The Old School, Brewhouse Hill, Wheathampstead,
Hertfordshire AL4 8AN, UK
www.ufaw.org.uk

Animal Welfare 2015, 24: 151-160
ISSN 0962-7286
doi: 10.7120/09627286.24.2.151

Application of the Welfare Quality® animal welfare assessment system in Finnish pig production, part I: Identification of principal components

C Munsterhjelm*, M Heinonen and A Valros

Department of Production Animal Medicine, PB 57, FIN-00014 University of Helsinki, Finland
* Contact for correspondence and requests for reprints: camilla.munsterhjelm@helsinki.fi

Abstract

The Welfare Quality® (WQ) on-farm welfare assessment protocols for fattening pigs (n = 95 farms) and sows, as well as suckling piglets (n = 103 farms), were applied on Finnish farms. In order to identify distinct types of welfare problems (WPTs) Principal Component Analysis (PCA) was applied to the pooled animal-based items within both categories of animals. Measures describing suckling piglets did not contribute to the WPTs. The main WPTs (seemingly) reflected fighting in fattening pigs and lack of bedding in both fattening pigs and sows. The results imply that WQ includes biologically plausible shortlists of animal-based measures with decent to good internal consistency describing distinct types of welfare problems in growing pigs and in sows. The 20 descriptors of Qualitative Behavioural Assessment were analysed similarly to identify distinct mood types, which were named active positive, passive positive and passive positive behaviours. The different mood types had close to identical build-up in both fattening pigs and in sows and suckling piglets.

Keywords: *animal welfare, growing pig, internal consistency, Principal Component Analysis, sow, Welfare Quality®*

Introduction

The increasing public interest in food animal welfare has augmented the need for valid, reliable and feasible assessment tools for on-farm use. The most comprehensive contribution in this field is the Welfare Quality® system (WQ), developed by a research collaboration in 2004–2009 within the 6th EU Framework programme. Aims of the project were to develop scientifically based, standardised ways of measuring animal welfare and, at the same time, produce information useful both for the consumer and for animal unit managers (Blokhuis *et al* 2003). The WQ systems rely on animal-based attributes and include assessments of behaviour, one of which is Qualitative Behaviour Assessment (QBA), a method estimating emotional state by allowing the observer to subjectively describe the 'body language' of animals according to pre-defined descriptors or expressive qualities (Wemelsfelder *et al* 2000; Wemelsfelder & Millard 2009). For pigs, protocols exist for growing pigs and for sows in all production stages, including suckling piglets (Welfare Quality® 2009).

To date, the application of the WQ systems has been limited for other than research purposes. Time-consuming and thus costly data collection is probably the most important cause, however, some reliability and validity issues have also been raised (Knierim & Winckler 2009). To address feasibility issues and produce methods for a broad range of different purposes, the European Food Safety Authority Panel on Animal Health and Welfare (AHAW) put forward a novel approach in on-farm welfare assessment methodology in 2012 (AHAW 2012). The idea is based on 'toolboxes' or collections of animal-based welfare measures. The tools in the boxes are animal-based measures or shortlists thereof, each of which are intended to be applied for specific purposes or situations. A specific aim could, for example, be to evaluate actual effects of a known environmental hazard, such as low space allowance or lack of enrichment on a farm with growing pigs. In the example cases the assessments would concentrate on the types of welfare problems known to be caused by crowding and by barren surroundings. The toolbox approach may originate from the ideas of Bracke (2007), suggesting an interplay between input and output measures, where the latter are used as critical control points verifying the predictions being made by the former.

The WQ systems may be used both for standardised data collection (Forkman & Keeling 2009) during the process of toolbox building as well as a source of candidate attributes for inclusion in the toolboxes. Numerous ongoing research projects serve to accumulate data, and knowledge on validity and reliability exists for most of the measures (Forkman & Keeling 2009). Being comprehensive collections of animal-based welfare measures, the WQ systems can be hypothesised to contain information about distinct dimensions or types of animal welfare problems. Identified welfare problem types (WPTs) have the form of shortlists of attributes measuring a common phenomenon, which in psychometrics are referred to as scales. The degree to which the attributes in a scale measure the underlying phenomenon can be evaluated by calculating Cronbach's alpha (Cronbach 1951). These shortlists are possible tools in the AHAW toolboxes.

In this study WPTs will be identified using Principal Component Analysis (PCA), a descriptive or exploratory statistical technique determining structures of correlations within a set of variables. The method has extensive use in psychometrics, behavioural and social sciences (DeVellis 2003), but in animal (welfare) science it has mainly been applied to limited (welfare) issues such as skin lesions in pigs (Baumgartner 2007) or behavioural signs and body lesions related to different cubicle design in cows (Veissier *et al* 2004). In addition to WQ attributes, the 20 descriptors of QBA will also be subjected to PCA for identification of mood types. PCA has been the choice in previous analyses on QBA data (in pigs: Mullan *et al* 2011; Temple *et al* 2011, 2013).

The present paper describes two data sets collected in Finland in accordance with the WQ protocols for pigs. With a coverage of 7–8% of predominantly randomly selected pig farms, the results give an insight into pig welfare in the country. In short, the aims of this paper are to: i) describe data collected according to the WQ protocols on 7–8% of Finnish pig farms; ii) identify dimensions of pig welfare using PCA and investigate their quality as scales; and iii) identify different mood types in growing pigs, sows and suckling piglets based on the descriptors of QBA and investigate their quality as scales. Associations between resources and WPTs as well as mood types will be established in a sister paper (Munsterhjelm *et al* 2015; this issue).

