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Original Research

Longitudinal Study of Growth and Osteoarticular Status in Foals Born to Between-Breed Embryo Transfers

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ABSTRACT

The role of antenatal events on growth and predisposition to osteochondrosis (OC) was investigated in foals born to between-breed embryo transfers. Pony (P), saddlebred (S), and draft (D) horses were used. Control P-P (n = 21) and S-S (n = 28) pregnancies were obtained by artificial insemination. Enhanced and restricted pregnancies were obtained by transferring P or S embryos into D mares (P-D, n = 6 and S-D, n = 8) and S embryos into P mares (S-P, n = 6), respectively. Control and experimental foals were raised by their dams and recipient mothers, respectively, and weaned at age 6 months. Body measurements were recorded from birth to age 18 months. Osteochondrosis status was evaluated shortly after weaning and at age 18 months. Fetal growth was enhanced in P-D foals with overgrowth of most body segments until age 18 months. Fetal growth was restricted in S-P foals compared with S-D foals. Body weight, shoulder, and hip width of S-P foals grew slower before weaning but subsequently caught up after weaning. Other segments did not catch up, resulting in reduced body weight and withers' height in S-P compared with S-D foals at age 18 months. The relative risk of developing OC was increased in restricted S-P foals compared with S-S and S-D foals shortly after weaning where all S-P foals were OC positive. Only two S-P foals were still OC positive at age 18 months. These data confirm the impact of the intrauterine environment on growth, skeletal health, and possibly athletic capacities of horses.

1. Introduction

The Developmental Origins of Health and Disease concept (or developmental programming) is based on the observation that alterations in fetal development caused by an environmental stimulus have long-term impacts on postnatal development and determine the adult phenotype and predisposition to noncommunicable diseases [1–5]. As demonstrated by experimental models in foals, postnatal consequences of adverse intrauterine conditions include alterations of growth patterns at least until 3 years of age [6,7] and alterations of insulin secretion and sensitivity, not only in the immediate postpartum period [7–9], but also several months later [7,10] and even beyond 1 year of age (Peugnet et al, 2015, Personal Communication). Besides, an epidemiologic study recently showed a detrimental effect of feeding pregnant mares with concentrates on the development of osteochondrosis (OC) in their 1- to 3-year-

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old offspring [11]. This supported the previous hypothesis of a fetal origin of OC [12–16]. As a matter of fact, the incidence of OC in foals has been related to postprandial hyperglycemia and hyperinsulinemia [17], causing a defect in chondrocytes maturation and subsequent bone formation [14,18]. This has been investigated through epidemiologic studies [19] and through the study of experimental foals fed high versus low energy rations [17,20,21]. To date, however, the fetal origin of OC has not been demonstrated experimentally.

We previously induced increased versus restricted fetal growth using embryo transfers between breeds of different sizes (ponies, saddlebreds, and draft horses). Increased pony-in-draft foals developed an early resistance to insulin, whereas restricted saddlebred-in-pony foals demonstrated a higher sensitivity to insulin at weaning (Peugnet et al, 2015, Personal Communication) [7]. The purpose of the present research was to explore the effects of between-breed embryo transfers on growth patterns and osteoarticular status in these foals. Body measurements and four biomarkers linked to bone and cartilage turnover (osteocalcin, bone-specific alkaline phosphatase [b-AlP], C-telopeptide of type II collagen [CTX-II], and hydroxyproline), together with bone health as assessed by radiographic examination, were monitored from birth to 540 days of age.

2. Materials and Methods

Animal studies were approved by the local animal care and use committee ("Comité des Utilisateurs de la Station Expérimentale de Chamberet") and received ethical approval from the local ethics committee ("Comité Régional d'Ethique pour l'Expérimentation Animale du Limousin") under protocol number 5-2013-5.

2.1. Establishment of Experimental and Control Groups

Experimental and control groups were established over two successive breeding seasons (foaling in 2011 and 2012) using semen from one pony and two saddlebred stallions as previously described [7]. Pony mares were located at the "Institut National de la Recherche Agronomique" (INRA) experimental farm in Nouzilly, France (farm 1). Saddlebred and draft mares were located at the "Institut Français du Cheval et de l'Equitation" experimental farm in Chamberet, France (farm 2). Median mares' age was 6.2 years (range 3.0–19.2 years). Both herds included primiparous and multiparous mares (up to 10 pregnancies). The distribution of mares between groups according to body weight, withers' height, age, and parity is shown in Table 1.

Following embryo recovery after ovulation in the pony and saddlebred donor mares and between-breed transfer of the embryos into synchronized pony and draft recipient mares, six pony-in-draft (P-D), six saddlebred-in-pony (S-P), and eight saddlebred-in-draft (S-D) experimental foals were produced. Eleven pony-in-pony (P-P) and 21 saddlebred-in-saddlebred (S-S) control foals were produced by artificial insemination using the same stallions as for embryo production (Fig. 1). All the mares delivered spontaneously at term, without any dystocia.

2.2. Management of Mares and Foals

Planes of nutrition of mares and foals were previously described (Peugnet et al, 2015, Personal Communication) [7]. They were fed according to current INRA recommendations for pregnant and lactating mares and for growing foals [22]. Briefly, pregnant mares were kept on pasture from first pregnancy diagnosis at 14 days (spring) until November, when they were housed in boxes and fed a diet based on straw and hay complemented with concentrates (soybean or commercial pellets (Eperon, Tellus Nutrition Animale, France) with free access to mineral salts on farm 1 and either homemade pellets containing barley, soybean cake, molasses, minerals and vitamins, or moha hay on farm 2). The pregnant mares' diet was adjusted to requirements according to body weight and month of pregnancy.

After foaling, all mares and their foals returned to grazing. Experimental and control foals were raised by their surrogate mother or biological dam, respectively. On each farm, fillies and colts were kept in one same herd until weaning at 6 months of age. From weaning, foals were housed together in open barns and fed a diet based on straw and hay complemented with concentrates (oat and soybean cake with free access to mineral salts on farm 1 and homemade pellets containing barley, soybean cake, molasses, minerals and vitamins on farm 2). All colts were gelded around 9 months of age. From 12 months of age, fillies and geldings were conducted in one group in the same pasture until 18 months of age. At this time, they were housed in open barns again and fed a diet based on straw and hay complemented with concentrates

Table 1
Distribution of mares between the five groups according to body weight, withers' height, age and parity (median [minimum–maximum]), and number of foals obtained each year with sex ratio within each group.

	P-P	P-D	S-P	S-S	S-D
Mares' breed	Pony	Draft	Pony	Saddlebred	Draft
Body weight in the last month of pregnancy	338 (289–360)	840 (785–876)	405 (396–427)	641 (621–687)	843 (786–869)
Withers' height (cm)	121 (117–129)	158 (149–171)	133 (123–139)	160 (152–170)	158 (149–161)
Age (y)	9 (3–13)	5 (3–6)	9 (3–10)	7 (4–19)	4 (3–6)
Parity	1 (1–4)	1 (1–3)	1 (1–2)	2 (1–10)	1 (1–2)
Foals' breed	Pony	Pony	Saddlebred	Saddlebred	Saddlebred
Foals in 2011	5	5	2	13	8
Foals in 2012	6	1	4	8	0
Total number of foals	11	6	6	21	8
Females	6	4	2	13	6
Males	5	2	4	8	2

Abbreviations: P-D, pony-in-draft; P-P, pony-in-pony; S-D, saddlebred-in-draft; S-P, saddlebred-in-pony; S-S, saddlebred-in-saddlebred.