A Delphi exercise used to identify potential causes of variation in litter size of Ontario swine

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Abstract

Forty-eight people, considered to the swine experts, were asked to collaborate in a Delphi exercise to identify the factors which they believed affect litter size in Ontario swine. The panel included 16 animal scientists, 16 pork producers, and 16 veterinarians in swine practice. The ten factors with the highest ratings were parity of the sow, mycotoxins in the feed, infections with porcine parvovirus or *Leptospira* spp., breeding gilts on their second versus first observed estrus, the timing of breeding with respect to the onset of estrus, purebred versus crossbred sows, boar overuse (bred by a boar that was mated more than six times per week), pen versus hand mating, age of gilt when first bred, and body condition of the sow at the time of conception. The experts did not agree about the effect on litter size of the sow's previous lactation, factors ensuring adequate nutrient intake during lactation, health of the sow and the boar, breed of a purebred sow, or the ease of mating the sow.

Key items in the use of the Delphi technique to arrive at a consensus are discussed.

Résumé

Évaluation par la méthode Delphi des facteurs susceptibles d'influencer le nombre de petits par portée chez les truies en Ontario

Quarante-huit personnes ayant une expertise dans le domaine porcin ont participé à une étude en Ontario basée sur la méthode Delphi afin d'identifier les facteurs qui, selon eux, seraient susceptibles d'influencer le nombre de petits par portée chez les truies. La liste des participants comprenait 16 chercheurs dans le monde animal, 16 producteurs de porcs et 16 vétérinaires oeuvrant en pratique porcine. Parmi les 10 facteurs les plus haut côtés apparaissaient : la parité des truies, la présence de mycotoxines dans la moulée, les infections dues au parvovirus porcin ou à *Leptospira* spp, l'accouplement des jeunes truies au deuxième oestrus observé versus le premier, le moment de l'accouplement relativement au début de l'oestrus, des truies de race versus des truies croisées, la surutilisation du verrat (un verrat qui sert plus de six fois par semaine), la saillie en parc versus accouplement assisté, l'âge de la jeune truie à la première saillie et l'état général de la truie au moment de la conception. Les spécialistes avaient une divergence d'opinions sur l'influence des paramètres suivants sur le nombre de petits par portée : la lactation précédente de la truie, les facteurs régissant l'apport alimentaire adéquat durant la lactation, l'état de santé de la truie et du verrat, la race de la truie pur-sang et la facilité d'accouplement de la truie.

Les éléments clefs utilisés par la méthode Delphi pour arriver à un concensus y sont discutés.

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Introduction

Most health problems have multiple causes, yet there are few formal studies to identify and determine the magnitude of the effects of these causes or to elaborate their combined effects. Even when several published reports are available, there may be a paucity of validated information, or the literature may be very contradictory. In the absence of sufficient information about likely risk factors, epidemiologists often conduct so-called "fishing expedition" studies where a large number of factors are tested in an attempt to identify determinants of the outcome of interest. These studies, while valuable as initial approaches, may not have high statistical power to identify putative causes; they may also suffer from a high false positive (type I) error rate (1). These studies also take considerable time and effort.

Our long-term objective is to identify the important causes of litter size variation in swine and to formulate a model to describe the effect of the factors on litter size. Rather than basing our decisions about which variables to study on the diverse literature, we decided to try to narrow our focus by obtaining expert opinion on the subject. Our hope was that this would both restrict the number of variables to be examined in the subsequent observational study as well as ensure that important variables were included. Reducing the number of variables to be examined would allow a more indepth and refined study, enhance the power of the study, and improve our ability to formulate a model for the important multiple potential causes.

