What global maternal and child nutrition can learn from animal science

The main challenges to ensuring optimal nutrition of children in low-income and middle-income settings are prevention of undernutrition—including intrauterine growth restriction, stunting, and micronutrient deficiencies—and avoidance of becoming overweight.[1] Birth cohort studies show that linear growth in early life is associated with improved human capital (including intelligence, educational performance, and productivity) and has few, if any, deleterious effects regarding future risk of non-communicable diseases.[2] By contrast, rapid weight gain, above and beyond what is required for linear growth, does not confer any benefits in terms of human capital and is associated with an increased risk of chronic diseases.[2] Early undernutrition followed by exposure to an obesogenic diet in later childhood seems to result in especially poor outcomes. Ensuring that young children achieve optimal linear growth without putting on excessive weight represents a major challenge to public health and nutrition.

In 1951, the British nutritionist Isabella Leitch proposed an analogy between the growth of piglets and children.[3] Studying pigs that were undernourished early in life and then fed appropriately, she concluded that "skeleton and muscle will not grow as they would have done if they had had the opportunity at the right time, and the extra food will be used mainly to lay on fat".[3] She referred to these animals as "low-high"[3] pigs, and proposed they would be better off by remaining thin than by putting on weight, arguing that this condition "can probably be prevented only by the continuation of a spartan regime throughout life, which seems a bit hard".[3]

Whether Leitch's ideas were correct and her proposed interventions feasible, she was undoubtedly a pioneer in attempting to translate results from applied animal science to human nutrition.[4] Anyone who has seen or eaten pork for the past few decades will have noticed that today's animals have a larger skeletal frame and that their meat has become much leaner over time. This is partly because of breeding, but also because of precise formulation of animal diets.[5]

Could new approaches to global nutrition lead to interventions that would make children grow tall without putting on excessive fat, as is the case for present-day piglets? Animal science has been addressing this issue for a long time, although with rigorous studies that cannot be conducted in humans. More than 60 years after Leitch's paper,[3] Jack Odle and colleagues produced a landscape review[6] to address a crucial question: what can global human nutrition learn from animal science? The review covered four main areas, known in the global health literature as the continuum of care: preconception, gestation and pregnancy, lactation and suckling, and post-weaning and toddler phases. This review[6] resulted in more than a dozen key findings, suggesting some potential interventions that receive scant attention in global nutrition at present. In particular, the review highlighted "the quantitative importance of essential fatty acid and aminoacid nutrition in reproductive health; the suggested application of the ideal protein concept for improving the aminoacid nutrition of mothers and children; the prospect of using dietary phytase to improve the bioavailability of trace minerals in plant and vegetable-based diets; and nutritional interventions to mitigate environmental enteropathy".[6] The table shows the contrast between Odle and colleagues' potential recommendations and the comprehensive list of effective diet-related interventions published in the 2013 *Lancet* Nutrition Series (table).[7]

From the end of World War 2, the global community regarded protein deficiency to be the major nutritional problem in poor countries and called for policies and programmes to close the so-called protein gap. In the mid-1970s, prominent nutritionists declared this to be fallacious using terms such as "the great protein fiasco"[8] and world attention shifted from protein quantity and quality, to quantity of food. More recently, the concern with quality returned but with a focus on micronutrients.

The first major difference with respect to animal research is the extent to which human programmes today focus on micronutrients. At different stages during the continuum of care, global nutrition relies on promotion of intake of folic acid, iron, calcium, iodine, vitamin K, vitamin A, and multiple micronutrient

