1996)	
Starters/foals	69.9%
Winners/foals (starters)	46.9% (67.1%)
Repeat winners/foals (starters)	35.9% (51.4%)
Stakes winners/foals (starters)	3.5% (5.0%)
Graded SW/foals (starters)	0.8% (1.1%)
Grade 1 SW/foals (starters)	0.2% (0.3%)
Stakes-placed/foals (starters)	5.5% (7.8%)
Two-year-old starters/foals	34.3%
Two-year-old winners/foals (% 2yo starters)	11.5% (33.5%)
Two-year-old sw/foals (% 2yo starters)	1% (3%)
Average career starts/foal	14.9
Average career starts/starter	21.3
Average earnings/starter	$36,682
Average earnings/starter male (female)	$43,505 ($29,593)
Average earnings/start	$1,723
Average earnings/start male (female)	$1,779 ($1,642)
Average SSI of all starters	1.16

WEIGHT AND HEIGHT PERCENTILES AT DIFFERENT AGES

There was no difference in body weight percentile or height percentile between horses that were raced versus unraced as foals, sucklings, and weanlings (P>0.05). Yearlings that raced had significantly lower average weight percentiles than those that did not (46.73 ± 0.32 vs. 49.01 ± 0.65, p<0.01) (Figure 1). Horses that raced as two-year-olds were significantly shorter and lighter than those that did not start as two-year-olds in all age groups (p<0.05) (Figure 2). There was no significant difference in body weight percentile or wither height percentile between winners and non-winners in all age groups. Stakes and graded stakes winners were heavier and taller than non-stakes winners as sucklings, weanlings, and yearlings, but there was no difference in weight percentiles as foals (Figure 3). G1 winners had significantly larger weight percentiles than non-G1 winners as sucklings, weanlings, and yearlings, but not as foals. There was no difference in height percentile between G1 winners and non-G1 winners as foals, sucklings, and weanlings; however, G1 winners had significantly larger height percentiles as yearlings than non-G1 winners (Table 5).

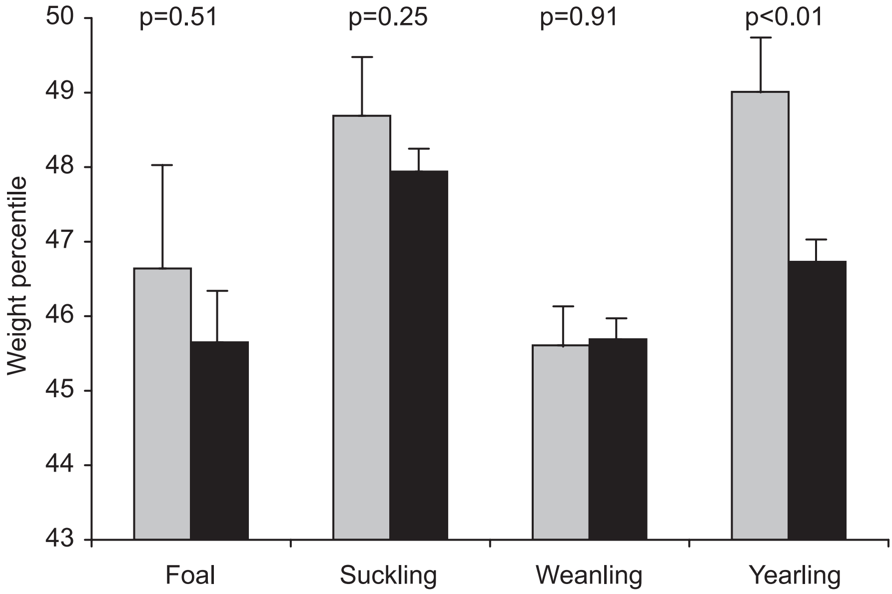

Figure 1. Weight percentile (mean ± sem) of raced (■)and unraced (□) horses as foals, sucklings, weanlings, and yearlings (p<0.01 indicates significant differences between factors).