One method of gaining expert input and assembling a list of "important" factors is to utilize the consensus of a panel of experts. This consensus is obtained through an iterative process called the Delphi method. The method involves obtaining an answer to a specific question from each expert. The experts then are given the opportunity to change their responses in light of the opinions of the others on the panel (2). The method was used by a pharmaceutical company, Smith, Kline and French Laboratories, to determine their long-term biomedical research priorities. A list of the most likely developments in this area was compiled by the company personnel involved with research

Table 1. The scale used to score the effect of factors on litter size

Score	Description of score
3	Very important influence (The factor has a strong association with litter size, is a first order priority, or is a very relevant factor.)
2	Important influence (The factor is associated with litter size, but is of second-order priority. It has a significant effect on litter size but less than some other factors.)
1	Slightly important influence (The factor is associated with litter size but is of third-order priority. A change in this factor has little effect on litter size, and is not a key determining factor for litter size.)
0	Unimportant, no influence (The factor has no measurable effect on litter size. It should be dropped as an item to consider.)

and development, and then the list was sent to 78 experts in the field who were asked to add their expectations (3). The Delphi method was also used to determine whether large scale campaigns to vaccinate people against swine influenza virus should be carried out (4).

A modification of the Delphi method, known as the Policy Delphi, was developed to examine opposing views on policy issues (5). In the Policy Delphi, participants assign a ranking to the list of outcomes. The ranking is based on a defined scale and forces the expert to think about the importance of each factor. This technique has been used to determine the criteria for evaluation of instructional materials used in veterinary medical education (6).

The purpose of our study was to use a combination of the Delphi method and the Policy Delphi, which we will call the Delphi exercise, to identify the factors that might influence litter size in swine and to rank these factors. We summarize herein our experience with this technique and the results of its application.

Materials and methods

Forty-eight people, considered by the authors to be experts on swine, were asked to collaborate. The panel included 16 animal scientists, 16 pork producers, and 16 veterinarians in swine practice. We constructed an initial list of 30 factors that were reported in the literature to influence litter size (7). Panel members were sent a questionnaire and asked to score these 30 factors with respect to their effect on porcine litter size in Ontario. A covering letter was included with the questionnaire; it described the Delphi exercise and the backgrounds of the participants. The identity of the individual panel members was kept confidential. The questionnaire was introduced using a scenario which suggested that the panel member was investigating a farm with a low average litter size. The panel members were asked to assign a score, from zero to three, for each factor with respect to its effect on total (alive and dead) litter size. A description of how each score related to the perceived effect of each factor was included (Table 1). We stressed that it was the magnitude, not the direction, of the effect that was of concern. Furthermore, the 30 factors related only to individual swine, not the herd. For example, parity of the sow could be listed but the parity distribution of the herd would not be listed, as this was deemed to be a herd-level extension of the same factor.

The experts had an opportunity to comment on the initial 30 factors and/or suggest changes to the wording of a factor which could then become a new factor, or a more refined factor, in the next round. Panel members were asked to list any additional factors that they believed were associated with litter size but had been omitted from the initial list.

The second list of factors was prepared after consideration of the responses to the first survey. The participants' comments were noted and these comments guided the definition of the factors. None of the original factors were excluded. The new list of factors, the average scores for each of the factors from the first survey, and the member's own initial responses were mailed to each panel member, each of whom was asked to score the factors a second time. This process was repeated a third and fourth time. No new factors were added after the second survey.

The data from each survey were entered into microcomputer files using data base management software (DBase III-Plus, Ashton-Tate Corp., 20101 Hamilton Ave., Torrance, California, USA). Descriptive statistics were performed using the Statistical Analysis System for Personal Computers (PC/SAS) (SAS Institute, Cary, North Carolina, USA).

The distribution curves of the respondents' scores over successive rounds of the Delphi exercise were recorded to determine the stability of responses. The average difference in the number of respondents per score on successive rounds was calculated and expressed as a percent change in response. If the percent change in distribution of scores for a factor between successive surveys was less than 16% (e.g. fewer than eight of 48 scores changed between surveys), then it was assumed that the group had reached a consensus on that factor (8). The stable factors were removed from all subsequent questionnaires. In the final phase of analysis, the factors were ranked according to their relative effect on litter size using the average score for the factor from the survey at which it stabilized, or its average score on the fourth survey for those that did not stabilize.

A regression model, with the outcome of rank (the ordering of factors based on their overall average score) was used to evaluate differences in scores by occupational groups.