	Main effects on animal health	Global health considerations
Preconception–conception		
Early correction of nutrition excess	Normalises fetal growth, adiposity, and glucose–insulin metabolism	At present, no emphasis on correction of overweight before conception
Correction of energy deficit	Improves oocyte and embryo quality	Emphasis has so far been on correction of pre-conceptional underweight (through balanced energy–protein supplementation) and micronutrient deficiencies (eg, iron–folic acid and multiple micronutrients)
Optimisation of essential fatty acid intake	Improves oestrus expression, conception, and maintenance of pregnancy	Interventions for increasing intake of essential fatty acids are not part of global programmes
Gestation–pregnancy		
Alleviation of hyperthermia	Improves placental and fetal weight, and postnatal lean growth (more protein and less lipid)	No global recommendations for reduction of exposure to heat among pregnant women, which might represent a growing problem because of climate change
Optimisation of energy and aminoacid feeding, especially to young mothers to support gestation and lactation	Improves maternal tissue, fetal growth, milk production, and postnatal growth	Balanced energy-protein supplementation has long been a cornerstone of maternal nutrition in poor settings, but emphasis seems to have shifted to supplementation with specific micronutrients; prevention of adolescent pregnancies and improvement of the health of adolescent girls are priority actions
Optimisation of essential aminoacid intakes by formulation of diets for so-called ideal protein	Supports protein accretion rates in conceptus and maternal tissues by preventing aminoacid deficit	Emphasis on specific essential aminoacids is not an important component of global health and nutrition interventions
Optimisation of intake of functional aminoacids and fatty acids	Improves conceptus viability, development, and growth	Emphasis on specific essential aminoacids is not an important component of global health and nutrition interventions
Lactation–suckling		
Ensuring adequate intake of quality colostrum; maternal vaccination	Reduces mortality and improves intestinal health of the young	Intake of colostrum and early initiation of breastfeeding receive growing attention
Increased fat content in lactation diets	Increases milk fat content and neonatal growth and development	Manipulation of maternal diets to change the volume and composition of breastmilk is not part of global programmes, other than supplementary feeding for severely undernourished women during lactation
Optimisation of essential aminoacid intakes by formulation of diets for so-called ideal protein	Supports milk production, growth, and development of suckling offspring, and maternal body condition by prevention of aminoacid deficits	Manipulation of maternal diets to change the volume and composition of breastmilk is not part of global programmes, other than supplementary feeding for severely undernourished women during lactation
Judicious supplementation with nutritionally balanced full-strength milk formula	Maintains neonatal growth when breastmilk is insufficient because of infection, agalactia, or heat stress	Global recommendations discourage introduction of formula or animal milk, particularly before the age of 6 months, because of the increased risk of infectious diseases
Postweaning–toddler		
Optimisation of essential aminoacid intakes by formulating diets for so-called ideal protein	Supports healthy lean growth	Although nutrition counselling programmes promote the intake of high-quality animal protein, no emphasis on specific aminoacids
Supplementation of diets with phytase	Improves bioavailability of iron and zinc in plant foods	Phytase supplementation is not part of global nutrition programmes
Dietary medium-chain fatty acids, glutamine, arginine, plasma proteins, lactoferrin, and zinc	Improves aspects of intestinal health and might promote growth, especially under challenging environmental conditions	Iron and zinc supplements are promoted in global programmes, but not fatty acids, aminoacids, or plasma proteins

***Table*: Main findings from Odle and colleagues' review[6] and status of interventions in global nutrition programmes[7]**

supplements. By contrast, animal studies give more comprehensive attention to macronutrients, such as specific aminoacids and fatty acids, which are not considered at all in global human nutrition programmes. Even programmes that promote nutrition counselling with use of locally grown foods or provision of protein-energy supplements do not focus on specific macronutrients. Odle and colleagues[6] emphasise that, in the case of protein and fat, it is crucial to consider both the quantity provided by the diet as well as the pattern of essential aminoacids and fatty acids ingested. They further declare that "the basic information needed to formulate diets to meet aminoacid needs in humans represents a serious gap in knowledge",[6] unlike animal science where aminoacid patterns resulting in ideal proteins are well described and widely used.[5,6]

This is not to imply that micronutrient supplementation does not have a major place in global nutrition. Indeed, animal studies are strongly supportive, for example, of zinc supplementation to prevent environmental enteropathy leading to growth failure. What strikes us is how concerns with micronutrients might have distracted attention from consideration of essential macronutrients and the interplay between micronutrient and macronutrient deficiencies that commonly exist in low-income and middle-income countries.

Odle and colleagues[6] also suggest some innovative potential interventions in areas that are unexplored in global nutrition. Temperature control, widely used in animals to avoid heat stress, is not mentioned in global programmes. Admittedly, temperature control is difficult to implement at large scale in a cost-effective manner. Dietary microaddition of phytase aimed at destruction of phytic acid, a powerful antinutrient, is also worthy of further exploration in global nutrition.

Regarding lactation, maternal supplementation to modulate the quantity and quality of human milk has received little attention in global health, as there is a common assumption that the quality of breastmilk is relatively constant even among undernourished mothers, and that these women are able to produce enough milk. By stark contrast, such interventions are widely used in animal science, with well-documented effects on milk quality and quantity, and a striking effect on litter growth. Animal scientists sometimes use formula to supplement breastmilk if there is evidence of growth faltering. By contrast, the risk of infections and mortality led the global nutrition community to strongly discourage the use of formula and feeding bottles in early infancy. Renewed attention to maternal diets might help improve infant growth in the first 6 months of life, when exclusive breastfeeding is essential for preventing infections, yet growth faltering is already taking place.[9]

Animal scientists have been remarkably successful in reducing mortality and growth faltering in controlled breeding situations, and in producing animals that are lean and achieve their full growth potential. Global nutrition has much to learn in this respect. Not all interventions will be effective, feasible, or even desirable for humans. Furthermore, neurocognitive outcomes—a priority for global child health—are not assessed in animal science. However, robust findings from the long history of experimentation in animal science suggest that the time for some lateral thinking in global nutrition is long overdue.

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