Materials and methods

Sampling and farms

Pig farms included in this study (n = 158) were introduced in three ways, including: i) a stratified random sample (n = 106); ii) voluntarily (n = 24); and iii) chosen by slaughterhouse companies for advisory visits as a part of a new contract, or for screening of welfare status within the company (n = 28).

The random sample was drawn from a national Finnish database in October 2010. The sampling was stratified to emphasise a large farm size in order to gain information relevant also in the near future in an industry undergoing a very rapid increase in average farm size. The aim was to gain over-representation of fattening farms with at least 1,500 animal places at any one time (capacity units, CU), integrated farms with at least 150 sows and piglet-producing units with at least 400 sows. The farms were contacted by telephone by familiar slaughterhouse company personnel and offered a free welfare assessment with feedback. The compliance rate was 61%.

Altogether, 198 WQ assessments were performed on 158 farms (on 40 farms with integrated production both pig categories were assessed). The protocol for growing pigs was applied on 95 farms, including 55 fattening units (purchasing piglets of 25–30 kg from one or several piglet producers) with a median CU of 1,070 (range 80–4,200) and 40 integrated farms with CU 512 (range 60–1,330). The farms produced or raised mainly cross-bred pigs (Finnish or Norwegian Landrace × Finnish Yorkshire × Duroc, with or without Hampshire), with a minority of pure Finnish Landrace or Yorkshire. The pigs were not tail docked, in accordance with Finnish legislation.

WQ for sows and piglets was assessed on a total of 103 farms, including 41 integrated units with a median of 116 sows (range 30–877), 55 piglet producing farms (126 sows, 40–1,285), one sow pool central unit (insemination and pregnancy) of 350 sows, another central unit (2,000 sows) allowing some of the sows to farrow at the unit, four sow pool satellites (farrowing and lactation) with 40–550 sows, and one farm with CU 105 raising gilts from 50 kg to late pregnancy.

Fattening pigs were mainly kept on part-slatted floors (88% of farms). Ten percent of farms had solid floors. On two farms, a minority of pens were fully slatted and the majority part-slatted. On most farms (88%), fattening pigs were fed liquid feed from a trough. Ten percent of the farms provided dry feed from a feeder, and two farms utilised both methods. All farms supplied the animals with some kind of deformable rooting material, such as straw, wood-shavings or newspaper. Most farms (57%) used no bedding, but reported to provide the animals twice daily with a small amount of chewable enrichment material. The median group size at assessment was 10.0 (range 2–240) and space allowance 0.99 m^2 per pig (range 0.66–2.02). Animals were assessed at an estimated farm average of 30–120 kg bodyweight (median 60 kg).

On sow farms, early pregnancy was spent in stalls in 59% of units. A typical sow group at this stage had 9.5 individuals (median, range 4–40) and a space allowance outside feeding stalls (if any) of 2.64 m^2 per sow (range 0.80–8.67). During mid-late pregnancy 95% of the farms utilised group housing, with a median group of 11.0 sows (range 2–200) and space allowance of 2.56 m^2 per sow (excluding feeding stalls, range 0.30–6.02). The vast majority of sow groups were fed in feeding stalls, with 8% of the farms utilising some kind of individual feeder in mid-late pregnancy. The use of bedding or enrichment was evaluated as the average for the three phases of the dry period. The most prevalent enrichment regimes during pregnancy were 'no bedding but twice daily enrichment' (37% of farms) or thin bedding (27%). Outdoor paddocks were used on one farm for a short summer period.

A median farrowing pen measured 4.7 m^2 (range 3.7–8.1). It had a partly slatted floor (typically roughly 1/3 slats and 2/3 solid) on 51% of farms, solid on 27% and fully slatted (usually with a small solid creep area) on 22%. Twelve percent provided the animals in farrowing pens with no enrichment material, 28% used only small amounts of enrichment material and/or toys, and the others different amounts of bedding. Further details on housing and production are given in Munsterhjelm *et al* (2015; this issue).

Welfare Quality® assessments

Farm visits were conducted by female assessors familiar with pig production through an occupation as veterinarian (n = 1) or production advisor (n = 5). The assessors were trained and certified by the Welfare Quality® Consortium in November 2010. Each assessor conducted her two first assessments in a group in order to further harmonise the methods. These assessments were included in the data set.

https://doi.org/10.7120/09627286.24.2.151 Published online by Cambridge University Press

Table 2 Animal-based measures included in the Welfare Quality® assessment systems in suckling piglets on 100 farms. Percentiles are given on the litter level.

Measure	Definition	Farms affected	5th Percentile	50th Percentile	95th Percentile
Mortality	Not including euthanasia	100%	0.8	7.1	12.1
Lameness score 1	1 piglet, weight-bearing	17%	0.0	0.0	10.0
Lameness score 2	> 1 piglet weight-bearing or 1 more severe	14%	0.0	0.0	10.0
Splay leg score 1	1 piglet per litter	6%	0.0	0.0	3.3
Splay leg score 2	> 1 piglet per litter	0%			
Neurological disorders	At least 1 piglet	0%			
Pumping	Laboured breathing in at least 1 piglet	0%			
Coughing	Per litter per 5 min	22%	0.0	0.0	0.4
Sneezing	Per litter per 5 min	59%	0.0	0.2	1.9
Diarrhoea	Evidence	24%	0.0	0.0	20.0
Panting	At least 1 piglet	0%			
Huddling	> 20% of resting piglets in pen huddle	37%	0.0	0.0	40.0

Farms were visited between December 2010 and September 2011 and April and June 2013.