Results

The 42 persons who responded to the first questionnaire listed 76 variables that they believed were associated with litter size but were not included in the initial survey. Some of these were new factors and some were refinements that more clearly defined factors from the original survey list. The additional variables were grouped and/or integrated with the 30 initial factors. As a result, the second survey included 56 factors. Forty persons (40/48) returned the second survey. The third survey was sent only to those 40 who returned the second survey. Thirty-six persons returned the third survey (36/40), all of whom (36/36) responded to the

Table 2. Factors believed to affect litter size, listed in descending order of score, as determined by a panel of experts

Average score	Number of respondents per score 0	1	2	3	Factor
2.86	0	0	5	31	[a]Parity of the sow
2.83	0	1	4	31	Mycotoxins in the feed
2.69	0	4	3	29	[a]Infections with porcine parvovirus or *Leptospira* spp
2.67	1	0	9	26	[a]Gilt bred on 2nd versus 1st observed estrus
2.67	0	1	10	25	Timing of the breeding with respect to the onset of estrus
2.64	1	2	6	27	[a]Purebred versus crossbred (including other selection processes for heterosis)
2.64	0	11	1	24	[a]Boar overuse (bred by a boar that was mated more than 6 times per week)
2.61	0	2	10	24	[a]Pen versus hand mating
2.58	0	1	13	22	[a]Age of gilt when first bred
2.53	0	3	11	22	[a]Body condition of sow at time of conception
2.50	0	1	16	19	Attitude of the person who does the hand mating (stockmanship)
2.47	0	2	15	19	[a]Use of artificial insemination (including the ability of the person who does the artificial insemination)
2.41	0	5	11	20	Sow weight loss in previous lactation
2.19	0	1	27	8	[a]Breed of purebred sow[c]
2.16	0	2	26	8	Health of the sow and the boar (including soundness, previous cesareans or previous uterine infections and constipation)[c]
2.14	0	2	26	8	Mated by a boar used more than twice in the last 24 hours
2.11	0	3	26	7	Previous lactation less than 21 days[c]
2.11	0	3	26	7	[a]Temperature of the dry sow barn too hot
2.09	0	3	27	6	[a]Number of matings per breeding period
2.05	0	3	28	5	Factors ensuring adequate nutrient intake during lactation (including water intake, cooling methods and ration density)[c]
2.05	0	4	26	6	Quality and duration of the breeding
2.05	0	4	26	6	The ease of mating (including floor conditions in the breeding area and ease of moving the sow to the boar)[c]
2.05	1	5	21	9	Timing of the mixing after conception
2.03	0	2	31	3	Length of estrus versus timing of the mating
2.02	0	2	31	3	[a]Length of sow's previous lactation (0 to 42 days)[c]
1.92	1	4	28	3	[a]Weight of gilt when first bred
1.88	0	5	30	1	[a]Gilt fed *ad libitum* after selection (nutrition of gilt from 70 kilograms to breeding)
1.74[b]	1	10	21	3	Flush gilts for 5 to 10 days before breeding
1.72	1	11	21	3	[a]*Ad libitum* feeding after breeding for gilts
1.72	1	10	23	2	Weaning-to-conception interval
1.61	1	12	23	0	*Ad libitum* feeding after breeding in sows
1.56	2	14	18	2	Temperature of the dry sow barn too cold
1.50	1	17	14	4	[a]Weaning-to-breeding interval more than 8 days
1.50	0	18	18	0	Boar to sow proximity or contact
1.44	4	13	18	1	[a]Feed restriction after previous weaning
1.39	2	23	6	5	Age of boar
1.41	1	20	14	1	Genetic make-up of the boar
1.30	1	24	10	1	[a]Presence of vaginal discharge during gestation
1.28	1	25	9	1	Size of boar versus size of sow
1.27	0	26	10	0	Previous lactation between 21 and 28 days
1.26	1	26	8	1	Stalls versus pens for gilts
1.25	2	23	11	0	[a]Hours of artificial light
1.22	2	24	10	0	Boar libido
1.17	6	18	12	0	[a]Month of conception
1.16	2	27	6	1	[a]Previous lactation more than 28 days[c]
1.14	2	29	3	2	Previous litter size of sow
1.11	1	30	5	0	[a]Pen space per sow (including availability of exercise for sows)
1.08	2	29	5	0	[a]Number of sows in area
1.03[b]	2	30	3	0	Ration density after previous weaning
1.05	3	28	5	0	[a]Stalls versus pens (in confinement housing)
1.00	4	28	4	0	Fat in lactation feed
1.01	7	24	3	2	Temperament of the sow
0.94	6	26	4	0	[a]Confined versus loose housing
0.81	10	23	3	0	[a]Windows in the dry sow barn
0.72	12	22	2	0	[a]Use of split weaning in previous litter
0.39	23	12	1	0	[a]Use of cross fostering in previous litter