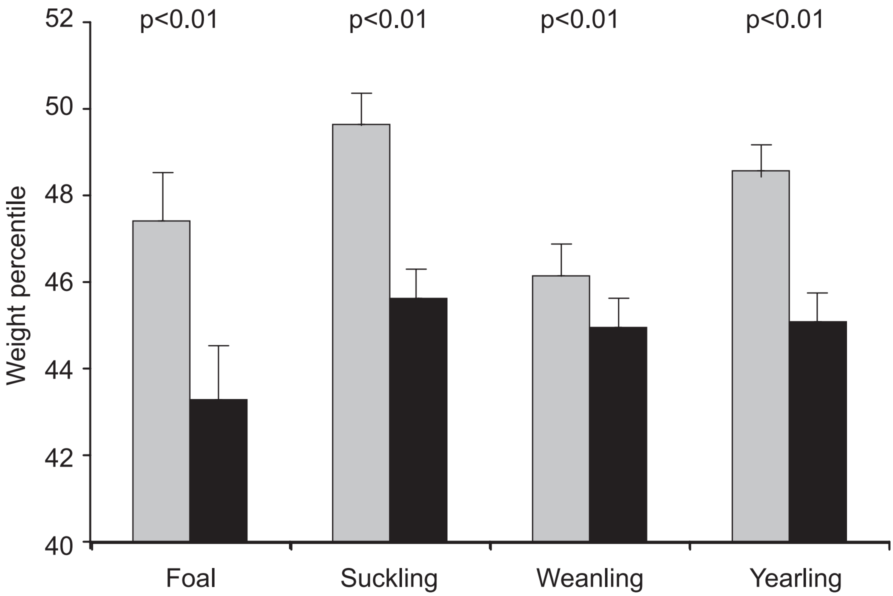

Figure 2. Weight percentile (mean ± sem) of horses that raced at two years old (■) and those that did not race at two years old (□) as foals, sucklings, weanlings, and yearlings (p<0.01 indicates significant differences between factors).

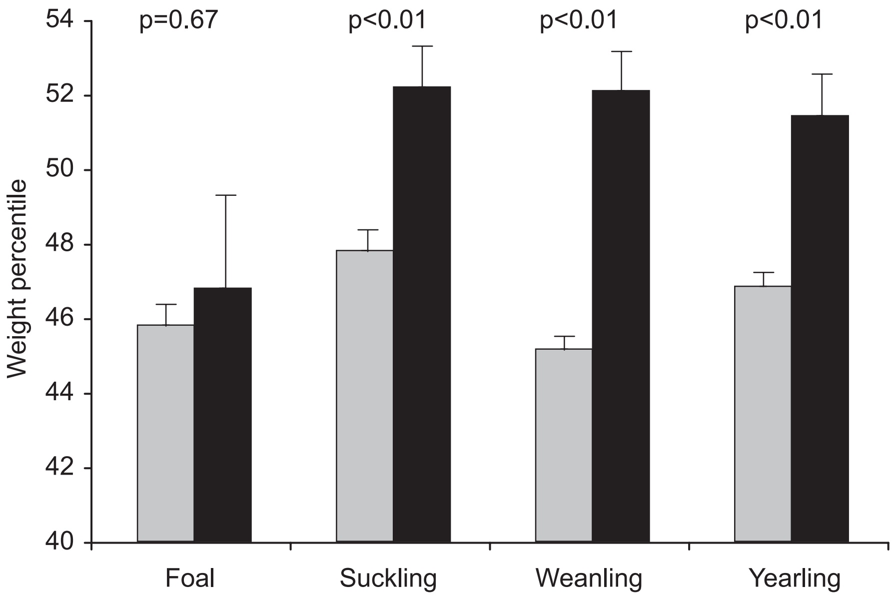

Figure 3. Weight percentile (mean ± sem) of stakes winners (■) and non-stakes winners (□) as foals, sucklings, weanlings, and yearlings (p<0.01 indicates significant differences between factors).

