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Short- and long-term racing performance of Standardbred pacers and trotters after early surgical intervention for tarsal osteochondrosis

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Summary

Reasons for Performing Study—Osteochondrosis (OC) is commonly diagnosed in young Standardbred racehorses, but its effect on performance when surgically treated at a young age is still incompletely understood. This is especially true for Standardbred pacers, which are underrepresented in the existing literature.

Objective—To characterise the short- (2-year-old) and long-term (through 5-year-old) racing performance in Standardbred pacers and trotters after early surgical intervention (<17 months of age) for tarsal OC.

Study Design—Retrospective clinical study.

Methods—The study population consisted of related, age-matched Standardbred racehorses (n = 278; 151 pacers, 127 trotters) with (n = 133) or without (n = 145) one or more tarsal OC lesions. All OC-affected horses were treated surgically prior to being sold as yearlings. Data obtained from publicly available race records for each horse included starts, wins, finishes in the top 3 (win, place, or show), earnings, and fastest time. Comparisons between OC-affected and unaffected horses were made for the entire population and within gaits. A smaller related population (n = 94) had these performance measures evaluated for their 2- through 5-year-old racing seasons.

Results—Osteochondrosis status was associated with few performance measures. Trotters were at higher risk for lesions of the medial malleolus, but lower risk for lesions of the distal intermediate ridge of the tibia compared to pacers. Horses with bilateral OC lesions and lateral trochlear ridge (LTR) lesions started fewer races at 2 years of age than those with unilateral lesions or without LTR lesions.

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Authors' declaration of interests The authors have declared no competing interests.

Ethical Animal Research The guidelines of the University of Minnesota Institutional Animal Care and Use Committee (IACUC) were followed during the course of this study. Owners informed consent for participation in this retrospective of clinical records was obtained.

Authorship A.M. McCoy was primarily responsible for study design and execution, data analysis and interpretation, and preparation of the manuscript. M.E. McCue contributed to study design, data analysis and interpretation, and editing of the manuscript. S.L. Ralston contributed to study execution and edited the manuscript. All authors approved the final version of the manuscript.

Conclusions—Osteochondrosis seemed to have minimal effect on racing performance in this cohort, although horses with bilateral and LTR lesions started fewer races at 2 years. There was evidence for different distribution of OC lesions among pacers and trotters, which should be explored further. Standardbreds undergoing early removal of tarsal OC lesions can be expected to perform equivalently to their unaffected counterparts.

Keywords

horse; osteochondrosis; performance; Standardbred; racing; arthroscopy

Introduction

Osteochondrosis (OC) is a widely recognised manifestation of developmental orthopaedic disease characterised by disruption of normal endochondral ossification at the ends of long bones. Certain joints in the horse are considered predilection sites for OC, including the stifle, tarsus, and metacarpo-/metatarsophalangeal joints, and the relative importance of each predilection site varies by breed [1]. Osteochondrosis of the tarsocrural joint is commonly diagnosed in young Standardbred racehorses, either on radiographic studies prior to yearling sales or with the onset of clinical signs (i.e. joint effusion and/or mild lameness) shortly after being put into race training. The prevalence of tarsal OC in Standardbreds has been reported to range from 10.1-26.2% based on a number of radiographic surveys, and this breed is considered to be predisposed to lesions in this joint [2-6].

While the high prevalence of tarsal OC is well-documented in Standardbreds, the effect of this disease, and its treatment, on racing performance has been debated in the literature. Successful racing careers have been reported for 73.5% [7] and 84% [8] of surgically treated horses, while a “good” outcome was reported in only 23% of conservatively-treated Standardbreds [9], but these reports did not include a control group for comparison. Studies that do include matched controls variably report impaired performance in OC-affected Standardbreds [10-12] or no significant differences in performance parameters between groups [2,10,13-16]. However, the majority of these previous studies have the limitation of either a control group made up of horses with unknown history (i.e. some could have been OC-affected), or an affected group with unknown treatment status (i.e. performance could be affected by treatment). No study has reported on performance outcome in surgically-treated OC-affected horses compared to related, age-matched OC-unaffected horses for which the entire early history was known.

Standardbred racing in North America is somewhat unique in that horses compete at either the trot (2-beat, diagonal, symmetrical) or the pace (2-beat, lateral, symmetrical), whereas in Scandinavia and continental Europe only trotters race. However, while this phenotype is well-characterised, and modern breeding distinctly separates pacing lines from trotting, limited prospective information about relative performance of horses with these biomechanically distinct gaits is available in the literature [17-19]. There are no reports of how OC affects race performance in pacers, nor any comparisons of the relative impact of the disease on pacers versus trotters.