[a]Factors which were included in the first survey. The 30th factor on the first survey was "boar effects"
[b]Only 35 respondents scored these factors
[c]These factors did not stabilize by the fourth survey

Table 3. Average score for the third and fourth survey for factors that did not stabilize

Mean score Third survey	 Fourth survey	Factor
2.06	2.11	Previous lactation less than 21 days
2.31	2.19	Breed of purebred sow
1.58	2.06	Ease of mating (including floor conditions in the breeding area and ease of moving the sow to the boar)
2.36	2.17	Health of the sow and the boar (including soundess, previous cesareans or previous uterine infections and constipation)
1.31	2.03	Length of sow's previous lactation period (0 to 42 days)
1.89	2.06	Factors ensuring adequate nutrient intake during lactation (including water intake, cooling methods, and ration density)
1.08	1.17	Previous lactation more than 28 days

final questionnaire. Twelve pork producers, 14 animal scientists, and 10 veterinarians returned the fourth survey. These differences among occupations in response rates were not significant ($p > 0.05$).

After three rounds, 29 factors had not stabilized; hence only these "unstable" factors comprised the fourth survey. After the fourth survey, 49 of the 56 factors met the criteria for stability. All factors, including those which did not stabilize, are shown in descending order of average score (referred to as rank) in Table 2. The unstable factors were length of the sow's previous lactation (0 to 42 days), previous lactation length less than 21 days, previous lactation length more than 28 days, factors ensuring adequate nutrient intake during lactation, health of the sow and boar, breed of purebred sow, and ease of mating (including floor conditions in the mating area and ease of moving the sow to the boar). Of these seven unstable factors, five ratings increased and two ratings decreased between the third and fourth surveys (see Table 3).

The top ten factors, as scored by each profession, are listed in Tables 4–6. Differences in average score per rank among members of the three occupational groups were not statistically significant ($p > 0.05$).

Discussion

Based on published reports, a large number of factors should be considered as putative causes of variation in litter size of swine (7). Our intent was to ascertain which factors might have an "important" influence on litter size, and then subsequently to investigate those that are particularly amenable to either a laboratory approach or a field study approach. We chose to use a Delphi exercise to identify the important factors.

Since the Delphi method is not widely used in veterinary medicine, a brief discussion of it is warranted. Between successive survey rounds, it was expected that there would be some change in scores within the group even if their beliefs had not changed appreciably. This is conceptualized as the underlying error rate or variability. In our study, the percent change in the distribution of scores was measured for each factor to determine the stability of responses between questionnaires. Any two distributions with marginal changes less than 16% were deemed to have reached stability. This measure of stability has greater power and validity than parametric tests of variance (8). It also functions as a stopping criterion and preserves any well defined, stable disagreements. In general, the propensity for individuals to change their scores is a function of their distance from the average score and their own strength of belief on the issue. If a person's judgement is far from the mean for a given factor, he/she will be more likely to change their score than if their judgement is close to the panel mean.

Alternative tests of stability include determining if the interquartile range is two units or less on a ten unit scale (8), or assuming stability when at least 60% of the respondents identify the factor as one that is important (3). However, these techniques do not take full advantage of the information available in the distributions. For example, if the distribution of a particular factor is bimodal, the conclusion based on the latter rules would be that a consensus was not achieved. Our belief, which is supported by others (8), is that a bimodal distribution represents an important and apparently unresolved difference in opinion within the panel. For example, in our survey, scores on boar overuse appear to have a bimodal distribution (Table 2).