Table 5. Yearling weight and height percentiles (average ± sem) for each performance category.

	Weight percentile	*Height percentile*
All foals	47.2 ± 0.3	50.5 ± 0.3
Starters	46.7 ± 0.3	50.4 ± 0.4
Two-year-old starters	45.0 ± 0.5	48.6 ± 0.5
Winners	47.0 ± 0.4	51.0 ± 0.4
Stakes winners	51.3 ± 1.0	58.3 ± 1.2
Graded stakes winners	55.6 ± 1.6	63.6 ± 1.9
G1 stakes winners	53.8 ± 2.8	58.9 ± 3.7
Millionaires	60.9 ± 2.7	78.6 ± 3.2

SIRE INDEX

In all age groups, SI was significantly greater in the fourth weight and height quartile than in the first weight and height quartile (Figures 4 and 5). There was no significant difference in SI between raced and unraced horses as foals. However, as yearlings, raced horses had a significantly lower SI than unraced (2.23 ± 0.2 vs. 2.35 ± 0.03, $p<0.001$). Similarly, there was no difference in SI between winners and non-winners as foals, but as yearlings winners had a significantly lower SI than non-winners (2.18 ± 0.002 vs. 2.36 ± 0.002, $p<0.001$). Interestingly, horses that started as two-year-olds had significantly lower SI as foals and yearlings than those that did not ($p<0.01$).

Sire index of graded stakes winners was significantly greater in both foals and yearlings than those that did not win a graded stakes race (2.87 ± 0.11 vs. 2.33 ± 0.003 in foals and 2.60 ± 0.05 vs. 2.23 ± 0.001 in yearlings, $p<0.001$).

RACED AND RACED AS TWO-YEAR-OLDS

There was no significant difference in percentage of horses that raced across either weight or height quartiles at any age group; an even percentage of horses raced in each quartile. A greater percentage of horses ($p<0.05$) in the lower two weight and height quartiles in all age groups started as two-year-olds than in the upper two weight and height quartiles, indicating that smaller horses as foals, sucklings, weanlings, and yearlings are more likely to start as two-year-olds.

NUMBER OF STARTS

Horses in the lowest weight quartile at all age groups had significantly more starts than those in the upper weight quartile (13 vs. 9 starts in the first and fourth foal weight quartiles, and 14 vs. 10 starts in the first and fourth yearling weight quartiles, $p<0.01$).

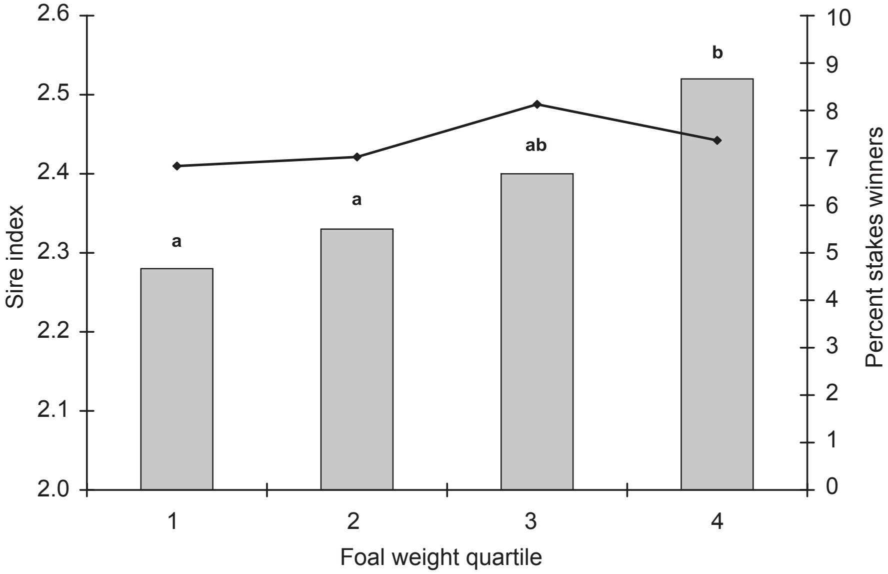

Figure 4. Sire index (□) and percent stakes winners (-◆-) in each foal weight percentile (a, b, etc.; different letters within a factor indicate significant differences).