Data were collected by observing the animals according to the WQ protocol for growing pigs, and for sows in all stages of production, including suckling piglets (referred to as 'pig categories'; Welfare Quality® 2009). The most aversive action to the pigs was probably marking with spray. Each farm visit started with a discussion with a stockperson to clarify details on management practices and to sketch down the building with pen-level information on the animals. In order to obtain a random and unbiased sample, the assessor determined focal pens before entering the barn. Sick pens, as well as animals subjected to injections or mixing of groups within a week, were not assessed. Pen dimensions were measured using a laser device and the functionality of drinkers tested by visually estimating water flow. At the farm, data were recorded on a PDA device or on paper using tables modified from the appendices in Welfare Quality® (2009). The farmer was not present during data collection except for the introductory discussion and a short wrap-up.

Full details on WQ-assessments are given in Welfare Quality® (2009). Animal-based measures are defined in Tables 1 (see supplementary material to papers published in *Animal Welfare* on the UFAW website: www.ufaw.org.uk) and 2. Collection of data was initiated by 20 min of behavioural observation for a farm-level QBA. The following phase of the assessment was either health and environment or behaviour, chosen according to the time of feeding to avoid behavioural observations in the time from 1 h before to 1 h after feeding.

For growing pigs, collection of environmental, health and thermal comfort data as well as fear of humans included evaluation of 10–15 pens and 150 pig individuals per farm. Fear of humans was assessed on pen level according to the response of the majority of the animals on the second of two slow walks around the pen. The other behavioural observations (social and explorative behaviours) were performed in 150–180 pigs using scan sampling (five scans per pig). According to the WQ protocol, observations of pneumonia, pleurisy, pericarditis and white spots on the liver should be conducted in the slaughterhouse. In the present study this information was collected, however, from slaughterhouse records as percentages of condemnations for all pigs slaughtered during one year preceding the visit.

The WQ assessment for sows and piglets followed the same principles as for growing pigs. Health and thermal comfort was assessed in 30 pregnant and ten lactating sows, as well as ten suckling litters per farm. Fear of humans was evaluated individually in 20 pregnant sows, and social and explorative behaviours in 40–60 sows according to the ethogram for growing pigs (Welfare Quality® 2009; pp 59–60). Fear of humans and occurrence of stereotypic actions was evaluated in 40 sows.

Statistical analysis

Correlation

Statistical analyses were conducted using SPSS software, version 21 (SPSS Inc, Chicago, IL, USA). The experimental unit was farm. Correlations were calculated between all measures, expressed as prevalences, in order to scan for overlap. Items divided in severity-based classes (score 1 and 2 in Tables 1 [see supplementary material to papers published in *Animal Welfare* on the UFAW website: www.ufaw.org.uk] and 2) were included as these two separate variables. Average inter-item correlations were calculated for all items within each principal component (described below) by taking the average of the correlation

Table 3 Spearman's Rank correlation coefficients (r_s) for the items of the Welfare Quality® assessment system for growing pigs on 95 farms.

	Health							Behaviour						
Factor	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Bursitis score 1												0.66		
Tail lesions score 1						0.50					0.47			
Wounds score 2				0.79										
Skin condition														
Coughing frequency						0.54			0.43		0.52			
Sneezing frequency									0.41					
Pneumonia condemnations								0.79		0.63				
Pleurisy condemnations										0.58				
Pericarditis condemnations														0.48
Liver condemnations														
Negative social behaviour													0.44	0.46
Exploration of fittings													–0.43	–0.50
Exploration of enrichment														0.57
QBA score														

1: Bursitis score 1; 2: Tail lesions score 1; 3: Wounds score 2; 4: Skin condition; 5: Coughing frequency; 6: Sneezing frequency; 7: Pneumonia condition; 8: Pleurisy condemnations; 9: Pericarditis condemnations; 10: Liver condemnations; 11: Negative social behaviour; 12: Exploration of fittings; 13: Exploration of enrichment; 14: QBA score.
Only correlations with $r_s \geq 0.40$ are shown. All correlations are significant at the $P < 0.001$ level.

coefficients between all possible pairs. Items with negative loadings on the components were included as opposite values. Spearman's Rank correlation coefficient (r_s) or Pearson's Product-moment correlation coefficient (r_p) was applied according to the distribution of variables.

Principal Component Analysis and internal consistency

The number and composition of possible sub-scales within the animal-based items of the WQ systems for growing pigs and for sows and piglets were established using PCA. Animal-based items were pooled for the analyses in order to enable any underlying structure to become evident, although the measures are grouped as principles and criteria in the WQ systems (Welfare Quality® 2009). The principal components produced are combinations of variables, each assigned a different weight according to its potential to describe variations in the data set.

WQ scores were expressed as percentages of affected animals, or pens for the pen-level items diarrhoea, huddling, shivering and panting and all measures in piglets. Behavioural measures were expressed as percentages of scans with active behaviour, and QBA as a score between 0–100 (WQ 2009). Measures divided into two severity-based classes were included as two variables, as preliminary analyses showed different loading patterns between classes of the same variable, indicating a different background or meaning.

