

Relationship Between Foal Growth, Survey Radiographic Findings, and Sales and Racing Performance in Thoroughbred Racehorses: A Pilot Study

Dr. Joe Pagan¹, Megan Garzillo², Steve Caddel² and Eileen Phethean¹
Kentucky Equine Research, Versailles, Kentucky¹ and Hallway Feeds, Lexington, Kentucky²

Introduction

Skeletal soundness is of prime importance for Thoroughbred racehorses, and breeders pay particular attention to radiographic abnormalities that may affect a yearling's sale price or future racing performance. Most breeders take survey radiographs of yearlings to assist in decisions regarding future medical or surgical treatment. While large foal body size and excessive growth rates have been implicated as factors contributing to developmental disorders in Thoroughbreds, it is still unclear how these are associated with the incidence of abnormalities in survey and sale radiographs. Therefore, a pilot study was conducted in Kentucky to assess whether foal body weight or withers height is significantly associated with these radiographic findings and whether radiographic findings are associated with sales and racing performance.

Pilot Study Materials and Methods

Six commercial Thoroughbred breeding farms in Kentucky participated in a study from 2013-2017 to evaluate the relationship between the body weight and withers height of foals with findings from radiographic survey and sale radiographs. Each of these farms was enrolled in a weighing program conducted by Hallway Feeds in Lexington, Kentucky. On a monthly basis, Hallway technicians weighed and measured withers height of the foals at each farm. A total of 318 foals from 12 individual foal crops were included in the study.

Growth measurements (body weight using an electronic scale and withers height using a measuring stick) were taken approximately every 30 days. Growth variables were converted into population percentiles for analysis using Kentucky Equine Research's Gro-Trac® growth-monitoring software. Percentiles rank the relative size of individuals in a population regardless of gender and age.

The average percentile body weight (BW) and withers height were calculated for each foal at four ages: the first age range was from birth to 30 days of age (foal); the second age group was from 31 to 180 days of age (suckling); the third age range was from 181-360 days of age (weanling); and the final age group was >360 days of age (yearling). The foals were further divided into quartiles based on whether they were in the lowest 25% (1st quartile), the 25-50% (2nd quartile), 50-75% (3rd quartile) or highest 25% (4th quartile) for both body weight and withers height. Additionally, foals were divided into groups based on their month of birth.

To evaluate the relationship between size and skeletal problems, the foal's survey radiographs were assessed for osteochondritis dissecans (OCD) and sesamoiditis. Sale radiographs were also assessed for yearlings offered for sale at public auction. Sales and racing performance data were gathered from publicly available records.

Incidence of OCD

Survey Radiographs

The majority (93%) of the surveys occurred in February (56%) and March (37%) of the foal's yearling year. In these surveys, 16% of the foals had findings reported as either OCD or osteochondrosis, with 43% of the lesions located in the hock, 32% in the stifle, and 25% in the fetlock. This probably underestimated the true incidence of developmental lesions in the fetlock since there were also findings in the fetlock reported as fragments or chips, which may actually have been osteochondrosis. Veterinary clinics in the area typically report a higher incidence of fetlock OCD.

Surgical OCD

The incidence of surgical OCD in this group of foals was 9.3%, which agrees with the incidence reported in two previous studies by Kentucky Equine Research in Kentucky Thoroughbreds (Pagan and Jackson, 1996; Pagan et al., 2001). Of the surgeries, 56% repaired hock OCDs, 26% stifles, and 17% fetlocks.

Sale radiograph OCD

The incidence of OCD in sale radiographs was quite low. This was either due to the lesions being repaired surgically following identification in the survey radiographs, resolution of lesions without surgery or, if the lesions were still present, the yearlings not being entered into a sale.

Incidence of sesamoiditis

Evidence of sesamoiditis was found in 24% of yearlings in surveys, and there was a 16% incidence in sale radiographs. The majority of these findings were described as mild.

Size and OCD (Survey Radiographs)

The incidence of OCD in small foals was low. Only 7-10 % of the foals with evidence of OCD in their survey radiographs (n=41) were in the 1st quartile (lightest 25% of population) for weight (Figure 1) and 5% in 1st quartile for height (Figure 2) as foals (1-30 days), sucklings (31-180 days), or weanlings (180-360 days) (Figure 2).

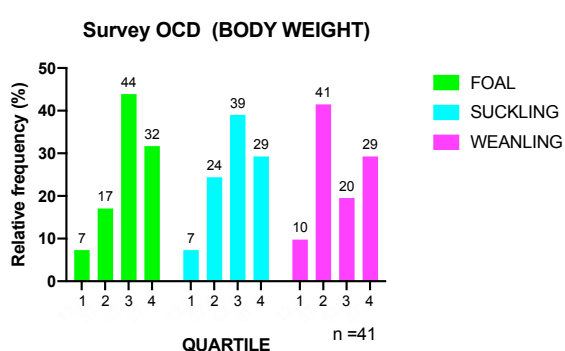


Figure 1. Survey OCD body weight

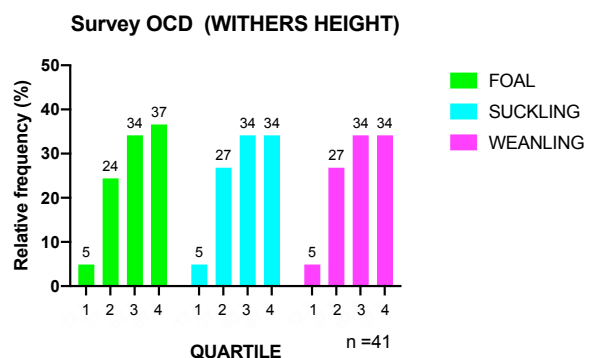


Figure 2. Survey OCD height

The incidence of OCD in all 1st and 2nd body weight quartile foals was 9% and 11%, respectively, compared to 24% and 22% in 3rd and 4th quartile foals, respectively (Figure 3).

The incidence of OCD was lowest (5%) in 1st height quartile foals and greatest (27%) in 4th height quartile foals (Figure 4).

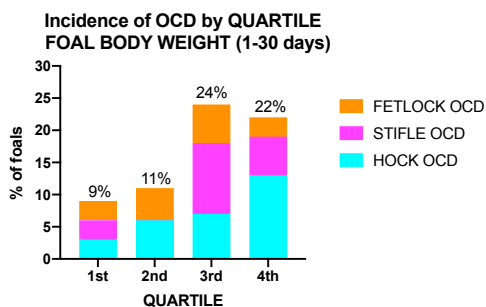


Figure 3. Incidence of OCD by foal BW quartile

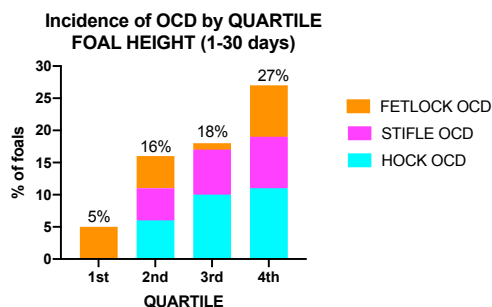


Figure 4. Incidence of OCD by foal height quartile

During their first month, foals that were heavier than the population median (50th percentile) had three times greater chance of developing OCD ($p < .05$).

