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Original Research

Left-Sided Ovulation Favors More Male Foals Than Right-Sided Ovulation in Thoroughbred Mares

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ABSTRACT

The side of pregnancy has been observed to impact the sex of offspring in different species of mammals. Accordingly, the present study was conducted to investigate the distribution of male and female foals in the left and right ovaries in Thoroughbred mares. To do so, data associated with sex of foals, side of ovulation, stallion ID, and age and parity of mares at conception were collected from four horse centers. In total, data consisted of 238 birth records from 238 dams and 23 sires. Data were analyzed using univariable and multivariable logistic regression analyses. The incidence of left and right ovulations were 51.3% (122/238) and 48.7% (116/238), respectively, which were not different ($P > .05$). Secondary sex ratio (SSR; the proportion of male foals at birth) in nulliparous mares (29/83, 34.9%) was lower than that in parous mares (82/155, 52.9%; adjusted odds ratio, 0.388; $P = .005$). Moreover, conception of oocyte ovulated from the left ovary resulted in higher proportion of males (70/122, 57.4%) than conception of oocyte ovulated from the right ovary (41/116, 35.3%; adjusted odds ratio, 3.636; $P < .0001$). Secondary sex ratio of right-sided ovulation was lower than the expected 50.0% SSR (odds ratio, 0.547; $P = .026$), but SSR of left-sided ovulation and overall SSR (111/238, 46.6%) did not differ from the expected 50.0% SSR ($P > .05$). In conclusion, the present study showed dissimilar distribution of male and female foals for left and right ovulations in ovaries of Thoroughbred mares. Moreover, the results indicated the effect of parity on the proportion of male foals in equine.

1. Introduction

The general assumption is that the proportion of male and female offspring is equivalent in mammals [1]; however, various factors have been observed to impact the sex ratio of offspring in favor of males or females, including maternal body condition [2–5] as well as change in maternal body condition before and after conception [6], nutrition [1,7], maternal glucose concentration during the early stages of embryogenesis [8,9], parity of dam [10–12], maternal hormonal profile [9,13], stress [14,15], climatic parameters [12,16–18], and sire [12,19,20].

Asymmetric distribution of male and female offspring within the left and right uterine horns has been reported in various species including Mongolian gerbils [21], mice [22], rabbits [23], and beef cattle [24,25]. Clark et al [26] found inversion of the sex ratio of fetuses in the left and right uterine horns in Mongolian gerbils after translocating the left and right ovaries by surgery. Furthermore, Hylan et al [24] found higher proportion of females than males in embryos originating from oocytes derived from the left

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Table 1
Distribution of male and female foals in the four different age groups considering sides of ovulation.

Age Group	Total	Side of Ovulation			
		Left		Right	
		Male (%)	Female (%)	Male (%)	Female (%)
1 (3–5 y)	64	19 (52.8)	17 (47.2)	9 (32.1)	19 (67.9)
2 (6–8 y)	124	34 (53.1)	30 (46.9)	19 (31.7)	41 (68.3)
3 (9–11 y)	38	14 (77.8)	4 (22.2)	11 (55.0)	9 (45.0)
4 (12–14 y)	12	3 (75.0)	1 (25.0)	2 (25.0)	6 (75.0)

ovaries; however, such phenomenon was not observed in pregnancies resulting from transferring embryos to the left uterine horns of recipients. Therefore, it has been surmised that ovarian factors might play a more significant role in sex ratio adjustment than does the uterine environment [24,26]. To our knowledge, no study has investigated the effect of side of ovulation on sex ratio of offspring in equine.

Although there is no absolute preference for a particular gender in horse industry, the sex of foals could be important for horse breeders [20,27,28], accentuating the significance of studies discovering factors affecting sex ratio in equine, which could further help develop methods to alter the sex ratio of foals toward the desired gender [20]. Therefore, a retrospective study was conducted to investigate the effect of side of ovulation on the secondary sex ratio (SSR; the proportion of male foals at birth) in Thoroughbred mares.