PCAs were conducted separately in the two pig categories (fattening pigs and sows including suckling piglets) starting with all variables listed in Tables 1 (see supplementary material to papers published in *Animal Welfare* on the UFAW website: www.ufaw.org.uk) and 2 showing any variability. Preliminary analyses produced more than ten components eligible for extraction due to the Kaiser rule (eigenvalues > 1.0; Kaiser 1960); but as the scree test (Cattell 1966) indicated that only three principal components existed for both pig categories, the procedures were re-run aiming at three extracted components. Variables with poor representation in the component space, indicated by low extraction communality (h^2) were removed step-wise until satisfactory levels were reached, leaving eleven items for both categories in the final analyses. As most unrotated factors contained several variables with moderate loadings a varimax rotation with Kaiser normalisation was performed to enhance interpretability of the results.

https://doi.org/10.7120/09627286.24.2.151 Published online by Cambridge University Press

Table 4 Spearman's Rank correlation coefficients (r_s) for the items of the Welfare Quality® assessment system for sows and piglets on 99 farms.

	Health						Behaviour						Other	
Factor	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Bursitis score 1							0.54		0.52					
Skin condition score 2										0.43				
Coughing frequency				0.59										
Sneezing frequency														
Mastitis						0.58								
Uterine prolapse														
Exploration of fittings									0.60		–0.44			
Exploration of enrichment													0.44	
Stereotypies											–0.42			
Human-animal score 1														
Human-animal score 2														
QBA score														0.43
Space allowance in gestation														
Piglet mortality														

1: Bursitis score 1; 2: Skin condition score 2; 3: Coughing frequency; 4: Sneezing frequency; 5: Mastitis; 6: Uterine prolapse; 7: Exploration of fittings; 8: Exploration of enrichment; 9: Stereotypies; 10: Human-animal score 1; 11: Human-animal score 2; 12: QBA score; 13: Space allowance in gestation; 14: Piglet mortality.
Only correlations with $r_s \geq 0.40$ are shown. All correlations are significant at the $P < 0.001$ level.

Cronbach's alphas were calculated for each principal component as a measure of homogeneity of items within a scale, or internal consistency reliability (Cronbach 1951). Alpha should be applied only in scales with unidimensionality ensured by, eg PCA (Cortina 1993).

PCA was also applied to the 20 descriptors of QBA in order to establish the existence and type(s) of different mood types in the data. Each descriptor was expressed as the score drawn on the visual analogue scale, that is, between 0 (the expressive quality was totally absent) and 125 mm (the quality was dominant across all observed animals). The analyses were conducted as described above, including step-wise reduction of the data according to extraction h^2 and a varimax rotation. Three main components were identified for both fattening pigs and sows with piglets, including 16 and 14 descriptors, respectively. Descriptors removed due to low extraction h^2 were fearful, agitated, tense and irritable in both pig categories, as well as listless and indifferent only in sows and piglets.

Results

Inter-item correlations

Correlations between items are given in Tables 3 and 4. The number of even moderate correlations ($0.40 \leq r_s \leq 0.60$ was low. For fattening pigs, the highest correlations existed between score 2 (severe) wounds and skin condition, and pneumonia and pleurisy condemnations ($r_s = 0.79$; $P < 0.001$ for both), score 1 (moderate) bursitis and exploration of fittings ($r_s = 0.66$; $P < 0.001$), and liver and pneumonia condemnations ($r_s = 0.63$; $P < 0.001$). For sows with piglets no correlations with absolute value above 0.60 existed.

Principal Component Analysis and internal consistency

PCA results for fattening pigs are summarised in Table 5. The item-to-case ratio was 1:8.6 and the average extraction h^2 0.64 (range 0.49–0.82). Assumptions of the procedure were met as indicated by a significant Bartlett's test ($P < 0.001$) and a Kaiser-Meyer-Olkin Measure of Sampling Adequacy (MSA) of 0.63. The resulting compo-

Table 5 Components extracted from a Principal Component Analysis on all animal-based items (names shortened) comprising the Welfare Quality® assessment for growing pigs.

Item	Component		
	1 'Fighting'	**2 'Lack of bedding'**	**3 'Disease'**
Skin condition	0.91		
Wounds score 2	0.84		
Lameness score 1	0.74		
Wounds score 1	0.66		
Exploration of pen fittings		0.83	
QBA score		–0.81	
Bursitis score 1		0.73	
Exploration of enrichment		–0.70	
Pericarditis condemnations			0.80
Negative social behaviour			0.77
Pneumonia condemnations			0.75
Variation explained	23.6%	22.4%	17.9%
Cronbach's alpha	0.67	0.77	0.57
Average inter-item correlation	0.26	0.45	0.22

Only loadings of > 0.30 or < –0.30 are shown.

Table 6 Principal components extracted from a Principal Component Analysis on all animal-based items (names shortened) comprising the Welfare Quality® assessment for sows and suckling piglets.