Size and surgical OCD

Only 4% of yearlings that had OCD surgery ($n=23$) were in the 1st quartile for either body weight (Figure 5) or height (Figure 6) as foals or sucklings, and no foals were in the 1st quartile for height as weanlings. Of the yearlings with surgical OCD, 43% were in the 4th quartile for weight (heaviest 25% of population) when they were weanlings (181-360 days) (Figure 5). As with survey OCD, foals that were heavier than the 50th percentile (population median) during their first month of age had three times greater odds of having OCD surgery ($p < .05$).

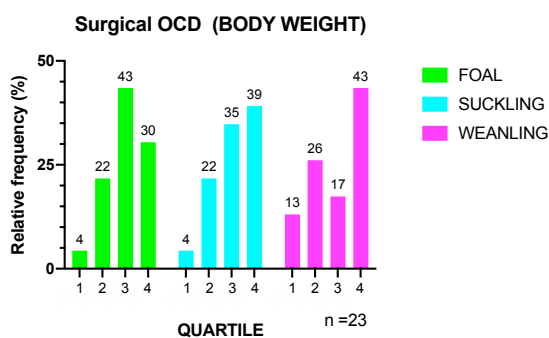


Figure 5. Surgical OCD body weight

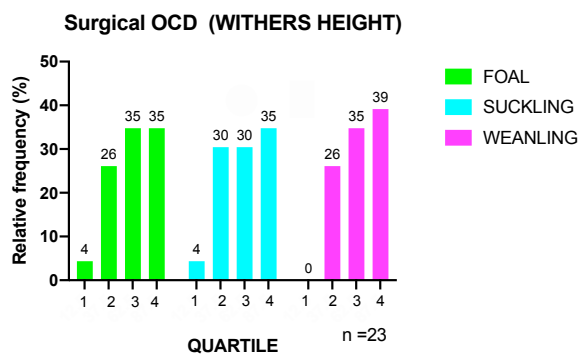


Figure 6. Surgical OCD height

Size and sesamoiditis

Yearlings with sesamoiditis in their surveys ($n=60$) were of average weight and height as foals (Figures 7 and 8). Their body weight did not change significantly as sucklings or weanlings, but percentile height was significantly taller ($p < .05$) as both sucklings and weanlings compared to foal height (Figure 8).

Survey Sesamoiditis (BODY WEIGHT)

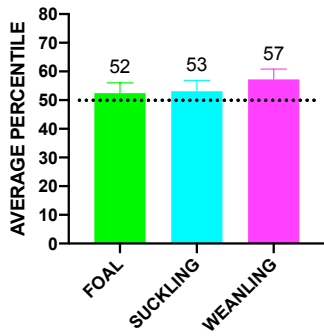


Figure 7. Survey sesamoiditis AVERAGE body weight

Survey Sesamoiditis (WITHERS HEIGHT)

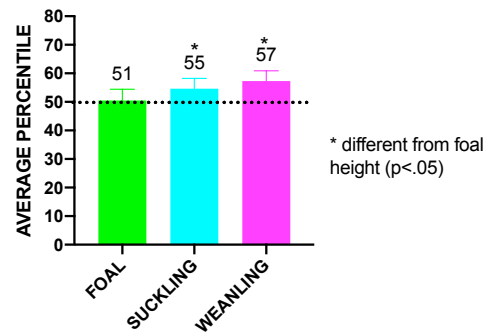


Figure 8. Survey sesamoiditis AVERAGE height

Yearlings that had sesamoiditis in their sale radiographs (n=39) tended to be average weight as foals and slightly below average as sucklings. They gained weight as yearlings and were significantly heavier at sale time (p<.05) (Figure 9). Average height was unchanged from foal through yearling age (Figure 10).

Sesamoiditis SALE WEIGHT

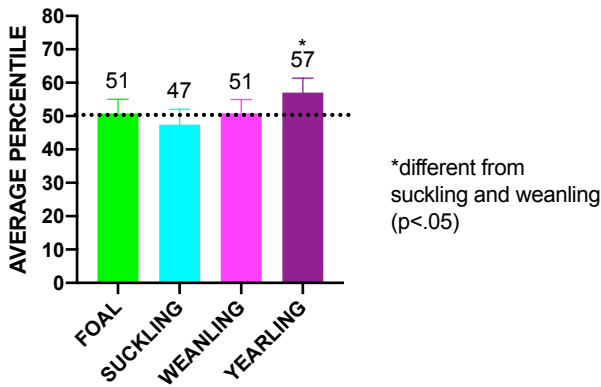


Figure 9. Sale sesamoiditis AVERAGE body weight

Sesamoiditis SALE HEIGHT

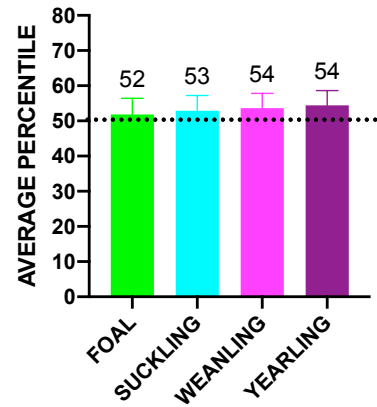


Figure 10. Sale sesamoiditis AVERAGE height

Incidence of OCD by birth month

Five percent of foals in this study were born in January, 26% in February, 29% in March, 28% in April, and 12% in May. In survey radiographs, the incidence of OCD was skewed towards later foals (January 4%, February 14%, March 25%, April 41%, May 16%) (Figure 11).

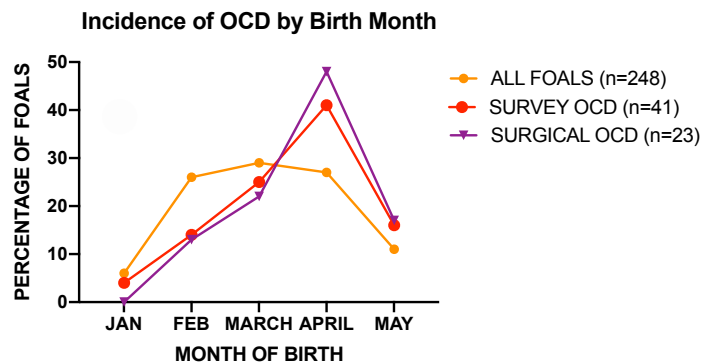


Figure 11. Incidence of OCD by birth month

This was even more pronounced in foals requiring OCD surgery. In this group, 65% were born in April and May (January 0%, February 13%, March 22%, April 48%, and May 17%).