The purpose of this study was: 1) to report early (2-year-old season) race performance in a cohort of Standardbred yearlings that underwent surgical treatment for removal of tarsal OC fragments prior to being sold as yearlings and to compare them to related age-matched horses that were unaffected with OC; 2) to report long-term (2-5-year-old seasons) race performance in a subset of these horses; and 3) to compare the effect of OC on early race performance within and between pacers and trotters.

Materials and methods

Horses

The study population for evaluating short-term race performance was 278 Standardbred horses raised on a single breeding farm in the Eastern United States that were born in 2007 (n = 59 horses), 2009 (n = 114), or 2010 (n = 105) and identified for inclusion in the study as yearlings being prepared for sale. Osteochondrosis (OC) lesions were radiographically identified in one or both tarsi of 133 individuals and were surgically removed prior to the sale preparation period (<17 months of age). One hundred forty-five related age-matched controls were identified, all radiographically confirmed to be free of OC.

The study population for evaluating long-term race performance was 94 Standardbred horses born and raised on the same breeding farm described above (and 59 of which are included in the short-term performance cohort). Thirty-two of these individuals had surgically removed OC lesions of one or both tarsi. Of the 62 age-matched related controls, 28 were radiographically confirmed to be free of OC and 34 were presumed unaffected because of lack of clinical signs including effusion and lameness. Although complete radiographic examinations (i.e. “repository films”) were not available for all individuals, horses with musculoskeletal lesions other than tarsal OC were not knowingly included in either study cohort. Information regarding foaling date, gender, sire, gait, sale, and sale price for all yearlings was obtained from the farm. Distribution of OC-affected limbs, lesion location, and surgery date for affected horses was obtained from the written veterinary records of the attending surgeon or the farm veterinarian.

Performance Records

All 278 horses in the short-term performance cohort had completed their 2-year-old season by 31 December 2012. Ninety-four horses, born in 2007, had completed their 5-year-old season by this date. Race records were obtained from the United States Trotting Association. Thirteen horses had been exported to Europe and records for these horses were collected from the appropriate country’s trotting association. Collected data included number of starts, wins, and top 3 finishes (win, place, or show), earnings, and fastest qualifying time over a mile for each season. The summation of starts, wins, top 3 finishes, and earnings across 4 seasons were calculated as career performance results, if applicable. Horses that started a race but did not win any money were assigned a nominal earnings value of $1 to differentiate them from horses that never started a race.

Additionally, a randomly chosen subset of all 2010 offspring from 19 Standardbred stallions with progeny included in the study population were selected (n = 288, representing 25% of all offspring from these stallions in the 2010 foaling season) for comparison to the horses in the present study. Freely available records for these individuals were obtained from the United States Trotting Association. Collected data included yearling sale price, number of starts at 2 years, earnings at 2 years, and fastest qualifying time at 2 years. This was done to determine if the individuals in the study cohort were representative of their contemporaries.

Data Analysis

Two-year-old performance (“short-term performance”) was evaluated in all horses (n = 278) in the short-term performance study cohort. Additionally, models were fit separately for 2-year-old performance in all pacers (n = 151), all trotters (n = 127), and all horses affected with OC (n = 133). Performance for the 2-5-year-old seasons (“long-term performance”) was evaluated in all horses born in 2007 (n = 94). For each of these analyses, outcome variables of interest were 1) whether the horse started in a given season (yes/no); 2) number of starts; 3) number of wins; 4) number of top 3 finishes (win, place, or show); 5) earnings; 6) earnings per start, 7) fastest recorded time over a mile, and 8) yearling sales price. Earnings and earnings per start were evaluated only in horses that started a race. In the long-term performance group, outcome variables were examined by season as well as cumulatively over 4 seasons as appropriate. OC status (affected vs. unaffected) was evaluated as an outcome in the entire short-term performance cohort as well as separately in pacers and trotters. In the OC-affected cohort, lesion location (DIRT, MM, LTR) and lesion distribution (bilateral vs. unilateral) were also examined as outcome variables.

