Journal of Equine Veterinary Science 48 (2017) 143–153

Contents lists available at ScienceDirect

Journal of Equine Veterinary Science

journal homepage: www.j-evs.com

Original Research

Enhanced or Reduced Fetal Growth Induced by Embryo Transfer Into Smaller or Larger Breeds Alters Postnatal Growth and Metabolism in Weaned Horses

Pauline Peugnet [a,*], Laurence Wimel [b], Guy Duchamp [c], Charlotte Sandersen [d], Sylvaine Camous [a], Daniel Guillaume [e,f,g,h], Michèle Dahirel [a], Cédric Dubois [b], Fabrice Reigner [c], Valérie Berthelot [i,j], Stéphane Chaffaux [a], Anne Tarrade [a], Didier Serteyn [d], Pascale Chavatte-Palmer [a]

[a] *INRA, UMR1198 Biologie du Développement et Reproduction, Jouy en Josas, France*
[b] *IFCE, Station Expérimentale de la Valade, Chamberet, France*
[c] *INRA, UE1293, Nouzilly, France*
[d] *Clinique équine, Faculté de Médecine Vétérinaire, CORD, Université de Liège, Liège, Belgium*
[e] *INRA, UMR85, Physiologie de la Reproduction et Comportements, Nouzilly, France*
[f] *CNRS, UMR7247, Nouzilly, France*
[g] *Université François Rabelais de Tours, Tours, France*
[h] *IFCE, Nouzilly, France*
[i] *INRA, UMR791 Modélisation Systémique Appliquée aux Ruminants, Paris, France*
[j] *AgroParis Tech, Paris, France*

ARTICLE INFO

Article history:
Received 5 November 2015
Received in revised form 20 March 2016
Accepted 22 March 2016
Available online 6 April 2016

Keywords:
Horse
DOHaD
Growth
Glucose metabolism
Insulin sensitivity
Thyroid hormones

ABSTRACT

Embryo transfer between breeds of different sizes impacts fetal growth in horses. We have shown that it elicits various postnatal adaptations in terms of growth and glucose metabolism until weaning. Postweaning effects remain to be described. Pony (P), saddlebred (S), and draft (D) horses were used. Control Pony-in-Pony (P-P; n = 21) and Saddlebred-in-Saddlebred (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 (Pony-in-Draft [P-D], n = 6 and Saddlebred-in-Draft [S-D], n = 8) and S embryos into P mares (Saddlebred-in-Pony [S-P], n = 6), respectively. Control and experimental foals were raised by their dams and recipient mothers, respectively and weaned on day 180. Weight gain, growth hormones, and glucose metabolism were investigated in foals between days 180 and 540. Pony-in-Draft (P-D) remained heavier than P-P on days 180, 360, and 540, with lower glucose and higher non-esterified fatty-acids on days 180, 360, and 540 and higher T_3 on day 180. Insulin sensitivity was similar between pony groups on days 200 and 540. S-P were lighter than S-D on day 180 but caught up by day 540. S-P had higher glucose than S-D on days 180, 360, and 540, as well as lower non-esterified fatty-acids and higher T_3 on day 180. Insulin sensitivity was higher in S-P than in S-D on day 200. No difference was observed between saddlebred groups thereafter. In conclusion, in horses, fetal growth is determinant for postnatal metabolism, especially for energy availability.

* Corresponding author at: Pauline Peugnet, Molecular Animal Breeding and Biotechnology, LMU Munich, Hackerstraße 27, 85764 Oberschleißheim, Germany.

E-mail address: peugnetpauline@gmail.com (P. Peugnet).

0737-0806/$ – see front matter © 2016 Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.jevs.2016.03.016

1. Introduction

Developmental conditions play a crucial role in determining some of the physiological characteristics of adults, as demonstrated by epidemiologic studies in humans [1] and experiments in animal models [2]. Programming effects may vary according to the timing, duration, and nature of the intrauterine perturbation [3], as well as to the individual's genotype and gender [4]. Although a reduced birth weight (considered as a marker of suboptimal fetal growth) was first pointed out as an indicator of increased risks of developing metabolic pathologies in human adults, it is now established that excess birth weight also leads to adverse programming [5]. The critical time of tissue plasticity in response to environmental "stimuli," however, extends beyond birth and especially to the suckling period during which milk quantity and quality are important programming factors [3,6,7]. Therefore, the early postnatal environment may either improve or exacerbate structural and functional alterations programmed *in utero*.