Incidence of sesamoiditis by birth month

Yearlings with sesamoiditis in their surveys were overrepresented in February (34% vs 26% of overall population) compared to the entire study population (Figure 12). The incidence of sesamoiditis in sales radiographs was not affected by month of birth.

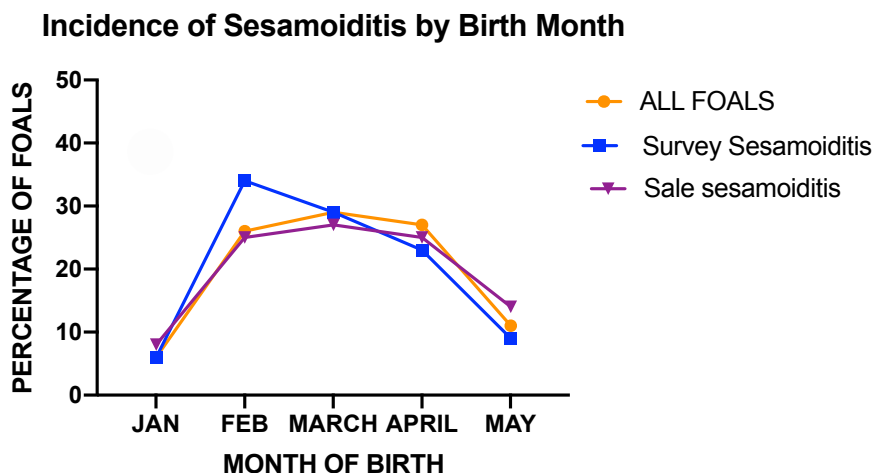


Figure 12. Incidence of sesamoiditis by birth month

OCD and sesamoiditis occurs in different foals

In this study, month of birth affected the incidence of both OCD and sesamoiditis. OCD was more prevalent in late foaling foals while sesamoiditis in survey radiographs was more common in February-born foals. Interestingly, only 20% of the yearlings that had OCD in their survey radiographs also had sesamoiditis, and only 16% of foals diagnosed with sesamoiditis in their surveys also had OCD lesions in these radiographs (Table 1).

Table 1. Incidence of OCD and sesamoiditis in the same foals in survey radiographs

	OCD		Sesamoiditis
no sesamoiditis	80%	no OCD	84%
sesamoiditis	20%	OCD	16%

Yearlings that develop OCD are larger as foals (1-30 days) than yearlings that develop sesamoiditis

Foals (1-30 days) that developed sesamoiditis were lighter (Figure 13) and shorter (Figure 14) than foals that developed OCD ($p < .05$). Of foals that developed OCD, 74% were heavier than the median (50th) percentile compared to only 48% of foals that developed sesamoiditis (Figure 15). Of foals that developed OCD, 68% were taller than the median (50th) percentile compared to 43% that developed sesamoiditis (Figure 16).

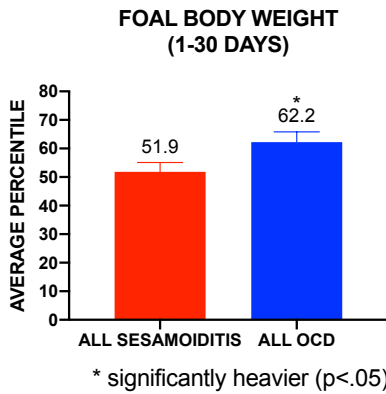


Figure 13. OCD vs sesamoiditis (foal weight)

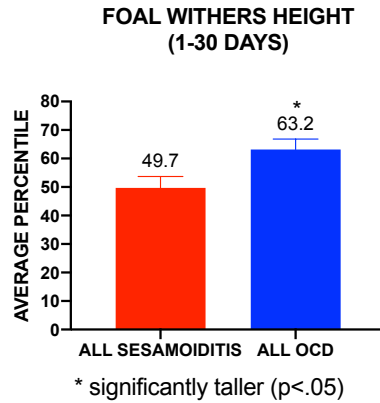


Figure 14. OCD vs sesamoiditis (foal height)

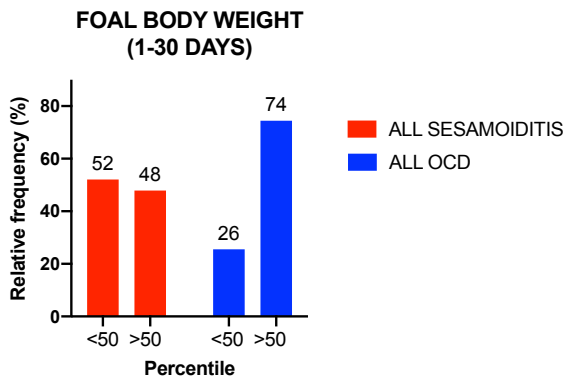


Figure 15. OCD vs sesamoiditis (foal weight)

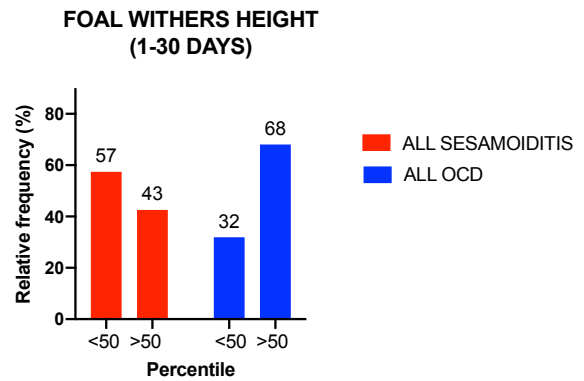


Figure 16. OCD vs sesamoiditis (foal height)

Effect of Month of Birth (MOB) on Foal Body Weight

Foals born in January, February, and March were significantly lighter than foals born in April or May (p<.05) (Figure 17). In April and May foals, 74% and 83% were heavier than the median (50th) percentile during the first 30 days (Figure 18).