A technique which can alter the rate at which the factors stabilize is to ask the experts to rate their own expertise. In this technique, the experts indicate whether or not they feel competent in classifying the effect of each factor. The group is then given this information as feedback. On subsequent questionnaires the experts can decide whose opinion, if any, they wish to consider (9,10). We did not use this method as we believed it would have made the process too complicated.

After four rounds of the Delphi exercise, 49 of the 56 factors had stabilized. The top ten of these factors, listed in order of rank, were parity of the sow, mycotoxins in the feed, infections with porcine parvovirus or *Leptospira* spp., breeding gilts on their second versus first observed estrus, the timing of breeding with respect to the onset of estrus, purebred versus crossbred sows, boar overuse, pen versus hand mating, age of gilt when first bred, and body condition of the sow at the time of conception. The reader should note that this ranking is the result of pooling the opinions of experts; no specific hypothesis testing of the effect of these factors was used in the Delphi exercise.

The factors upon which the experts did not reach a consensus are listed in Table 3. There are several possible reasons for lack of stability of the scores. First, if the panel represents a sample of diverse backgrounds, the interpretation of the questionnaire may differ according to background (1). Our panel of experts included three distinct groups, and, based on an inspection of our results, it appears that each group ranked the factors in a different order (see Tables 4–6). In addition, the animal scientists tended to have a lower score per rank than the other two groups, but

Table 4. The top ten factors believed to affect litter size as determined by a group of animal scientists

Score	Rank	Factor
2.86	1	Parity of the sow
2.86	1	Timing of the breeding with respect to the onset of estrus
2.86	1	Mycotoxins in the feed
2.75	2	Infections with porcine parvovirus or *Leptospira* spp
2.75	2	Boar overuse (bred by a boar that was mated more than 6 times per week)
2.57	3	Body condition of sow at time of conception
2.57	3	Pen versus hand mating
2.50	4	Attitude of the person who does the hand mating (stockmanship)
2.50	4	Gilt bred on 2nd versus 1st observed estrus
2.50	4	Purebred versus crossbred (including other selection processes for heterosis)

Table 5. The top ten factors believed to affect litter size as determined by a group of pork producers

Score	Rank	Factor
3.00	1	Infections with porcine parvovirus or *Leptospira* spp
2.75	2	Mycotoxins in the feed
2.70	3	Parity of the sow
2.70	3	Purebred versus crossbred (including other selection processes for heterosis)
2.60	4	Timing of breeding with respect to onset of estrus
2.60	4	Body condition of sow at time of conception
2.60	4	Boar overuse (bred by a boar that was mated more than 6 times per week)
2.60	4	Pen versus hand mating
2.60	4	Age of gilt when first bred
2.50	5	[a]Gilt bred on 2nd versus 1st observed estrus
2.50	5	[a]Sow weight loss in previous lactation
2.50	5	[a]Attitude of the person who does the hand mating (stockmanship)

[a]Factors tied for tenth place

Table 6. The top ten factors believed to affect litter size as determined by a group of swine veterinarians

Score	Rank	Factor
3.00	1	Parity of the sow
3.00	1	Gilt bred on 2nd versus 1st observed estrus
2.75	2	Purebred versus crossbred (including other selection processes for heterosis)
2.75	2	Age of gilt when first bred
2.75	2	Mycotoxins in the feed
2.67	3	Use of artificial insemination (including the ability of the person who does the artificial insemination)
2.67	3	Pen versus hand mating
2.58	4	Sow weight loss in previous lactation
2.50	5	Attitude of the person who does the hand mating (stockmanship)
2.50	5	[a]Timing of the breeding with respect to the onset of estrus
2.50	5	[a]Boar overuse (bred by a boar that was mated more than 6 times per week)

[a]Factors tied for tenth place

this difference was not significant ($p > 0.05$ in the regression model).

Second, factors whose effects are controversial tend not to be selected as being of primary importance (11). This phenomenon was observed in the present study where lactation length, a factor with a large amount of ambiguity about its effect, was not chosen as one of the top ten factors influencing litter size even though there is considerable evidence that it has an important effect (12,13).