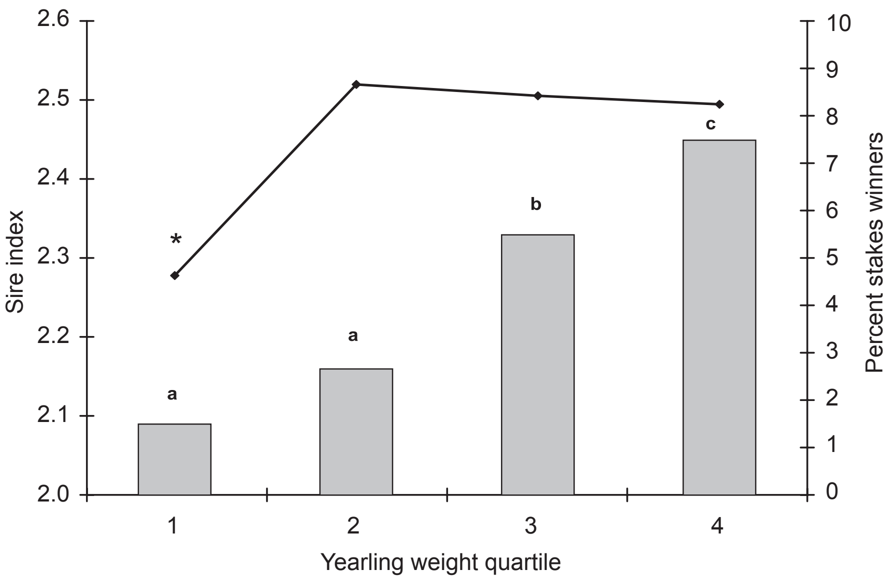

Figure 5. Sire index (□) and percent stakes winners (-◆-) in each yearling weight percentile (* $p<0.01$) (a, b, etc.; different letters within a factor indicate significant differences).

WINNERS AND WIN PERCENTAGE

Significantly fewer foals in the fourth weight quartile went on to become winners (53% versus 60%, 62% and 59% in the first, second, and third foal weight quartiles, respectively ($p<0.05$). However, as sucklings and weanlings this trend was reversed as there were significantly fewer winners in the first weight quartile ($p<0.05$) than in the second, third, and fourth quartiles. There was no significant difference in the percentage of winners in each weight quartile as yearlings, where approximately 60% in each weight quartile went on to become winners. There was no significant difference in the percentage of winners across height percentile in each of the age groups ($p>0.05$). Win percentage of horses that started in a race was significantly greater in horses that were in the third and fourth weight and height quartiles as yearlings.

STAKES WINNERS

There were significantly fewer stakes winners in the first weight quartile as sucklings, weanlings, and yearlings (but not in foals) than in the second, third, or fourth weight quartiles. Fewer horses in all age groups in the first height quartile went on to win a stakes race than in the second, third, and fourth height quartiles (Figures 4 to 7).

GRADED STAKES WINNERS

There was no difference in percentage of graded stakes winners in each foal weight quartile as foals, but in sucklings and weanlings there were fewer graded stakes winners in the first weight quartile than in the second, third, or fourth. There were fewer graded stakes winners in the first yearling weight quartile (n=13) than in the other weight quartiles (n=17, 20, and 21 for the second, third, and fourth weight quartiles, respectively) and 7 times as many graded stakes winners in the fourth height quartile as yearlings (n=20) than in the first (n=3).

EARNINGS

There was no significant difference in the average earnings among the four weight or height quartiles as foals. However, as weanlings and yearlings there were significantly fewer earnings in the first quartile than in the second, third, and fourth quartiles for both weight and height (Figures 6 and 7).