Foals (1-30 days)

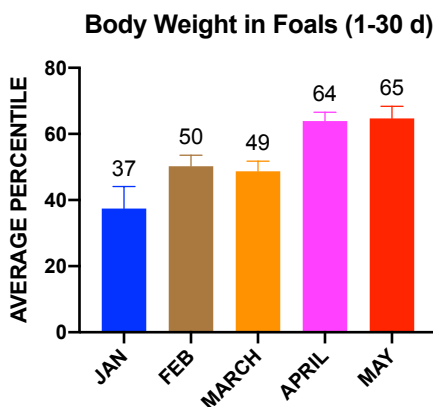


Figure 17. MOB foal weight

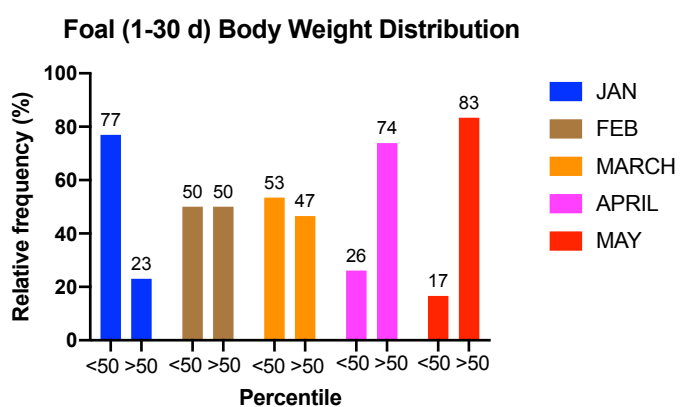


Figure 18. MOB foal weight distribution

Sucklings (31-180 days)

As sucklings (31-180 days of age), April and May foals were heavier than foals born in January ($p < .05$) (Figures 19 and 20).

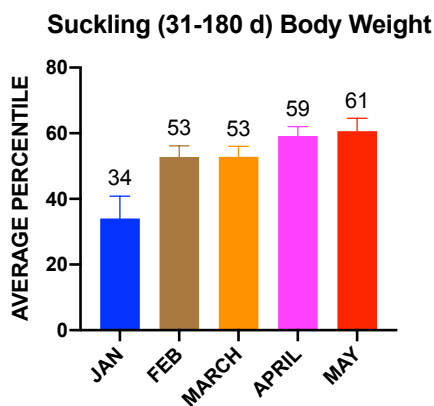


Figure 19. MOB suckling weight

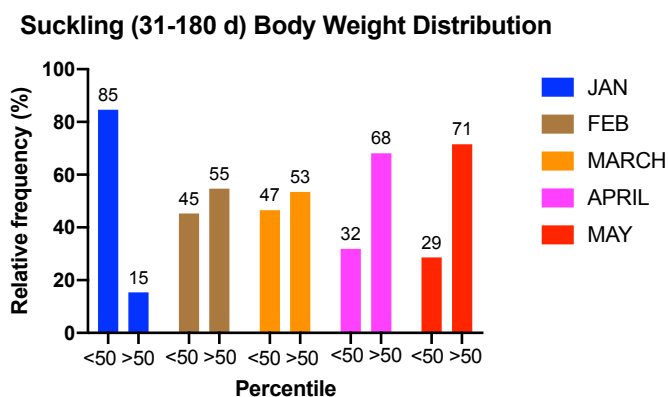


Figure 20. MOB suckling weight distribution

Weanlings (181-360 days)

By the time the foals were weanlings (181-360 days of age), there was no significant difference due to month of birth (Figure 21). March-, April-, and May-born weanlings now had about an even distribution of foals above and below the median (50th) percentile, but 64% of February foals were now above the median body weight (Figure 22).

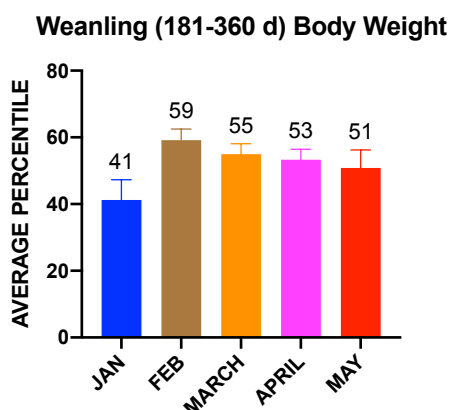


Figure 21. MOB weanling weight

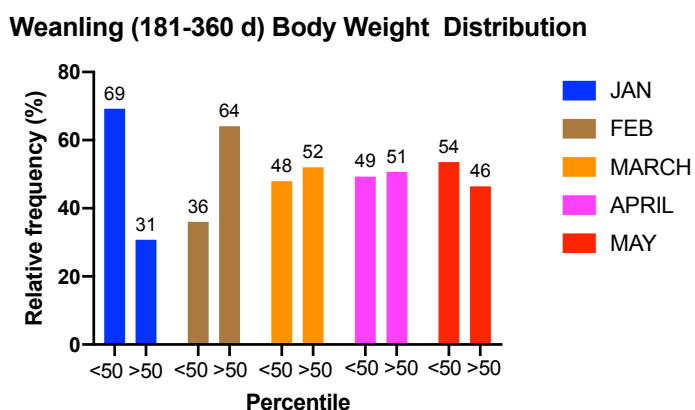


Figure 22. MOB weanling weight distribution

Yearlings (>360 days)

As yearlings, January-born foals were lighter than April- and May-born foals (Figure 23). A majority of February-, March-, April-, and May-born yearlings were above the median percentile. This was particularly pronounced in April and May foals, where 68% and 75% were heavier than the median percentile (Figure 24).

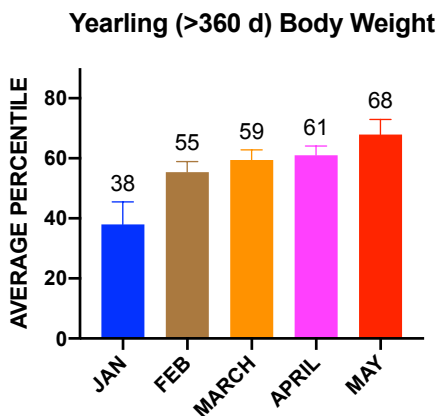


Figure 23. MOB yearling weight

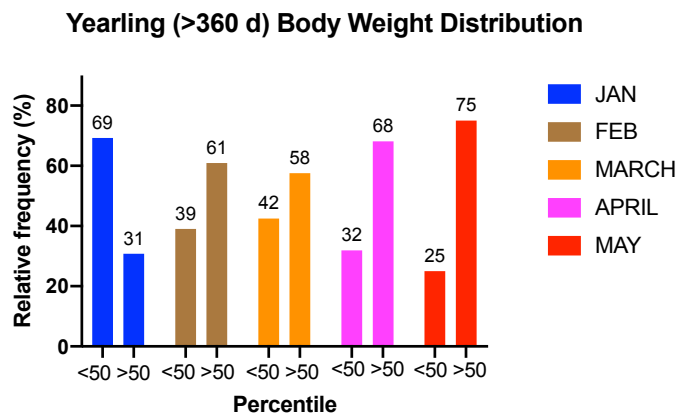


Figure 24. MOB yearling weight distribution

Month of birth plays an important role in the growth of foals. January-born foals in this study were born light and stayed light, even as yearlings. February- and March-born foals were average size as foals (average 50th and 49th percentiles, respectively) but as weanlings were as large as later-born foals. Conversely, April and May foals were heavier as foals (average 64th and 65th percentiles, respectively) but were only in the 53rd and 51st percentiles as weanlings. They returned to 61st and 68th percentiles as yearlings.