Multiple regression was performed for all outcome variables. OC status (categorical variable) was the primary predictor variable of interest in these models, but other covariates included gender, gait (pace vs. trot), number of starts, fastest recorded time, yearling sale location, and sire, as appropriate (see Supplementary Item 2 for a detailed description of multiple regression model construction). When OC status (or specific lesion location or distribution) was the outcome of interest, predictor variables included gender, gait, and sire. Analysis of 2-year-old performance in the OC-affected group was performed using multiple regression models that included lesion location (DIRT, MM, LTR) and distribution (bilateral vs. unilateral) as predictor variables. In all cases, multiple regression was performed using generalised linear regression models for binomial (quasibinomial model) and count (negative binomial model) outcome variables and ordinary linear regression for continuous outcome variables (see Supplementary Item 2). Selected findings of interest are reported in the main text, but full results of all regression models are reported in Supplementary Item 4. Proportions (i.e. proportion of horses starting in a given season) were compared between groups using a two-sided test. Comparison between the short-term performance study cohort (n = 278) and the randomly chosen 2010 offspring (n = 288) was performed using a Kolmogorov-Smirnov test, which tests the entire distribution of data rather than only the population average. Examined variables included yearling sale price, number of starts at 2 years, earnings at 2 years, and fastest qualifying time at 2 years. In all analyses, outcome variables reported as a dollar amount were log-transformed to normalise the data. No other data transformations were performed. All statistical tests were performed in the R statistical computing environment [20] using the packages ‘car’ [21] and ‘MASS’ [22]. Significance was set at $p<0.05$.

Results

Short-term performance: All horses at 2 years of age

Of the 278 horses in this group, 156 (56.1%) were colts and 122 (43.9%) were fillies. Among the 133 OC-affected horses, colts (n = 81) appeared to be overrepresented compared to fillies (n = 52), but the proportion of affected individuals was not significantly different between genders (Δ proportion = 0.093, 95% CI −0.032-0.218, p = 0.2). There were 151 (54.3%) pacers and 127 (45.7%) trotters. Yearlings were sold at one of 5 breed-recognised sales held between September and November of each year; 2 OC-affected horses were not sold and were not included in the analysis of sale price. Osteochondrosis status did not significantly affect yearling sale price (OC-affected median $20,000; range $1,500-260,000; OC-unaffected median $25,000; range $1,500-260,000) in multiple regression analysis (p = 0.3). The remaining predictor variables in this model, gender, sale and sire, were all significantly associated with sale price (p<0.002) (Supplementary Items 5 and 6).

Performance data for the 278 horses by OC status are summarised in **Table 1**. The proportion of horses starting at least one race did not differ between OC-affected (75/133 [56.4%]) and OC-unaffected (96/145 [66.2%]) groups (Δ proportion = 0.098, 95% CI −0.023-0.22, p = 0.1). In multiple regression analysis, OC status was not significantly associated with the number of starts, wins, or top 3 finishes, fastest time, or earnings and earnings per start. Full regression analysis results are reported in Supplementary Item 5.

To determine if the individuals in the study cohort were representative of their contemporaries, yearling sale price, proportion of horses starting at 2 years, number of starts at 2 years, earnings at 2 years, and fastest qualifying time at 2 years were compared between the short-term performance group and the randomly chosen subset of 2010 foals (n = 288). There were no significant differences between the two groups for any of these outcome measures (Supplementary Item 7).

Short-term performance: Pacers and trotters at 2 years of age

Irrespective of OC status, trotters were significantly less likely to start a race at 2 years than were pacers (OR 0.56, 95% CI 0.34-0.93, p = 0.03) and started significantly fewer numbers of races (Incident Rate Ratio [IRR] 0.54, 95% CI 0.41-0.71, p<0.001). On average, trotters were 2.9 s slower than pacers (95% CI 1.71-4.15, p<0.001). Earnings were significantly different between pacers and trotters, but this effect disappeared once earnings were adjusted for the number of starts (that is, Earnings Per Start). Gait did not significantly affect the number of wins or top 3 finishes. The proportion of OC-affected individuals was significantly higher in trotters (71/127 [55.9%]) than pacers (62/151 [41.1%]) (Δ proportion = 0.148, 95% CI 0.024-0.272, p = 0.02). When OC was examined as an outcome variable in a model that included the predictor variables gender, gait, and sire, only gait was significantly associated with affectation status (p = 0.03) (Supplementary Item 8). Full regression analysis results are reported in Supplementary Item 5.

Performance data for the 151 pacers are summarised by OC status in Table 2. The proportion of horses starting at least one race did not differ between OC-affected (41/62 [69.7%]) and OC-unaffected (62/89 [66.1%]) groups (p = 0.78, 95% CI −0.13-0.2). In multiple regression analysis, OC status was not significantly associated with the number of starts, wins, or top 3 finishes, fastest time, or earnings and earnings per start (Supplementary Items 9 and 10**)**.