Item	Principal component		
	1 'Lack of bedding'	**2 'Lack of resources'**	**3 'Lack of fibre'**
Exploration of pen fittings	0.82		
Bursitis score 1	0.81		
QBA score	–0.73		
Stereotypies	0.76		
Vulva lesions score 2		0.87	
Body condition score 2		0.78	
Skin condition score 1		0.74	
Constipation (early pregnancy)			0.79
Wounds score 2			0.77
Dirtiness score 1			0.77
Wounds score 1		0.56	0.48
Variation explained	22.2%	22.0%	20.0%
Cronbach's alpha	0.75	0.36	0.63
Average inter-item correlation	0.47	0.25	0.18

Only loadings of > 0.30 or < –0.30 are shown.

https://doi.org/10.7120/09627286.24.2.151 Published online by Cambridge University Press

Table 7 Principal components representing mood types extracted from Principal Component Analysis on the descriptors of Qualitative Behaviour Assessment according to the Welfare Quality® protocol for fattening pigs ('Fattening') and for sows and sucking piglets ('Sows and piglets').

QBA descriptors	1 'Active positive behaviour'		2 'Passive negative behaviour'		3 'Passive positive behaviour'	
	Fattening	Sows and piglets	Fattening	Sows and piglets	Fattening	Sows and piglets
Lively	0.90	0.82				
Positively occupied	0.87	0.86				
Active	0.85	0.79				
Sociable	0.81	0.82				0.56
Happy	0.81	0.83				
Playful	0.75	0.92				
Enjoying	0.52	0.59			0.72	
Content					0.80	0.90
Listless			0.81			
Distressed			0.69	0.77		
Aimless			0.86	0.77		
Relaxed					0.91	0.84
Frustrated			0.80	0.85		
Bored			0.89	0.85		
Calm					0.89	0.92
Indifferent			0.93			
Variation explained	30.7%	33.0%	28.4%	22.5%	19.5%	19.3%
Cronbach's alpha	0.94	0.93	0.91	0.83	0.91	0.87

Only loadings of > 0.50 or < –0.50 are shown.

nents accounted for 63.4% of the variance in the (reduced) data, which corresponded to about one-third of variability in the total data (all animal-based measures pooled).

PCA results for sows with piglets are summarised in Table 6. The item-to-case ratio was 1:8.8, the average extraction h^2 0.64 (range 0.55–0.77), Bartlett's test significant ($P < 0.001$) and MSA 0.63. The resulting components accounted for 62.2% of the variance in the (reduced) data, which corresponded to about one-third of variability in the total data (all animal-based measures pooled).

PCA results on QBA descriptors for both pig categories are given in Table 7. For fattening pigs, the item-to-case ratio was 1:5.9, average extraction h^2 of 0.79 (range 0.55–0.90), MSA 0.86 and Bartlett's test significant ($P < 0.001$). For sows and piglets the item-to-case ratio was 1:6.9, average extraction h^2 0.75 (range 0.66–0.87), MSA 0.84 and Bartlett's test $P < 0.001$.

Discussion

In this study, PCA was applied to identify distinct types of welfare problems in animal-based data from the Welfare Quality® assessment systems for fattening pigs, and for sows and piglets. The main WPTs (seemingly) reflected fighting in fattening pigs and lack of bedding in both animal categories. The descriptors of QBA included distinct mood types that were close to identical in both pig categories.

The results have to be interpreted with the reference population in mind. No animals were tail-docked or nose-ringed. The fattening units represented a fairly narrow selection of growing systems even from a European perspective, with both fully slatted floors and outdoor systems absent. On sow farms the diversity in conditions was somewhat larger.

A large number of animal-based items were dropped from the PCAs due to insufficient contribution to the main WPTs.

Removal does not necessarily mean that a measure does not contribute to an overall on-farm welfare assessment or that it is unimportant in terms of pig welfare on the sample farms. A phenomenon captured by a low number of measures may not be evident as a WPT due to a small contribution to the total variability, whereas another phenomenon, equally prevalent but measured by a large number of items will. Although the measures in the WQ systems were chosen to span different aspects of welfare comprehensively, the number of items is limited in order to keep the system feasible for on-farm use.

The removal of 'tail lesions' may raise questions as tail biting is considered to be one of the most important indicators of decreased welfare in growing pigs, perhaps even fit to be used as an 'iceberg indicator' (Spoolder *et al* 2011). The inclusion of tail lesions in the WPT 'lack of bedding' would have been very logical, as environmental enrichment is recognised as perhaps the most effective preventive measure for tail biting in conventional production systems (van de Weerd & Day 2009). However, all farms provided the animals with chewable enrichment, probably decreasing the effect of bedding in the analysis. Other reasons for the result may be that tail lesions represented different types with different underlying causes, as described by Taylor *et al* (2010), or that the method of tail-lesion recording produced very low prevalences of tail lesions on the study farms. Only fresh lesions with blood, swelling or worse were included in the preliminary PCA (less severe score 1 lesions were noted on-farm but not included in the WQ assessment), and sick pens were not inspected at all. Moreover, the PCA was conducted on prevalences without consideration for the relative impact on pig welfare, which according to WQ is significantly higher for tail lesions than, eg bursitis or dirtiness (Welfare Quality® 2009; pp 71–72).

Low extraction h^2 in so many animal-based items is not surprising, as the PCAs in this study were applied for exploratory purposes in an index not built according to psychometric principles, which have establishment of reliability and validity incorporated into the development process (Fayers & Machin 2007). The same explanation is probably also valid for the MSA values barely exceeding the generally accepted minimum of 0.60. With this background some surprisingly strong components were found.

PCA and related procedures lack inferential statistical tests and ways to calculate or control the probability of making an error of inference. The criteria ensuring sound PCA methodology continue to be a much-debated area, with attention given not only to sample size, but also to item-to-subject ratio, h^2, number of variables per component and their loadings. At least some of these factors interact (Osborne & Costello 2004).