These differences in weight between birth months may explain some of the differences observed in the incidence of OCD and sesamoiditis. February foals had a high incidence of sesamoiditis in their survey radiographs. These horses were of average size as foals (50.3 ± 3.3 mean \pm SEM) but as weanlings were significantly heavier (59.2 ± 3.2) ($p < .05$). In a previous study (Pagan et al., 2006), February foals were born lighter than April and May foals and grew more slowly during their first month of life. Their dams also lost weight during the first month of lactation and probably produced less milk, resulting in slower early growth. February foals are typically weaned in mid to late summer and spend most of their weaning growth period during the autumn when pasture is usually abundant. This gives them the opportunity to compensate for their smaller earlier size by growing faster during this time. This may play a role in developing sesamoiditis, apparent in their survey radiographs, which are taken around one year of age.

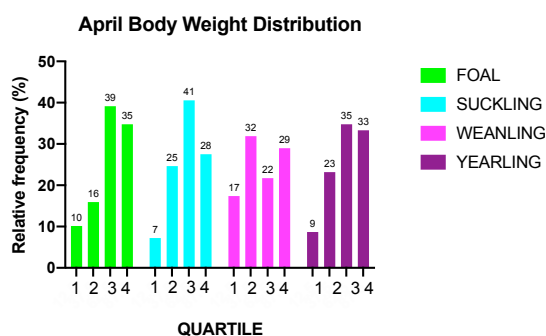


Figure 25. April-born foal body weight distribution

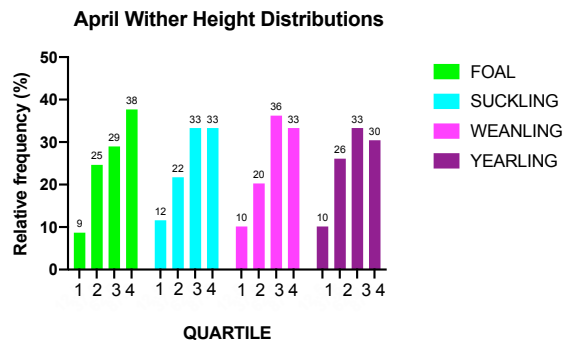


Figure 26. April-born foal height distribution

April and May foals start out large but lag in growth post weaning, probably due to a combination of earlier weaning ages and spending a large portion of their weaning growth period during the winter. During the sales-prepping period, these foals regain weight and

end as heavier yearlings. As well as being heavier as foals (Figure 25), April-born foals tend to be tall (Figure 26). Only about 10% of April foals were in the 1st quartile for weight or height at any stage of growth except as weanlings when 17% were in the 1st quartile for weight. The high incidence of OCD observed in April-born foals may be related to their large size as foals.

Size affects sales price

There was a strong positive association between both yearling body weight and withers height and yearling sale price (Figures 27 and 28), which agrees with previous studies (Brown-Douglas et al., 2007). The median price for yearlings in the 4th quartile for body weight was five times higher than foals in the 1st quartile and 2.8 times higher for withers height.

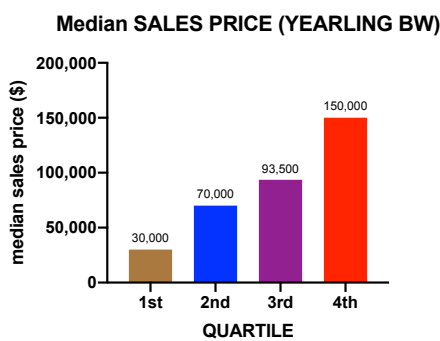


Figure 27. Sale price by weight

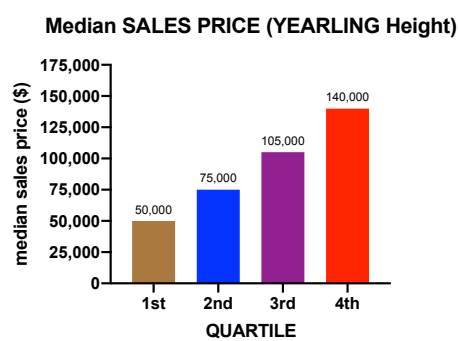


Figure 28. Sale price by height

Some of this large discrepancy in sale price was due to the session in which the yearlings were sold. Previous research has shown that yearlings sold in early sessions are larger than those sold later in the sale (Brown-Douglas et al., 2007). Even taking this into account, yearlings that were in the 4th quartile for weight sold for 2.3 times more than 1st quartile yearlings (Figure 29).

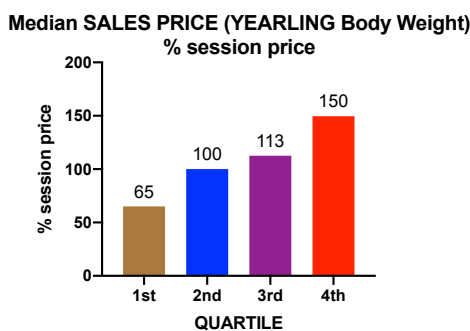


Figure 29. Sale price by weight (% session median)

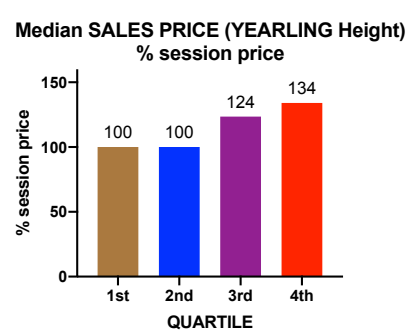


Figure 30. Sale price by height (% session median)

Size and racing performance

Raced

Horses that were in the 2nd quartile as foals were more likely to race (Figure 31). Only 59% of 1st quartile height foals raced. Fewer horses that were in the 3rd BW and height quartile as yearlings raced (Figure 32).

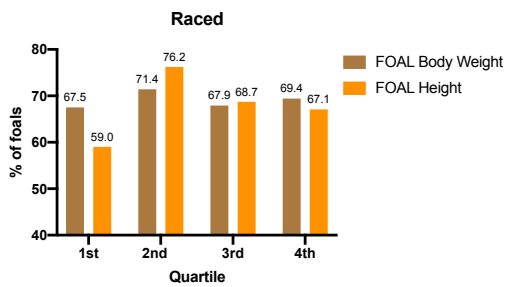


Figure 31. Raced horses by foal BW and height quartile

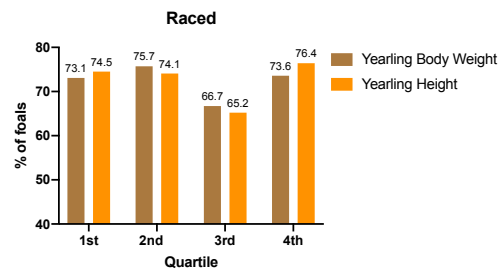


Figure 32. Raced horses by yearling BW and height quartile

Age at first start

Yearlings that were in the 3rd and 4th BW and height quartiles were significantly older ($p < .05$) at their first start than 1st and 2nd quartile yearlings (Figures 33 and 34).