Performance data for the 127 trotters are summarized by OC status in Table 2. The proportion of horses starting at least one race did not differ between OC-affected (34/71 [47.9%]) and OC-unaffected (34/56 [60.7%]) groups (Δ proportion = 0.128, 95% CI −0.051-0.317, p = 0.2). Similarly to the pacers, in multiple regression analysis, OC status was not significantly associated with the number of starts, wins, or top 3 finishes, fastest time, or earnings and earnings per start (Supplementary Items 11 and 12**)**.

Short-term performance: OC-affected horses at 2 years of age

Average age at the time of surgery for the 133 OC-affected horses was 11.8 months (median 12 months; range 7.5-17 months). Lesion distribution in 132 horses (264 joints) with complete records was as follows: 134 joints (50.8%) in 93 horses (69.9%) had lesions of the distal intermediate ridge of the tibia (DIRT), 73 joints (27.7%) in 48 horses (36.4%) had lesions of the medial malleolus (MM), 49 joints (18.6%) in 37 horses (28%) had lesions of the lateral trochlear ridge (LTR), and 5 joints (1.9%) in 5 horses (3.8%) had a lesion of the medial trochlear ridge (MTR). Thirty-nine horses had 2 different lesions (DIRT + MM, n = 15; DIRT + LTR, n = 16; MM + LTR, n = 4; DIRT + MTR, n = 2; LTR+MTR, n = 1; MM + MTR, n = 1). Six horses had 3 different lesions (DIRT + MM + LTR, n = 5; DIRT + MM + MTR, n = 1). Eight horses were noted in the surgical record to have extensive lesions (2 DIRT, 2 MM, 4 LTR). In total, there were 261 lesions in 207 joints of these 132 horses. Seventy-six of the 133 affected horses (57.1%) were affected bilaterally with one or more types of lesion, while 57 (42.9%) were unilaterally affected. When gender and gait were considered as predictors for individual lesion locations and distribution (bilateral vs. unilateral) in a regression model, trotters had significantly increased odds of being affected with a MM lesion (OR 5.01, 95% CI 2.27-11.82, p<0.001) and significantly decreased odds of having a DIRT lesion (OR 0.27, 95% CI 0.11-0.62, p = 0.003) (Supplementary Item 13). When sire was added to the model (i.e. gender, gait, and sire as predictor variables), gait remained significantly associated with MM and DIRT lesions (p<0.001 for both), but sire was significantly associated only with DIRT lesions (p = 0.016) (Supplementary Items 14-17). Lesion location and distribution were not significantly associated with yearling sale price in this group (Supplementary Items 18 and 19).

Performance data are summarized in **Table 3** by OC lesion location and distribution. Horses with a bilateral lesion (any location) started significantly fewer numbers of races (IRR 0.6, 95% CI 0.36-1.00, p = 0.03) than horses with unilateral lesions. Similarly, horses with LTR lesions started 0.56 the number of races as horses without LTR lesions (95% CI 0.32-0.98, p = 0.033) Other factors significantly affecting the number of starts at 2 among OC-affected horses were gender and gait, with mares and stallions starting fewer races than geldings (IRR 0.58, 95% CI 0.34-0.97, p = 0.03; and IRR 0.47, 95% CI 0.25-0.86, p=0.01, respectively), and trotters starting fewer races than pacers (IRR 0.45, 95% CI 0.27-0.73, p = 0.001) (**Table 4**). Only 3 of the 8 horses with “extensive” lesions started a race at 2 years (37.5%). OC lesion location and distribution were not significantly associated with number of wins or top 3 finishes, nor, when only starters were considered, with earnings or earnings per start (Supplementary Item 18).

Long-term performance: 2007 horses, 2- through 5-year-old seasons

Of the 94 horses in this group, 62 (66%) were colts and 32 (34%) were fillies. Colts appeared to be overrepresented in the OC-affected group (n = 25) compared to fillies (n = 7), but the proportion of affected individuals was not significantly different between genders (Δ proportion = 0.184, CI −0.008-0.403, p = 0.08, 95%). Similarly to the larger cohort reported above, OC status did not significantly affect sale price in this group. Sales price was significantly affected by sale location and sire (p<0.001), but, in contrast to the larger cohort, not by gender (Supplementary Items 20 and 21).