LOGISTIC REGRESSION TO PREDICT STAKES WINNERS

In foals, height percentile was the only variable included in the model that significantly predicted the probability of being a stakes winner. Foals with greater height percentiles had a higher chance of becoming stakes winners. In sucklings and yearlings, sire index,

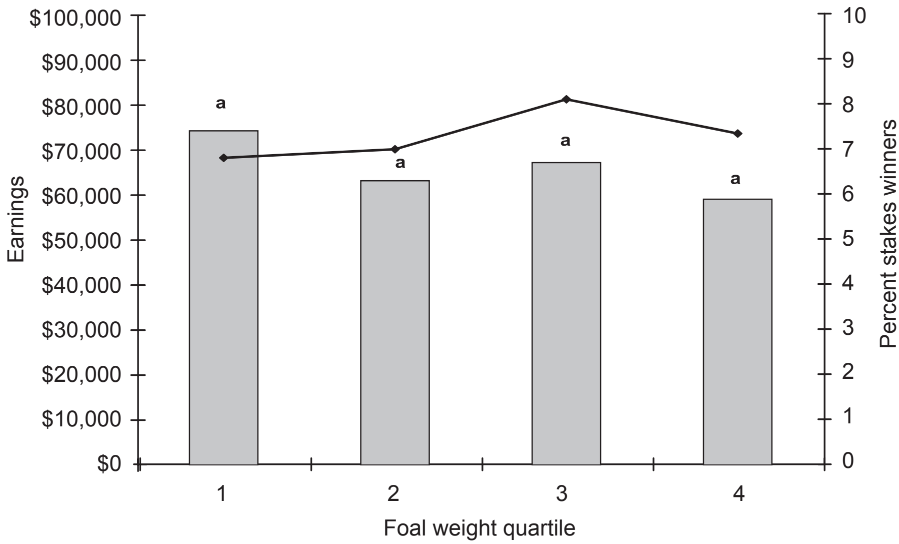

Figure 6. Average earnings (□) and percent stakes winners (-◆-) in each foal weight percentile (a, b, etc.; different letters within a factor indicate significant differences).

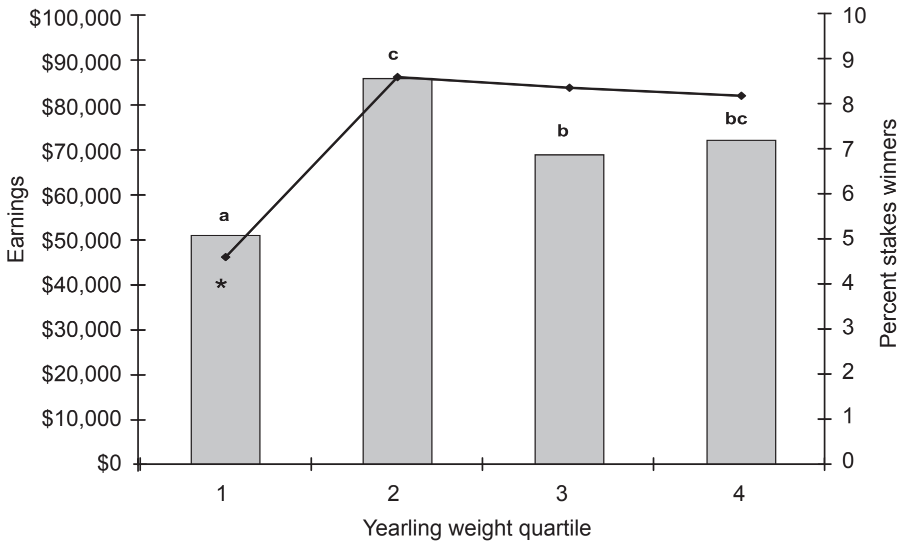

Figure 7. Average earnings (□) and percent stakes winners (-◆-) in each yearling weight percentile (* p<0.01) (a, b, etc.; different letters within a factor indicate significant differences).