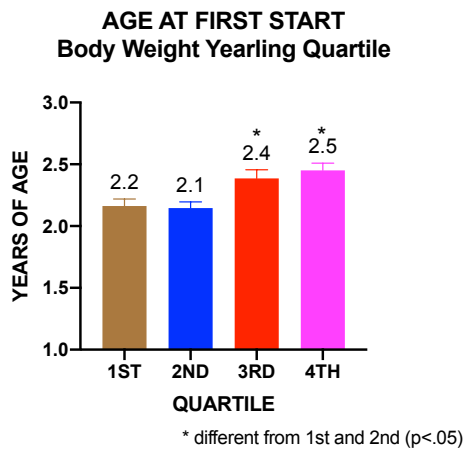


Figure 33. Age at first start yearling BW quartile

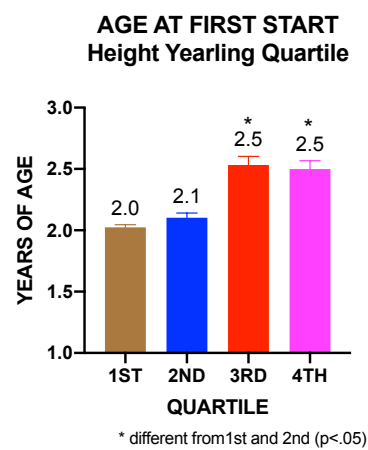


Figure 34. Age at first start height BW quartile

Non-winners from starters

There was a higher percentage of horses that raced but did not win represented in the 4th BW and height quartile as foals and yearlings than any other size range (Figures 35 and 36).

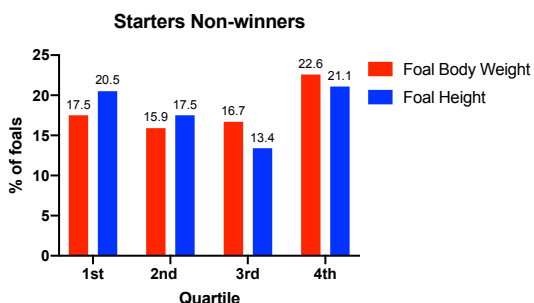


Figure 35. Non-winners from starters foal BW and height

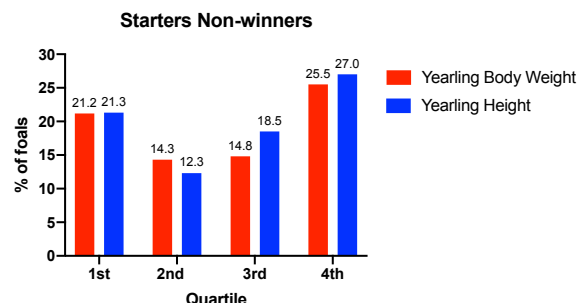


Figure 36. Non-winners from starters yearling BW and height

Winners

The highest percent of winners were in the 2nd quartile for BW and height as both foals and yearlings (Figures 37 and 38). The lowest number of winners were in the 1st quartile for height in foals (Figure 37).

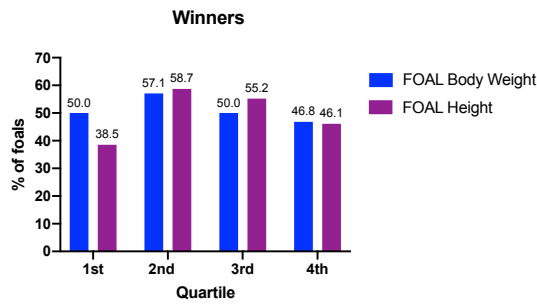


Figure 37. Winners foal BW and height

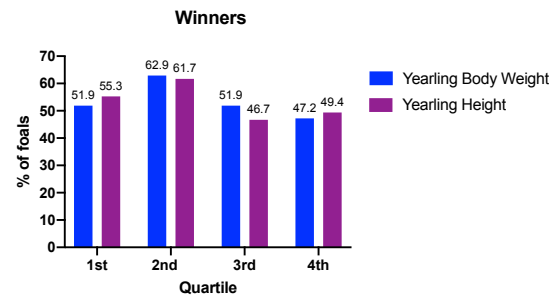


Figure 38. Winners yearling BW and height

Stakes winners

Few stakes winners were in the 1st quartile for weight or height as either foals or yearlings (Figures 39 and 40). The highest percentage of stakes winners were in the 2nd quartile for BW and height as foals and yearlings.

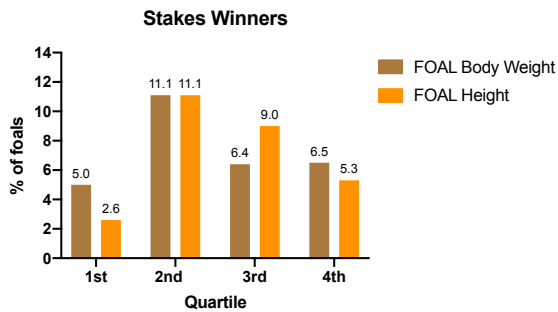


Figure 39. Stakes winners foal BW and height

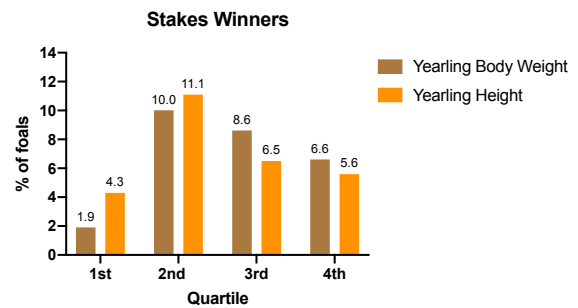


Figure 40. Stakes winners yearling BW and height

Graded stakes winners

The greatest percentage of graded stakes winners were in either the 2nd or 4th foal weight quartile or from the 2nd and 3rd foal height quartile. No graded stakes winners came from the 1st foal or yearling weight quartile (Figures 41 and 42).