Performance data for the 2-year-old through 5-year-old seasons, as well as cumulative data over all 4 race seasons, of 94 horses are summarised by OC status in Supplementary Item 1. The proportion of horses starting at least one race in any season, individually or cumulatively, did not differ between OC-affected and OC-unaffected groups. When seasons were examined individually, OC status was not significantly associated with the number of starts, or wins, fastest time, or earnings and earnings per start. OC status was significantly associated with the number of top 3 finishes at 3 years - horses with OC had 1.32 times the number of top 3 finishes than horses without OC in that year (95% CI 1.10-1.59, p = 0.004) (Supplementary Item 24). When cumulative performance over 4 seasons was considered, however, OC status was significantly associated with fewer wins – horses with OC won 0.76 times the number of races as those without OC (95% CI 0.6-0.97, p = 0.028) (Supplementary Item 20). Other factors that were significant in these 2 multiple regression models were gait (IRR 1.28, 95% CI 1.03-1.59, p = 0.035 for top 3 finishes at 3 years; IRR 1.58, 95% CI 1.22-2.04, p = 0.001 for cumulative wins), number of starts (IRR 1.06, 95% CI 1.04-1.07, p<0.001 for top 3 finishes at 3 years; IRR 1.016, 95% CI 1.011-1.021, p<0.001 for cumulative wins) and fastest time (0.94, 95% CI 0.91-0.97, p<0.001 for top 3 finishes at 3 years; 0.89, 95% CI 0.85-0.93, p<0.001 for cumulative wins). Full regression analysis results are reported in Supplementary Items 20-25.

Discussion

Osteochondrosis (OC) of the hock is highly prevalent in the Standardbred horse [2-6], but its effects on performance are debated in the literature [2,7-16,23]. Here, we report early (2-year-old) and long-term (2- through 5-year-old) race performance in a cohort of age-matched related horses raised on a single breeding farm where surgical removal of OC lesions prior to yearling sales is standard of care. This is the first report of performance in a cohort of OC-affected individuals with early surgical intervention and similar breeding to matched controls with known early medical history. In the short-term performance cohort, OC status was not significantly associated with any performance measure. In the smaller long-term performance cohort, OC status was significantly associated with only 2 performance measures, but with opposite effects – OC-affected individuals had a higher number of top 3 finishes at 3 years, but lower cumulative wins over 4 race seasons. It is difficult to explain why OC would have opposite effects on 2 measures that would be expected to be correlated. For both models, gait, number of starts, and fastest time were also significantly associated with the outcome and likely explained the largest amount of variation between individuals. It is possible that if other unmeasured factors (i.e. related to inherent racing ability) could be included in a regression model that the statistical association with OC status would disappear in this group. Since similar effects were not seen in the larger study cohort (albeit looking at a more limited time frame), it is also possible that these are spurious associations related to the relatively small sample size or were significant by chance due to the multiple testing conducted within this group. Overall, OC status seemingly had minimal effect on performance in these study cohorts.

Among OC-affected individuals, those with bilateral lesions started significantly fewer races during their 2-year-old season when compared to those with unilateral lesions. OC-affected horses with LTR lesions also started significantly fewer races at 2 years than did affected horses without lesions in this location. It has previously been reported that horses with LTR lesions were not as successful after surgery as horses with other lesions [7]. We did not detect any other effects of any specific lesion location on performance, but it is possible that the number of lesions in this group of horses (especially LTR and MM) was not large enough to detect such effects. It is of note that a smaller proportion of horses with unilateral or bilateral lesions noted to be “extensive” by the attending surgeon started a race at 2 years old (3 out of 8, 37.5%) when compared to the OC-affected group as a whole (75/133, 56.4%), although the number of such individuals was too small for a meaningful statistical comparison.

Reports in the literature of performance in Standardbreds affected with OC are conflicting and difficult to compare directly due to differences in cohort selection and disease definition. In horses for which the treatment status was unknown, OC-affected horses have been reported both to perform as well as their unaffected contemporaries [2,13,15,16] and to have impaired performance [8,12]. Conservative treatment of hock OC has been advocated by some based on the seemingly minimal effect of the disease on performance. Indeed, Brehm *et al*. reported no significant difference in number of starts, wins, or places, amount of earnings, or fastest time in a group of 147 horses with conservatively-treated tarsal OC when compared to a randomly chosen group of known unaffected controls over 3 racing seasons, although the proportion of horses starting a race was not reported for either group [14]. The proportion of horses in our long-term performance cohort with OC that started at least one race over multiple seasons (27/32; 84.4%) was higher than reported in previous survey studies [12,13], and similar to the proportion reported to race after surgical treatment of OC lesions [7,8,10]. It is impossible to say whether the affected individuals in the present cohort would have performed as well without surgery. However, arthroscopic removal of osteochondral fragments has become the standard of care for treatment of most tarsal OC in young horses because of concern over the risk for long-term degenerative changes in the joint if fragments remain in place [24]. Progressive osteoarthritis with associated pain and dysfunction has been reported in humans [25] and dogs [26] with conservatively treated OC of the ankle/tarsus, and it is logical to conclude that similar sequelae could occur in equine patients with lesions in this location, although the onset of signs may be delayed until after the end of a typical racing career.