The present analyses were obtained in small (Kline 1979) or even insufficient (eg DeVellis 2003) samples. However, according to Guadagnoli and Velicer (1988), sample size can be ignored if the components contain four or more variables with loadings above 0.60 which, in the present study, was true for most components. Moreover, evidence has been put forward that a low n may produce good results in analyses with a low number of variables (Osborne & Costello 2004), and with acceptable item-to-subject ratios (Kline 1979). Together, these results suggest that the present data indeed included information about distinct WPTs and mood types that occurred frequently enough to produce fairly strong principal components in small data sets with small numbers of variables to reveal them.

Biological plausibility is one requirement for PCA-derived components to be considered as fit to describe existing WPTs and mood types. This can be evaluated based on scientific evidence for common backgrounds in items within a PWT, whereas for the present mood type common sense seems to suffice.

The most important WPT in fattening pigs was named 'fighting' due to its composition of skin condition, wounds, and moderate (weight-bearing) lameness. A common cause for these findings, occurring together on a farm, may be trauma due to aggressive behaviour. Wounds are established indicators of agonistic behaviour in pigs at least during short times of high agonistic activity that are avoided in the WQ assessment (Erhard *et al* 1997; Spoolder *et al* 2000; Turner *et al* 2006). In the present data, skin condition, usually either an outspread infection or reddening probably due to lying on a wet surface, correlated positively with wounds indicating a common background. Lameness may occur secondary to restlessness or fighting, and is a cause for prolonged lying which, on damp surfaces, may lead to skin irritation. Considering the low number of items (known to reduce alpha; Cortina 1993) the 'fighting' WPT had an acceptable alpha, indicating the degree of the items measuring one underlying construct (Cronbach 1951).

The second WPT 'lack of bedding' in growing pigs included exploration of enrichment (relative to active behaviour) and the QBA score as a measure of positive mood, loading in the opposite direction to exploration of pen fittings and moderate bursitis. These signs have all been associated with the use of bedding in pigs. Lack of bedding is an established risk factor for bursitis (Mouttotou *et al* 1999; Temple *et al* 2012). Exploration of pen fittings is thought in pigs to be redirected behaviour indicating that the environment does not provide enough substrate for the pronounced need to explore (Jensen & Pedersen 2010). The mood of the animals would most probably not be very positive in a situation of frustrated explorative needs. The QBA score may also be affected by lack of the insulation and comfort qualities of bedding material (Fraser *et al* 1991). 'Lack of bedding' can be classified as a useful scale truly measuring one underlying phenomenon, due to enough high-loading items and fair or even good internal consistency considering the low number of items.

The usefulness, as a scale, of the third fattening pig WPT 'disease' is, according to De Vellis (2003), uncertain due to only three items and an alpha just below acceptable. The composition, with pneumonia and pericarditis condemnations and negative social behaviour, may still be biologically plausible. Studies conducted in other species indicate that proinflammatory cytokines may play an important role in the regulation of aggression at least in a number of non-porcine species (Siegel *et al* 2009). Although condemnations and

https://doi.org/10.7120/09627286.24.2.151 Published online by Cambridge University Press

behavioural assessments were from different animals they probably reflect farm-specific factors affecting these outcomes.

In analyses on sows and piglets, all piglet variables were dropped during the PCA, indicating that they did not correlate with the major welfare dimensions in the data (or count for a significant amount of total variation in the data, which was unlikely due to the low number of piglet-specific variables). The most important WPT, closely resembling 'lack of bedding' in fattening pigs with the addition of stereotypic behaviour, was the only WPT with a decent reliability as a scale. Stereotypies have been suggested to indicate an adaptation problem at the individual level (Vieuille-Thomas *et al* 1995).

The second WPT in sows, 'shortage of resources', had an unacceptably low alpha indicating that the items may not measure a single underlying construct despite being mathematically inter-correlated. The WPT consisted of severe vulvar lesions, thin sows, moderate wounds and skin pathology. Still, this combination of items may suggest excessive competition for resources in group-housed sows, such as unsuccessful use of a feeder causing fights, vulva biting (Kroneman *et al* 1993; Brooks 2003) and undernutrition in low-ranking individuals (Kongsted *et al* 2007).

The third WPT in sows was assigned the heading 'lack of fibre', although its composition made the identification of a common background somewhat difficult. The WPT was comprised of constipation in early lactation, moderate dirtiness and wounds classified as either moderate or severe. Farrowing-related constipation in sows is predisposed by a physiologically declined intestinal activity in late pregnancy, and can be prevented by a sufficient fibre intake in late pregnancy (Wallace *et al* 1974). Wounds and skin pathology may decrease as a result of decreased aggression due to increased fibre intake in (restricted-fed) sows (Meunier-Salaun *et al* 2001).

The set of QBA descriptors contained strong, easily headlined underlying constructs or mood types in both fattening pigs and sows and piglets. Their composition was remarkably similar in both categories, and they were named equally as 'active positive', 'passive negative' and 'passive positive' mood. Apart from the passive positive mood type in sows and piglets the mood types represented good quality scales as judged by the number of items per category, their loadings and internal consistency. The main mood type (active positive) in fattening pigs carries a close resemblance to components reported in previous studies conducted across a wide range of production systems in UK and Spain (Mullan *et al* 2011; Temple *et al* 2011, 2013), with 'positively occupied' and 'happy' occurring in the main component in all four studies. These results suggest that the behaviour of pigs includes at least one dimension that is identifiable in very different surroundings and described using equal terms from a pre-defined list by independent observers. The same dimension may be present in sows and suckling piglets.