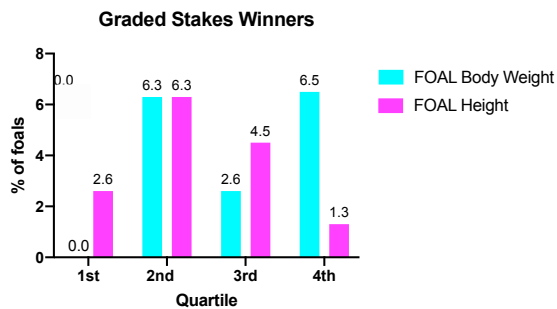


Figure 41. Graded stakes winners foal BW and height

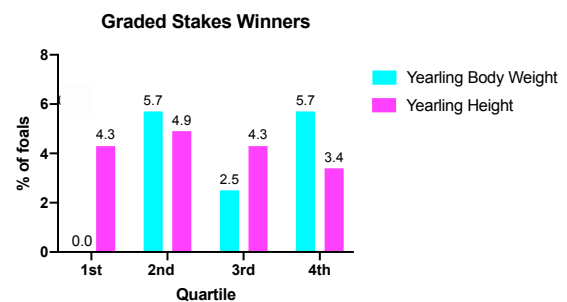


Figure 42. Graded stakes winners yearling BW and height

Sales price and OCD

The average price of all yearlings in the study was \$172,984, and the median price equaled \$76,000. Yearlings with hock and fetlock OCD in their survey radiographs sold for 101% and 154% of the study average, and 151% and 328% of the median price, respectively. Yearlings with stifle OCD in their survey radiographs sold for 19% of the study's average and median price (Table 2).

Table 2. Average and median yearling sales price of yearlings with OCD in their survey radiograph

AFFECTED JOINT	SURVEY RADIOGRAPH		
	NUMBER	AVERAGE PRICE	MEDIAN PRICE
STIFLE OCD	10	\$33,350	\$14,500
HOCK OCD	14	\$174,750	\$115,000
FETLOCK OCD	11	\$266,591	\$250,000

Few of the yearlings had OCD lesions in their sale radiographs (Table 3). The two yearlings that had stifle lesions also had stifle OCD evident in their survey radiographs. There were no yearlings with hock OCD at the sale, and there were four yearlings with fetlock OCD. These fetlock lesions were not present in the yearling surveys, suggesting that they developed after these radiographs were taken. Yearlings with fetlock lesions sold above the study's average and median price, and the two yearlings with stifle OCD sold poorly (Table 3).

Table 3. Average and median sales price of yearlings with OCD in their sales radiographs

AFFECTED JOINT	SALE RADIOGRAPH		
	NUMBER	AVERAGE PRICE	MEDIAN PRICE
STIFLE OCD	2*	\$5,500	NA
HOCK OCD	0	NA	NA
FETLOCK OCD	4**	\$279,000	\$143,500

*stifle OCD also present in survey radiograph
 **fetlock OCDs not present in survey radiograph

The results of this study suggest that hock or fetlock OCDs do not negatively affect sale price, but there were more yearlings (19% vs 9.2%) with hock OCDs withdrawn from the sale compared to the yearlings with no OCD in the study (Table 4).

Table 4. Sold vs unsold for yearlings with OCD in survey radiographs

	NO OCD	ALL OCD	HOCK	STIFLE	FETLOCK
SOLD	57.9%	67.9%	61.9%	66.7%	78.6%
OUT	9.2%	9.4%	19.0%	5.6%	0%
RNA	18.5%	15.1%	14.3%	16.7%	14.3%
NOT OFFERED	14.4%	7.5%	4.8%	11.1%	7.1%

Sesamoiditis and sales price

Yearlings with sesamoiditis in their sale radiograph sold for 70% of the average and 97% of the median of yearlings that sold without sesamoiditis in their sale radiographs (Figures 43 and 44).

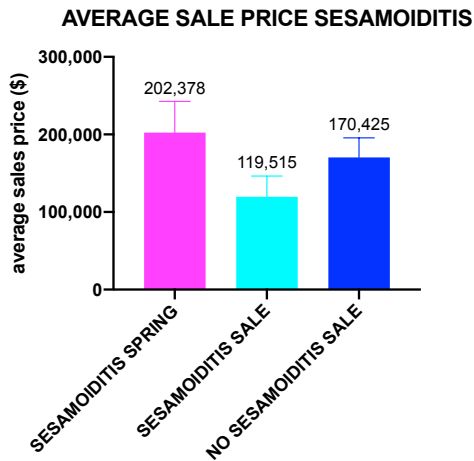


Figure 43. Average sale price sesamoiditis

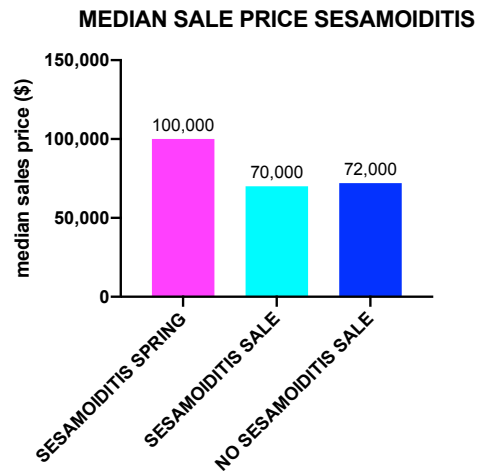


Figure 44. Median sale price sesamoiditis

A similar number of yearlings with sesamoiditis in their survey radiographs were offered for sale (84.7% vs 86.4%) compared to yearlings without sesamoiditis. More yearlings with sesamoiditis in both their survey and sales radiographs were withdrawn from the sale (16.1% vs 11.7%) or did not meet their reserve price (25.8% vs 17.8%) (Table 5).

Table 5. Sesamoiditis (sold vs unsold)

	NO SESAMOIDITIS		SESAMOIDITIS		
	ALL YEARLINGS	YEARLINGS OFFERED FOR SALE	ALL SURVEY	BOTH	ALL SALE
SOLD	61.0%	70.6%	56.9%	58.1%	67.4%
WITHDRAWN	10.1%	11.7%	11.1%	16.1%	13.0%
RNA	15.4%	17.8%	16.7%	25.8%	19.6%
NOT OFFERED	13.6%	NA	15.3%	NA	NA

OCD and racing performance

Horses with hock and fetlock OCD in their survey radiographs raced better (more starters, winners, stakes winners, and graded stakes winners from foals) than horses without OCD in their surveys. Horses with stifle OCD had similar starters and winners to yearlings without OCD but had no stakes winners (Table 6).

Table 6. Racing performance in yearlings with OCD in survey radiographs (% of foals)

	SURVEY OCD				
	NO OCD	ALL OCD	HOCK OCD	FETLOCK OCD	STIFLE OCD
UNRACED/foals	30.3%	23.5%	23.8%	14.3%	27.8%
STARTERS/foals	69.7%	76.5%	76.2%	85.7%	72.2%
WINNERS/foals	50.9%	58.8%	61.9%	64.3%	50.0%
STAKES WINNERS/foals	5.9%	5.9%	9.5%	7.1%	0%
GRADED STAKES WINNERS/foals	3.7%	5.9%	9.5%	7.1%	0%

Table 7. Racing Performance in yearlings with OCD in survey radiographs (% of starters)

SURVEY OCD					
	NO OCD	ALL OCD	HOCK OCD	FETLOCK OCD	STIFLE OCD
WINNERS/Starters	73.0%	76.9%	81.3%	75.0%	69.2%
STAKES WINNERS/starters	8.5%	7.7%	12.5%	8.3%	0%
GRADED STAKES WINNERS/starters	5.3%	7.7%	12.5%	8.3%	0%

Horses with hock OCD that raced made their first start at a later age than horses without OCD (Figure 45).