The optimal timing of surgical intervention is a question that to our knowledge has not been definitively addressed in the literature and cannot be fully addressed by our study since all of the horses in our cohort underwent surgery prior to being sold as yearlings. Based on radiographic changes of lesion appearance between 6 and 18 months of age, an argument has been made recently for delaying surgical intervention, especially for mild to moderate lesions, to allow for spontaneous healing to occur [27]. Previous work would suggest, however, that spontaneous healing of hock OC lesions is unlikely to occur after 5 months of age, and that lesions are permanent after 11 months of age [28]. In cases where clinical signs, including effusion, are present, delayed surgical intervention decreases the chances that these signs will resolve [29,30]. In our cohort, the majority of individuals underwent surgery at 11 months of age or older; those who were treated earlier typically had moderate to severe effusion of one or both joints. Examining this question from a performance perspective, Beard *et al*. reported that horses undergoing arthroscopy for tarsal OC were less likely to start as 2-year-olds compared to their unaffected counterparts and suggested that this could have been due to an interrupted training schedule [11]. Certainly, it has been reported that young horses with “planned training failure” related to arthroscopy lose more training days and have a lower financial return than those not requiring such intervention [31]. The proportion of OC-affected horses in the present cohort starting as 2-year-olds (75/133; 56.4%) was markedly higher than reported by Beard *et al*. (22%) for surgically-treated horses [11]. This difference may be due to the fact that early surgical intervention in the present study eliminated the treatment-related training disruption that would have otherwise occurred. Although the pathophysiology and natural progression of OC should be taken into account when making a decision about surgical intervention, these data suggest that early removal of OC lesions – i.e. prior to yearling sales – may be desirable for Standardbred racehorses.

Our data largely supports previous reports regarding performance differences between pacers and trotters. Trotters were slower than pacers, were less likely to start a race, and started fewer races in their 2 year old season. However, contrary to previous reports [17-19,32], once these factors were accounted for in multiple regression models, there were no differences in racing success as measured by wins, top 3 finishes, and earnings per start between gaits. The effect of OC on performance has not previously been compared between pacers and trotters. In our population, trotters were significantly more likely to be affected with OC than were pacers. Also, among OC-affected individuals, trotters were significantly more likely to be affected with MM lesions, while pacers were significantly more likely to be affected with DIRT lesions. Since pacing is naturally exhibited by young pace-bred Standardbreds prior to the onset of training, it is possible that the biomechanical differences between pacing and trotting could affect the manifestation of OC, as well as impact its effect on performance. There are at least 3 reported differences in the biomechanics of the trot and the pace that may have biological significance [33-36]. An alternative explanation could be that genetic risk factors vary between pacers and trotters, leading to the differences in disease prevalence and lesion distribution. The effect of sire on OC status was evaluated in our entire short-term performance population and was not found to be significant. When only OC-affected horses were considered, sire was not significantly associated with MM lesions, but was significantly associated with DIRT lesions. We hypothesise that pacers and trotters likely share genetic risk factors for disease and develop the same early lesions, but that biomechanical differences in their natural gait patterns may determine which lesions go on to heal and which develop into permanent OC lesions, resulting in the different lesion locations between gaits. Ideally, a prospective evaluation of a large cohort of Standardbred pacer and trotter foals would be carried out to evaluate this hypothesis. However, as OC status did not affect performance outcomes in either pacers or trotters, differences in lesion prevalence and distribution may not be clinically significant.