weight percentile, height percentile, the interaction between sire index and weight percentile, and weight percentile squared were all used in the model to predict the probability of being a stakes winner. In general, the model indicated that extremes in weight percentile (low or high) gave sucklings and yearlings a lower chance of being stakes winners, whereas a greater height percentile improved chances. Sire index was only important if weight percentile was low, and therefore sucklings and yearlings with the greatest chance of becoming stakes winners were tall and not too heavy, and had high sire indexes. In weanlings the model was based on sire index and weight percentile. Weanlings with a greater chance of becoming stakes winners had a high sire index and were in the middle weight percentiles. Height percentile did not have any significant effect on the model for weanlings.

Discussion

The study population exhibited some differences from the breed average including a greater number of starters, winners/foals, stakes winners, graded stakes winners, and G1 winners. Furthermore, horses in this study had greater average earnings from fewer career starts compared with the breed average. Differences observed between the study population and the breed average probably reflect a higher quality of horses in the study.

Growth measurements taken for foals (0-30 days) gave an indication of the horses' genetic or natural size, whereas measurements taken for yearlings represent how management influences size of the horse. In foals in this study, there was no difference in average weight or height percentile between those that raced or not, won or not, won stakes races or not, and won graded stakes races or not. However, horses that won stakes and graded stakes races were significantly heavier as yearlings than those that did not.

Surprisingly, across all age groups, those that started as two-year-olds were shorter and weighed less than those that did not (Figure 2). It is generally accepted that faster-maturing, heavier horses are more likely to be raced as two-year-olds, but these results indicate the opposite and it appears that smaller horses are likely to run earlier. Furthermore, across all age groups smaller horses had more career starts, indicating possible increased skeletal soundness in smaller-sized horses.

Foals and yearlings that weighed less than half the population had significantly lower sire indexes than those in the heaviest quarter. There was no difference in the percentage of stakes winners between all weight quartiles as foals. However, as yearlings there were significantly fewer stakes winners in the lowest weight quartile than in the upper three quartiles. These results indicate that yearlings in the second weight quartile are outperforming their pedigrees (Figure 5).

Yearlings in the first weight quartile (those that weighed less than 75% of the population) had lower earnings, fewer stakes winners, and a lower sire index than the rest of the population. However, yearlings below the 50th weight and height percentiles were more likely to start as two-year-olds and had more career starts than those above the 50th percentile.

Combining sire index, weight, and height percentile into a model to predict the probability of becoming stakes winners established that taller foals had a greater probability of becoming stakes winners, whereas weanlings that were not too heavy with high sire indexes also had more chance. Yearlings with the highest probability of becoming stakes winners were tall, not too heavy, and had high sire indexes.

A study of Virginia Thoroughbreds reported no significant correlations between career earnings and any yearling body measurement, but there was a trend ($p<0.1$) for wither height to be correlated favorably with earnings in fillies (Smith et al., 2006). The current study found that average earnings increased significantly ($p<0.01$) with yearling wither height and body weight in fillies and colts. The Virginia Thoroughbred study also reported that hip height, but not wither height, was favorably correlated with win percentage and horses that won or placed in a stakes race were significantly taller as yearlings. These findings are in agreement with the results of the current work, which found that win percentage was greater in heaver and taller yearlings and stakes winners were significantly taller and heavier as yearlings.

Conclusion

Data from this study suggest tall but not heavy young growing horses are more likely to become successful athletes. We therefore recommend weighing and measuring horses during growth and development to ensure the skeleton maintains a steady rate of growth, while preventing the animal from becoming too heavy.

These data provide insight into managing horses for different strategies. Smaller horses were more likely to start as two-year-olds and have more career starts; however, elite performers (stakes winners, graded stakes winners, G1 winners, and millionaires) were taller and heavier. This does not indicate that small horses will not become elite athletes, as 40% of millionaires as yearlings weighed below the median.

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