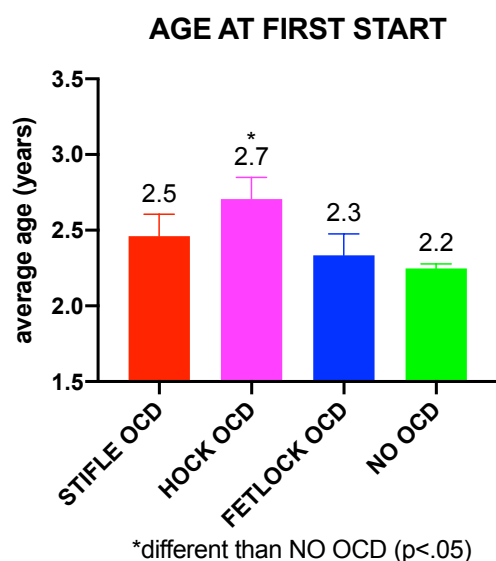


Figure 45. Age at first start for horses with OCD as yearlings

Sesamoiditis and racing performance

Horses that had sesamoiditis in their sale radiographs had more starters and winners from foals and winners from starters than horses without sesamoiditis, but they were represented by fewer stakes winners and graded winners (Tables 8 and 9).

Table 8. Racing performance in yearlings with sesamoiditis (% foals)

SESAMOIDITIS				
	NO SESAMOIDITIS	SURVEY	BOTH	SALE
UNRACED/foals	29.5%	30.6%	18.8%	19.6%
STARTERS/foals	70.5%	69.4%	81.3%	80.4%
WINNERS/foals	51.7%	52.8%	65.6%	62.7%
STAKES WINNERS/foals	6.8%	2.8%	3.1%	5.9%
GRADED STAKES WINNERS/foals	4.7%	1.4%	0%	2.0%

Table 9. Racing performance in foals with sesamoiditis (% starters)

SESAMOIDITIS				
	NO SESAMOIDITIS	SURVEY	BOTH	SALE
WINNERS/starters	73.3%	76.0%	80.8%	78.0%
STAKES WINNERS/starters	9.7%	4.0%	3.8%	7.3%
GRADED STAKES WINNERS/starters	6.7%	2.0%	0%	2.4%

Sesamoiditis in either survey or sale radiographs did not affect age to first start (Figure 46).

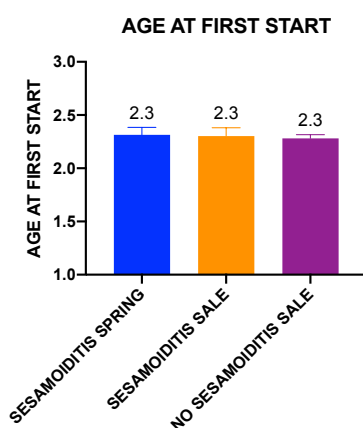


Figure 46. Age at first start for horses with sesamoiditis as yearlings

Summary

This study showed that the size and growth rate of foals is associated with the incidence of both OCD and sesamoiditis. Size also is related to sale price and racing performance.

1. Small foals (1st and 2nd quartile weight and 1st quartile height) are less likely to develop OCD than larger foals. Foals in the 3rd and 4th quartile are at greater risk.
2. Yearlings with sesamoiditis in their survey radiographs were of average weight as foals and their body weight did not change significantly as sucklings or weanlings, but percentile height was significantly taller as both sucklings and weanlings compared to foal height.
3. Yearlings that had sesamoiditis in their sale radiographs tended to be average weight as foals and slightly below average as sucklings. They gained weight as yearlings and were significantly heavier at sale time.
4. Survey sesamoiditis was higher in February foals.
5. February foals were small as foals and sucklings but grew rapidly as weanlings.
6. The high incidence of OCD observed in April-born foals may be related to their large size as foals.
7. There was a strong positive association between both yearling body weight and withers height and yearling sale price.
8. Second quartile foals and yearlings had the highest percentage of winners and stakes winners.

9. Hock and fetlock OCD did not adversely affect sales price or racing performance, but horses with hock OCD were older at their first start.
10. Stifle OCD adversely affected both sales price and racing performance.
11. Sesamoiditis at sale reduced sale price.
12. Horses that had sesamoiditis in their sale radiographs had more starters and winners from foals and winners from starters than horses without sesamoiditis, but they were represented by fewer stakes winners and graded stakes winners.
13. Sesamoiditis in either survey or sale radiographs did not affect age to first start.

Conclusions

This study showed that extremes in body weight and height (too big or too small) are not ideal for Thoroughbred racehorse performance. However, since large body weight and height are rewarded in the sale ring, striking a balance between size and soundness is important for commercial success. Month of birth is a critical factor in how foals grow and may play an important role in both OCD and sesamoiditis. February foals are born small and grow faster once weaned, while the opposite is true for later-born foals. April and May foals are born large, lag post weaning, and may experience compensatory growth during sales prep. Adjusting mare feeding to compensate for poor pasture availability early and maintaining consistent growth with later-born foals post weaning may help reduce the incidence of skeletal disorders in growing Thoroughbreds.

Since this study only involved 318 foals from 6 farms in central Kentucky, its findings should be considered preliminary. A larger study is currently being conducted with more Thoroughbred farms in Kentucky as well as with breeders in other major breeding centers around the world. The goals of these studies are to identify at-risk foals earlier, modify feed and management practices to reduce problems, and ultimately raise better racehorses.

References

Brown-Douglas, C.G., J.D. Pagan, A. Koch, S. Caddel, and P.J. Huntington. 2007. The relationship between size at yearling sale, price, and future racing performance in Kentucky Thoroughbreds. In: Proc. Equine Science Society Symposium 20:153.

Pagan, J.D., and S.G. Jackson. 1996. The incidence of developmental orthopedic disease (DOD) on a Kentucky Thoroughbred farm. *Pferdenheilkunde* 12:351-354.

Pagan, J.D., C.G. Brown-Douglas, and S. Caddel. 2006. Body weight and condition of Kentucky Thoroughbred mares and their foals as influenced by month of foaling, season, and gender. In: *Advances in Equine Nutrition, Vol. IV*, p. 134.

Pagan, J.D., R.J. Geor, S.E. Caddel, P.B. Pryor, and K.E. Hoekstra. 2001. The relationship between glycemic response and the incidence of OCD in Thoroughbred weanlings: A field study. In: Proc. American Association of Equine Practitioners 47:322-325.