There are several limitations of the current study design, including the relatively small sample size, especially for the long-term performance cohort; it is possible that some of the differences between groups that did not reach significance would have done so in a larger population. Another limitation, inherent in the retrospective design, is that although we have one to 4 years of race data available, direct follow-up with new owners after the yearlings were sold was not possible, so the subsequent medical history of these horses is unknown. Thus, there is no way to determine if performance failure in affected horses was related to OC or not. Similarly, it is possible that horses classified as unaffected as yearlings could have gone on to develop signs related to existing, but previously undiagnosed, OC lesions after being put into training, although it is unlikely that this would have happened in a large number of cases. This is of greatest concern in the long-term performance cohort, in which half of the controls did not have radiographs and were instead considered “clinically free” of OC. It is widely accepted that some horses with OC do not show any clinical signs, although the prevalence of this has not been reported. Presence or absence of effusion was not recorded for all of the OC-affected horses in the current cohort, so it is difficult to estimate how many clinically unaffected horses may have had a lesion. The decision was made to retain the non-radiographed controls because it was felt that the larger population would have more power to detect differences between groups, but we acknowledge the possible misclassification bias in our long-term performance results. However, we did carry out the same statistical analyses reported here in the long-term performance cohort using only radiographed controls and still found that OC was significantly associated with few performance measures (fewer wins at 5 years, slower time at 4 years, more top 3 finishes at 3 years; Supplementary Item 26). Thus, it is unlikely that misclassification of controls affected our overall conclusions.

The overall proportion of horses in this study starting at least one race during their 2-year-old season (171/278; 61.5%) as well as the overall proportion of horses starting at least one race over multiple seasons (77/94; 81.9%) was somewhat higher than that previously reported in randomly chosen control populations [11] or general radiographic surveys of Standardbred yearlings [12,13]. While this is unlikely to have been affected by selection bias, as the horses were chosen for inclusion prior to being sold as yearlings, it does raise the question of whether the conclusions drawn from this study are specific to horses raised on this single breeding farm. To help address this, a randomly chosen subset of all 2010 offspring from 19 Standardbred stallions with progeny also included in the short-term performance study population were selected for comparison to the horses in the present study. There was no significant difference in any examined outcome measure between the 2 groups. This suggests that our study population is similar to the larger population of racing

Standardbreds in North America and that it is reasonable to expect that our findings can be extrapolated to the wider population.

In summary, consistent with our hypothesis, we found that Standardbreds which underwent early removal of tarsal OC lesions performed equivalently to their unaffected counterparts during their 2-year-old race season as well as over 4 consecutive race seasons (2- through their 5-year-old). Among OC-affected individuals however, those with bilateral lesions started fewer numbers of races at 2 years than those with unilateral lesions. Similarly, horses with LTR lesions started fewer numbers of races at 2 years than those without lesions at this location. This suggests that even if bilateral lesions or LTR lesions are removed at an early age (i.e. before yearling sales, as in this group of horses), they can still negatively impact early race performance. Following a larger group of horses over several race seasons will help to determine if this effect is maintained over the long term. While pacers and trotters exhibited differences in race performance (as expected), including slower record times and fewer starts in trotters when compared to pacers, OC status did not seem to affect performance outcomes in horses of either gait. Unexpectedly, trotters were significantly more likely to be affected with OC than were pacers. When specific lesion locations were considered, trotters were more likely to exhibit MM lesions than pacers, while pacers were more likely to have DIRT lesions than trotters. Biomechanical or genetic differences between gaits may be involved in this seemingly differing manifestation of disease between groups. Further research should be conducted to validate this finding in a larger population of Standardbred racehorses.

Supplementary Material

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Table 1

Summary of 2-year-old performance measures for foals in the short-term performance cohort (n = 278) with (OC+) and without (OC−) surgically-treated tarsal OC lesions.

		OC+	OC−
Starting at 2		75/133 (56.4%)	96/145 (66.2%)
Sale Price	Mean	$32,010	$34,870
	Median	$20,000	$25,000
	Range	$1,500-260,000	$1,500-260,000
Starts	Mean	4.2	4.5
	Median	1	3
	Range	0-21	0-16
Wins	Mean	0.5	0.7
	Median	0	0
	Range	0-7	0-8
Top 3 Finish	Mean	5.4	5.8
	Median	1	4
	Range	0-30	0-23
Earnings (starters only)	Mean	$26,830	$28,650
	Median	$10,110	$7,742
	Range	$1-194,000	$1-531,900
Earnings per Start (starters only)	Mean	$2,935	$3,128
	Median	$1,070	$1,216
	Range	$0.25-18,450	$0.33-48,360
Fastest Time (s)	Mean	118.6	118.2
	Median	118.0	118.2
	Range	112.6-129.6 (n = 49)	111.2-125.4 (n = 62)

Table 2

Summary of 2-year-old performance measures for pacers (n = 151) and trotters (n = 127) with (OC+) and without (OC−) surgically-treated tarsal OC lesions.