In experiments using the Delphi method and for which the outcome is known, it has been found that relevant facts on return questionnaires improve the accuracy of the subsequent responses (10,11). For example, we commented that nutrient intake during lactation included adequate water intake. However, we did not present all comments made by participants, as the inclusion of too much information might have been confusing and could have altered the final scores (11). The driving force of the Delphi method is to seek the collective expertise of the co-operators involved, rather than to change their opinion (10).

Another reason for a lack of stability of the scores is the subdividing one factor into related sub-factors. For example, lactation length, which was one factor in the original survey, became four different factors in subsequent surveys. The four factors represented lactation lengths of less than 21 days, less than 28 days, between 21 and 28 days, and between 0 and 42 days. Many researchers have shown that there is an effect of lactation length on litter size, but the point at which weaning age affects the subsequent litter size seems quite variable (12,13). Because of this, it may have been difficult for the experts to consistently score these variables. This is one variable whose effects deserve further examination, particularly noting the lactation lengths suggested in this survey.

A final reason for instability of the scores is the use of poorly defined factors. In retrospect, our question concerning the health of the sow and boar was a poorly defined factor. Obviously, the nature and severity of the disease would have a bearing on subsequent litter size. Another poorly defined variable was ease with which the sow was mated. This variable included the floor conditions of the breeding pen as well as the ease with which the sow was moved to the boar. The latter factor could have been divided into two more clearly defined factors.

In conclusion, this Delphi exercise enabled us to accumulate a ranked list of factors which might influence litter size. Swine farmers, animal scientists, and veterinarians all have experience in this area and may each have valid, but somewhat different, opinions of the relative importance of these factors. Currently we are examining the effect of some of these factors on litter size in Ontario swine. These results will be used to develop a model to predict litter size, with the ultimate goal of increasing litter size in Ontario herds.

The Delphi method may be of value for forming a group consensus in a short time period and with little expense in a variety of areas within veterinary medicine.

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References

1. Snedecor GW, Cochran WG. Statistical Methods. 7th ed. Ames, Iowa: The Iowa State University Press, 1980: 232–233.
2. Linstone HA, Turoff M. General applications. In: Linstone HA, Turoff M, eds. The Delphi Method, Techniques and Applications. Reading, Massachusetts: Addison-Wellesley Publishing, 1975: 75–83.
3. Bender AD, Strack AE, Ebright GW, von Haunalter G. Delphic study examines developments in medicine. Futures 1969; 1: 289–303.
4. Schoenbaum SC, McNeil BJ, Kaver J. The swine influenza decision. N Engl J Med 1976; 295: 759–765.
5. Turoff M. The Policy Delphi. In: Linstone HA, Turoff M, eds. The Delphi Method, Techniques and Applications. Reading, Massachusetts: Addison-Wellesley Publishing, 1975: 84–101.
6. Johnson LM, Upson DW. Evaluation criteria for instructional materials in veterinary medicine. J Vet Med Educ 1990; 17: 52–55.
7. Dial G. Optimizing reproductive performance and establishing new horizons for sow productivity. Howard Dunne Memorial Lecture, Proc Am Assoc Swine Pract 1987: 149–174.
8. Scheibe M, Skutsch M, Schofer J. Experiments in Delphi methodology. In: Linstone HA, Turoff M, eds. The Delphi Method, Techniques and Applications. Reading, Massachusetts: Addison-Wellesley Publishing, 1975: 277–281.
9. Dalkey N, Brown B, Cochran S. The Delphi Method, IV: Effect of percentile feedback and feed-in of relevant facts. The Rand Corporation, Santa Monica, California, 90406, USA. Memorandum RM-6118-PR, 1970.
10. Dalkey N. Analyses from a group opinion study. Futures 1969; 1: 541–551.
11. Doyon LR, Sheehan TV, Zagor HI. Classroom exercises in applying the Delphi method for decision-making. Socio-Econ Plan Sci 1971; 5: 363–375.
12. Friendship RM. A reduction in litter size on an Ontario swine farm. Can Vet J 1987; 28: 120–123.
13. Cole DJA, Varley MA, Hughes PE. Studies in sow reproduction 2. The effect of lactation length on the subsequent reproductive performance of the sow. Anim Prod 1975; 20: 401–406.