The WQ systems have been used only to a limited extent in commercial pig production partly due to time-consuming, on-farm data collection. In these data, inter-item correlations were calculated as indicators for possibilities to drop items without compromising the amount of information. A correlation interesting in terms of shortening of the index would be in the range of at least 0.7, which implies that half of the variation between the two items is shared. Such associations existed only between pneumonia and pleurisy condemnations; and score 2 wounds and skin condition in fattening pigs. Bursitis score 1 and exploration of pen fittings, also in fattening pigs, came close with $r_s = 0.66$. Unfortunately, dropping the other item in these pairs would have a negligible effect on the time needed on the farm.

Animal welfare implications and conclusion

The results of this study indicated that distinct types of welfare problems exist on pig farms, which can be captured using shortlists of animal-based measures from the Welfare Quality® on-farm assessment systems. If strong relationships between these welfare problem types and environmental or other hazards can be established the shortlists may be useful for time-efficient assessment of animal welfare upon identification of the particular hazard.

Qualitative Behaviour Assessment in pigs includes information about distinct mood types, which may be universal across housing types at least in growing pigs. Mood types may be used to evaluate responses of pigs to any stimulus.

References

AHAW (EFSA Panel on Animal Health and Welfare) 2012 Statement on the use of animal-based measures to assess the welfare of animals. *EFSA Journal 10(6)*: 2767

Baumgartner J 2007 How to deal with complex data of skin lesions in weaner pigs. *Animal Welfare 16(2)*: 165-168

Blokhuis HJ, Jones RB, Geers R, Miele M and Veissier I 2003 Measuring and monitoring animal welfare: transparency in the food product quality chain. *Animal Welfare 12(4)*: 445-455

Brooks PH 2003 Group housing of sows: the European experience. *London Swine Conference: Maintaining Your Competitive Edge*. 9-10 April 2003, London, ON, Canada

Cattell RB 1966 The scree test for the number of factors. *Multivariate Behavioral Research 1*: 629-637. http://dx.doi.org/10.1207/s15327906mbr0102_10

Cortina JM 1993 What is coefficient alpha? An examination of Theory and Applications. *Journal of Applied Psychology 78(1)*: 98-104. http://dx.doi.org/10.1037/0021-9010.78.1.98

Cronbach LJ 1951 Coefficient alpha and the internal structure of tests. *Psychometrika 16*: 297-334. http://dx.doi.org/10.1007/BF02310555

DeVellis RF 2003 *Scale Development, Theory and Applications, Second Edition*. Sage Publications: Thousand Oaks, CA, USA

Erhard HW, Mendl M and Ashley DD 1997 Individual aggressiveness of pigs can be measured and used to reduce aggression after mixing. *Applied Animal Behaviour Science 54*: 137-151. http://dx.doi.org/10.1016/S0168-1591(97)00068-3

Fayers P and Machin D 2007 *Quality of Life: The Assessment, Analysis and Interpretation of Patient-reported Outcomes, Second Edition*. John Wiley & Sons: Hoboken, NJ, USA. http://dx.doi.org/10.1002/9780470024522

Forkman B and Keeling L 2009 *Assessment of Animal Welfare Measures for Sows, Piglets and Fattening Pigs. Welfare Quality® Reports No 10*. Cardiff University: Cardiff, UK

Fraser D, Phillips PA, Thompson BK and Tennesen T 1991 Effect of straw on the behaviour of growing pigs. *Applied Animal Behaviour Science 30*: 307-318. http://dx.doi.org/10.1016/0168-1591(91)90135-K

Guadagnoli E and Velicer WF 1988 Relation of sample size to the stability of component patterns. *Psychological bulletin 103*: 265-275. http://dx.doi.org/10.1037/0033-2909.103.2.265

Jensen MB and Pedersen LJ 2010 Effects of feeding level and access to rooting material on behaviour of growing pigs in situations with reduced feeding space and delayed feeding. *Applied Animal Behaviour Science 123*: 1-6. http://dx.doi.org/10.1016/j.applanim.2009.12.015

Kaiser HF 1960 The application of electronic computers to factor analysis. *Educational and Psychological Measurement 20*: 141-151. http://dx.doi.org/10.1177/001316446002000116

Kline P 1979 *Psychometrics and Psychology*. Academic Press: London, UK

Knierim U and Winckler C 2009 On-farm welfare assessment in cattle: validity, reliability and feasibility issues and future perspectives with special regard to the Welfare Quality® approach. *Animal Welfare 18(4)*: 451-458

Kongsted AG, Hermansen, JE and Kristensen T 2007 Relation between parity and feed intake, fear of humans and social behaviour in non-lactating sows group-housed under various on-farm conditions. *Animal Welfare 16(2)*: 263-266

Kroneman A, Vellenga L, van der Wilt FJ and Vermeer H 1993 Review of health problems in group-housed sows, with special emphasis on lameness. *Veterinary Quarterly 15*: 26-29. http://dx.doi.org/10.1080/01652176.1993.9694364

Meunier-Salaün MC, Edwards SA and Robert S 2001 Effect of dietary fibre on the behaviour and health of the restricted fed sow. *Animal Feed Science and Technology 90(1-2)*: 53-69. http://dx.doi.org/10.1016/S0377-8401(01)00196-1