		Pacers			Trotters	
		OC+	**OC−**		**OC+**	**OC−**
Starting at 2		41/62 (66.1%)	62/89 (69.7%)		34/71 (47.9%)	34/56 (60.7%)
Sale Price	Mean	$28,700	$34,390	Mean	$34,980	$35,630
	Median	$17,000	$22,000	Median	$22,000	$25,000
	Range	$1,500-115,000	$1,500-260,000	Range	$1,500-260,000	$2,500-170,000
Starts	Mean	5.9	5.3	Mean	2.7	3.3
	Median	4.5	5	Median	0	2
	Range	0-21	0-16	Range	0-15	0-14
Wins	Mean	0.6	0.9	Mean	0.5	0.4
	Median	0	0	Median	0	0
	Range	0-6	0-8	Range	0-7	0-5
Top 3 Finish	Mean	7.5	6.8	Mean	3.5	4.2
	Median	6.5	7	Median	0	2
	Range	0-30	0-23	Range	0-21	0-21
Earnings (starters only)	Mean	$26,800	$27,720	Mean	$26,860	$30,340
	Median	$10,990	$8,901	Median	$9,330	$3,522
	Range	$1-171,100	$1-531,900	Range	$1-194,000	$1-419,000
Earnings per **Start** (starters only)	Mean	$2,790	$3,062	Mean	$3,109	$3,249
	Median	$905	$1,216	Median	$1,248	$1,202
	Range	$0.25-17,110	$0.5-48,360	Range	$0.50-18,450	$0.33-29,930
Fastest Time (s)	Mean	117.9	116.8	Mean	119.6	121
	Median	117.6	116.8	Median	119.4	121.5
	Range	112.6-126.4 (n = 28)	111.2-125.4 (n = 42)	Range	115.8-129.6 (n = 21)	115.4-125.2 (n = 20)

Table 3

Summary of 2-year-old performance measures for OC-affected horses (n = 133). DIRT = distal intermediate ridge of the tibia. MM = medial malleolus of the tibia. LTR = lateral trochlear ridge of the talus.

		DIRT	MM	LTR	Bilateral Lesion (any location)
Starting at 2		56/93 (60.2%)	26/48 (54.2%)	17/37 (45.9%)	39/76 (51.3%)
Sale Price	Mean	$29,520	$31,890	$33,510	$33,580
	Median	$17,000	$20,000	$24,000	$17,000
	Range	$1,500-115,000	$1,500-260,000	$2,500-115,000	$1,500-260,000
Starts	Mean	4.4	3.2	3.1	3.6
	Median	2	1	0	1
	Range	0-21	0-14	0-13	0-21
Wins	Mean	0.5	0.5	0.4	0.5
	Median	0	0	0	0
	Range	0-7	0-7	0-4	0-7
Top 3 Finish	Mean	5.7	4.1	4	4.8
	Median	2	1	0	1
	Range	0-30	0-20	0-17	0-30
Earnings (starters only)	Mean	$26,300	$27,140	$19,940	$26,730
	Median	$8,549	$4,548	$4,750	$9,825
	Range	$1-194,000	$1-194,000	$1-171,100	$1-194,000
Earnings per **Start** (starte**rs only**)	Mean	$2,839	$3,039	$2,324	$3,094
	Median	$909	$944	$1,228	$943
	Range	$0.25-17,640	$0.25-18,450	$1-17,110	$0.50-18,450
Fastest Time **(s)**	Mean	118.9	118.3	117.8	118.7
	Median	118.0	117.8	118	117.8
	Range	112.6-129.6	113.2-129.6	114.2-121.6	112.6-129.6

Table 4

Multiple regression results for number of starts at 2 years for OC-affected horses (n = 133). DIRT = distal intermediate ridge of the tibia. MM = medial malleolus of the tibia. LTR = lateral trochlear ridge of the talus; bilat = bilateral; G = gelding; M = mare; S = stallion; P = pace; T = trot. Reference states for these binomial predictor variables were unaffected (no) for lesion location and unilateral (bilat [no]) for lesion distribution.

Outcome Variable	Predictor Variable	Estimate (IRR)	2.5%	97.5%	p-value
Starts (number)	DIRT (yes)	0.922376	0.507378	1.674533	0.782
	MM (yes)	0.865829	0.462288	1.667035	0.617
	LTR (yes)	0.556934	0.321267	0.980599	**0.033**
	bilat (yes)	0.599865	0.356129	1.004136	**0.03**
	gender(G)	REF	n/a	n/a	n/a
	gender (M)	0.575455	0.340365	0.969076	**0.031**
	gender(S)	0.470114	0.25938	0.860978	**0.011**
	gait (P)	REF	n/a	n/a	n/a
	gait (T)	0.450336	0.275834	0.728408	**0.001**