Although still in the early stages, studies of the Developmental Origins of Health and Disease are particularly relevant in horses, which have dual purpose as athletes and companion animals. There is a growing body of research showing that adequate management of broodmares might be used to produce healthy adult horses with the desired features, optimizing their economic value [8]. Using artificial insemination to crossbreed Shetland ponies and large Shire horses [9] or using the transfer of Polish pony embryos into the uterus of draft mares [10,11], Walton and Tischner were the first to demonstrate that the breed-specific growth potential of the foal can be regulated by the size of the mare, that is, the ability of the maternal environment to modulate the genetic potential of the foal for fetal and postnatal growth. More recently, Allen et al [12] used embryo transfers between breeds of different sizes (ponies and Thoroughbreds) as a model of restricted (Thoroughbred-in-Pony) or increased (Pony-in-Thoroughbred) nutritional supply to the fetus. Restricted or increased fetal and postnatal growth [12,13] were associated with neonatal alterations in glucose sensitivity of pancreatic β-cells [14]. Glucose homeostasis–related disorders such as laminitis, obesity, equine metabolic syndrome, and osteochondrosis are likely to alter reproductive performances [15,16] and sport capacities [17–19] of horses and to cause economic losses to the equine industry [19]. As their prevalence increased dramatically in the equine population over the past few years [20–22], the management of glycemic variations has become a burning issue of equine breeding systems.

We aim to clarify the impact of the maternal environment on the glucose homeostasis of growing foals beyond weaning. The present study is a follow-up of previous work in which fetal growth was enhanced by transferring pony and saddlebred embryos into draft mares or restricted by transferring saddlebred embryos into pony mares. These transfers induced different adaptive responses in terms of growth, endocrine profiles, and glucose metabolism in preweaning foals [23]. Overgrown ponies born to draft dams were less insulin-sensitive earlier than normal ponies, with reduced thyroid hormones and fasting glucose concentrations, whereas intrauterine growth–restricted saddlebreds were more insulin-sensitive than saddlebreds born to draft dams, with elevated thyroid hormones and fasting glucose concentrations. Here, we investigated weight gain, glucose homeostasis, and endocrine factors involved in both growth and energy regulation in the same foals from 6 (weaning) to 18 months of age.

2. Materials and Methods

The 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 described previously [23]. Both saddlebred stallions were of the Anglo-Arab breed and were 1.60 m and 1.65 m high at the withers. After embryo recovery in the pony and saddlebred donor mares and between-breed transfer of the embryos into synchronized pony and draft recipient mares, Pony-in-Draft (P-D, $n = 6$), Saddlebred-in-Pony (S-P, $n = 6$), and Saddlebred-in-Draft (S-D, $n = 8$) experimental foals were produced. Pony-in-Pony (P-P, $n = 21$) and Saddlebred-in-Saddlebred (S-S, $n = 28$) control foals were produced by artificial insemination. Experimental and control foals were raised by their surrogate mother and biological dam, respectively. All foals were weaned on day 180. The P-P and S-P groups of foals were kept at the Institut National de la Recherche Agronomique experimental farm in Nouzilly, France (farm 1, 47°32′56.6″N, O°47′11.6″E, 120 m). The P-D, S-S, and S-D groups of foals were kept at the Institut Français du Cheval et de l'Equitation experimental farm in Chamberet, France (farm 2, 45°34′55.17″N, 1°43′16.29″E, 442 m). The feeding routine, body weight, and body condition of mares throughout pregnancy and lactation were reported previously [23].

2.2. Nutrition and General Care of Weaned Foals

From days 180 to 330 (winter months), foals on both farms were group-housed in open barns consisting in a covered area with a straw litter and free access to an outdoor run. On farm 1, foals received oat, soybean cake, and pasture hay with free access to minerals and vitamins (Sodical, Salins Agriculture, France), with the exception of S-P foals receiving occasionally extra commercial pellets (Eperon; Tellus Nutrition Animale, France) or corn grain. On farm 1, feedstuffs were distributed twice a day (9 AM and 4 PM) by animal technicians. On farm 2, foals received homemade pellets made of barley, soybean cake, molasses, and minerals and vitamins (Excel Prima S; Chauveau Nutrition, France) with pasture hay, as well as hay crop