Mouttotou N, Hatchell FM and Green LE 1999 Prevalence and risk factors associated with adventitious bursitis in live growing and finishing pigs in south-west England. *Preventive Veterinary Medicine 39(1)*: 39-52. http://dx.doi.org/10.1016/S0167-5877(98)00141-X

Mullan S, Edwards SA, Butterworth A, Whay HR and Main DJC 2011 A pilot investigation of possible positive system descriptors in finishing pigs. *Animal Welfare 20*: 439-449

Munsterhjelm C, Heinonen M and Valros A 2015 Application of the of the Welfare Quality® animal welfare assessment system in Finnish pig production, part II: Associations between animal-based and environmental measures of welfare. *Animal Welfare 24*: 161-172. http://dx.doi.org/10.7120/096 27286.24.2.161

Osborne JW and Costello AB 2004. Sample size and subject to item ratio in principal components analysis. *Practical Assessment, Research & Evaluation 9(11)*. http://PAREonline.net/getvn.asp?v=9&n=11

Siegel A, Bhatt S, Bhatt R and Zalcman SS 2009 Cytokines and aggressive behavior. In: Siegel A and Zalcman SS (eds) *The Neuroimmunological Basis of Behavior and Mental Disorders* pp 235-239. Springer US: Philadelphia, PA, USA. http://dx.doi.org/10.1007/978-0-387-84851-8_12

Spoolder H, Bracke M, Mueller-Graf C and Edwards S 2011 Preparatory work for the future development of animal based measures for assessing the welfare of pigs. *Report 2: Technical report of preparatory work for the future development of animal based measures for assessing the welfare of weaned, growing and fattening pigs including aspects related to space allowance, floor types, tail biting and need for tail docking*. EFSA: Parma, Italy. http://www.efsa.europa.eu/en/supporting/pub/181e.htm

Spoolder HAM, Edwards SA and Corning S 2000 Aggression among finishing pigs following mixing in kennelled and unkennelled accommodation. *Livestock Production Science 63*: 121-129. http://dx.doi.org/10.1016/S0301-6226(99)00121-9

Taylor NR, Main DCJ, Mendl M and Edwards SA 2010 Tail biting: a new perspective. *The Veterinary Journal 186*: 137-147. http://dx.doi.org/10.1016/j.tvjl.2009.08.028

Temple D, Courboulay V, Velarde A, Dalmau A and Manteca X 2012 The welfare of growing pigs in five different production systems in France and Spain: assessment of health. *Animal Welfare 21*: 257-271. http://dx.doi.org/10.7120/09627286.21.2.257

Temple D, Manteca X, Dalmau A and Velarde A 2013 Assessment of test–retest reliability of animal-based measures on growing pig farms. *Livestock Science 151(1)*: 35-45. http://dx.doi.org/10.1016/j.livsci.2012.10.012

Temple D, Manteca X, Velarde A and Dalmau A 2011 Assessment of animal welfare through behavioural parameters in Iberian pigs in intensive and extensive conditions. *Applied Animal Behaviour Science 131*: 29-39. http://dx.doi.org/10.1016/j.applanim.2011.01.013

Turner SP, Farnworth MJ, White IMS, Brotherstone S, Mendl M, Knap P, Penny P and Lawrence AB 2006 The accumulation of skin lesions and their use as a predictor of individual aggressiveness in pigs. *Applied Animal Behaviour Science 96*: 245-259. http://dx.doi.org/10.1016/j.applanim.2005.06.009

Van de Weerd HA and Day JEL 2009 A review of environmental enrichment for pigs housed in intensive housing systems. *Applied Animal Behaviour Science 116*: 1-20. http://dx.doi.org/10.1016/j.applanim.2008.08.001

Veissier I, Capdeville J and Delval E 2004 Cubicle housing systems for cattle: Comfort of dairy cows depends on cubicle adjustment. *Journal of Animal Science 82*: 3321-3337

Vieuille-Thomas C, Le Pape G and Signoret JP 1995 Stereotypies in pregnant sows: indications of influence of the housing system on the patterns expressed by the animals. *Applied Animal Behaviour Science 44(1)*: 19-27. http://dx.doi.org/10.1016/0168-1591(95)00574-C

Wallace HD, Thieu DD and Combs GE 1974 *Alfalfa meal as a special bulky ingredient in the sow diet at farrowing and during lactation*. Research report, Department of Animal Sciences, University of Florida, Gainesville, FL, USA

Welfare Quality® 2009 *Assessment Protocol for Pigs*. Welfare Quality® Consortium: Lelystad, The Netherlands

Wemelsfelder F, Hunter EA, Mendl MT and Lawrence AB 2000 The spontaneous qualitative assessment of behavioural expressions in pigs: first explorations of a novel methodology for integrative animal welfare measurement. *Applied Animal Behaviour Science 67*: 193-215. http://dx.doi.org/10.1016/S0168-1591(99)00093-3

Wemelsfelder F and Millard F 2009 Qualitative indicators for the on-farm monitoring of pig welfare. In: *Welfare Quality® Reports No 10: Assessment of Animal Welfare Measures for Sows, Piglets and Fattening Pigs*. School of City and Regional Planning, Cardiff University: Cardiff, UK

https://doi.org/10.7120/09627286.24.2.151 Published online by Cambridge University Press