2. Materials and Methods

2.1. Data

To investigate the effect of side of ovulation on the proportion of male foals at birth, data associated with sex of foals, side of ovulation, sire ID, and age and parity of dams at conception were retrieved from the database of four horse centers. Only data of single ovulations were included in the analyses. All the mares ($n = 238$; age, 3–14 years) were of Thoroughbred breed, which had conceived after natural mating with stallions ($n = 23$) during the breeding season of 2013. The sex of foals had been determined at birth. The side of ovulation had been diagnosed using transrectal ultrasonography (Honda HS-1500; Tokyo, Japan). Mares were categorized in four age groups including 1 (3–5 years), 2 (6–8 years), 3 (9–11 years), and 4 (12–14 years). With regard to parity, mares were coded into two classes including nulliparous and parous (including primiparous and multiparous) mares.

2.2. Statistical Analysis

Data associated with the binary outcome variables including the incidence of ovulation and SSR were analyzed by logistic regression using LOGISTIC procedure. Model specification was based on backward elimination method. In the analysis of the incidence of ovulation, the full model included the fixed effects of age and parity. In the analysis of SSR, the full model included the fixed effects of side of ovulation, age, and parity. The threshold significance level for each explanatory variable to stay in the final model was $P < .05$. Next, SSR was analyzed using the respective final models, which had been built by LOGISTIC procedure, by GLIMMIX procedure (including function link logit in the model) considering horse center and stallion as random effects in the multivariable logistic regression analyses. Additionally, the observed SSR associated with the left and right ovaries and the overall SSR in the present study versus the expected hypothetical SSR of 50% were analyzed using univariable logistic regression (GLIMMIX procedure including function link logit in the model). The univariable and multivariable logistic regression analysis (in which the effects of multiple predictors were examined and the analysis was adjusted for the potential confounders) generated odds ratios (ORs) and adjusted odds ratios (AORs), respectively, as the estimates of the strength of difference. All analyses were conducted in SAS version 9.2 [29]. Based on the ORs generated by logistic regression analysis, risk ratios (RRs) were calculated using the formula developed by Zhang and Yu [30]: $RR = OR/[(1 - P_{ref}) + (P_{ref} \times OR)]$, in which RR, OR, and P_{ref} indicate the calculated RR, OR, and risk of the outcome in the reference group, respectively. Differences were considered statistically significant at $P < .05$.

3. Results

The incidence of left and right ovulations was 51.3% (122/238) and 48.7% (116/238), respectively. The incidence of ovulation was not different between the left and right ovaries ($P > .05$). The incidence of left and right ovulations was not different among age groups ($P > .05$; Table 1). Similarly, the incidence of left and right ovulations did not differ between nulliparous (40/83, 48.2% and 43/83, 51.8%, respectively) and parous (82/155, 52.9% and 73/155, 47.1%, respectively) mares ($P > .05$).

The overall SSR was 46.6% (111/238) in the present study. Secondary sex ratio did not differ among the age groups ($P > .05$; Table 1). But SSR in nulliparous mares (29/83, 34.9%) was lower than that in parous mares

Table 2
Adjusted odds ratio (AOR) and adjusted risk ratio (ARR) for the effect of side of ovulation (left-sided vs. right-sided ovulation) and parity (nulliparous vs. parous mares) on secondary sex ratio (SSR) in Thoroughbred mares.

Effect	Class	SSR, %	AOR[a] (95% Confidence Interval)	ARR[b] (95% Confidence Interval)	P Value
Side of ovulation	Left	57.4 (70/122)	3.636 (1.992–6.623)	1.883 (1.475–2.219)	<.0001
	Right	35.3 (41/116)	—	—	—
Parity	Nulliparous	34.9 (29/83)	0.388 (0.201–0.749)	0.574 (0.357–0.864)	.005
	Parous	52.9 (82/155)	—	—	—

[a] AORs were generated by multivariable logistic regression analysis.
[b] ARRs were calculated using the AORs generated by multivariable logistic regression analysis.