288. Marchant, J.N. and Broom, D.M. 1996. Factors affecting posture-changing in loose-housed and confined gestating sows. *Anim. Sci.*, 63, 477-485.

Factors affecting posture-changing in loose-housed and confined gestating sows

J. N. Marchant and D. M. Broom

Department of Clinical Veterinary Medicine, University of Cambridge, Madingley Road, Cambridge CB3 0ES

Abstract

The time taken to lie down and stand up was determined for dry sows from different housing systems and related to physical and genetic parameters. In experiment 1, the times taken to lie down by 32 sows in two dry-sow housing conditions were measured. Sows housed long-term in stalls took longer to lie down than group-housed sows (20·42 v. 9·28 s, $P < 0·001$). Group-housed sows took longer to lie down in the open than to lie down against a wall (11·07 v. 7·48 s, $P = 0·004$). The length of time taken for stall-housed sows to lie down had strongest association with body length ($P = 0·033$, $R^2 = 0·718$). The length of time taken for group-housed sows to lie down in the open had strongest association with the proportional weight of the extensor carpi radialis, *($P = 0·001$, $R^2 = 0·915$). In experiment 2, the times taken for 30 sows in stalls to lie down and stand up were measured and genotype differences investigated. There were no differences between genotypes in total times taken to stand up or lie down, but total times taken to stand up quickly and lie down had strongest association with body length ($P = 0·032$, $R^2 = 0·185$, and $P < 0·001$, $R^2 = 0·574$ respectively). The results indicate that sows housed long-term in gestation stalls experience difficulty of movement when standing up quickly and lying down. Although the chronic effects of lack of exercise and the acute effects of floor type may contribute to this difficulty, the major factor is likely to be space restriction as the times taken to lie down and stand up quickly both increase as body length, and hence dynamic space requirement, increases. Lying down in an unrestricted environment is under muscular control and the degree of control depends on the proportion of muscle weight to total body weight. The factors affecting lying down and standing up should be considered when designing dry-sow and farrowing accommodation.*

Keywords: *genotypes, housing, movement, posture, sows.*

Introduction

Freedom of movement and the opportunity to exercise most normal patterns of behaviour are two of the basic needs of animals detailed in the current United Kingdom Codes of recommendations for the welfare of livestock (Ministry of Agriculture, Fisheries and Food, 1990) expanded from the 'five freedoms' originally recommended by the Brambell Committee (1965) during their review of intensive husbandry systems. The Brambell Committee (1965) advocated that, at the very least, a farm animal should 'have sufficient freedom of movement to be able without difficulty, to turn round, groom itself, get up, lie down and stretch its limbs'. The intensification of livestock farming has, in general, led to higher stocking densities and therefore less space per animal. The ultimate development has been housing systems in which the animals are tethered, or confined in stalls, crates or cages. This confinement has resulted in a loss of ability to exercise and has forced some modification of animals' posture-changing behaviours. For example, Krohn and Munksgaard (1993) found that dairy cows housed in tie-stalls took longer to lie down than loose-housed dairy cows and they also showed a greater incidence of interruptions to the action. Krohn and Munksgaard (1993) suggested that cows in the tie-stalls found the behaviour of lying down aversive.

The modern domestic pig has been genetically selected to maximize weight and length of back for meat production (Whittemore, 1994). Consequently, its body shape has changed and the physical acts of standing up and lying down have become difficult, and relatively uncontrolled, even without any modification imposed by different housing systems. The importance of the spatial requirements of pigs in the design of housing has been noted by Petherick (1983) and more specifically for sows in confinement by Baxter and Schwaller (1983) and Curtis *et al.* (1989). The majority of dry sows in the European pig industry are kept in permanent stalls or tethers, and farrow and lactate in crates. Baxter and Schwaller (1983) found that the majority of farrowing crate designs in the United Kingdom (UK) are based on the static space requirements of the sow and do not make allowance for the dynamic space requirements during standing and lying. The same conclusion was reached by Curtis *et al.* (1989) following a study of farrowing crates in the United States (US).

Long-term confinement of sows during gestation greatly restricts the amount of exercise they have and results in a decrease in the amount of muscular tissue (Marchant and Broom, 1996) and cardiovascular fitness (Marchant and Rudd, 1993). It is also possible that confinement will alter lying and standing behaviours compared with sows without any spatial restrictions. Persistent difficulty in carrying out the movements necessary for standing and lying indicates that the welfare of the sow is poorer than if there were no such difficulties. The majority of piglet mortality is attributable to over-lying by the sow, both indoors (English and Wilkinson, 1982; English and Morrison, 1984) and outdoors (Edwards *et al.*, 1994). Many deaths due to crushing occur during lying and standing transitions (Edwards and Malkin, 1986; Marchant *et al.*, 1996) and hence, any difficulties in standing up and lying down may also have welfare implications for the litter (Baxter, 1984).

The objectives of these studies were to compare the time taken to lie down in sows from different dry-sow systems, and to investigate factors that affect or influence this behaviour. The times taken to lie down and stand up were then studied further within a confined gestation system on a commercial system and breed factors were investigated.

Material and methods

Two experiments were conducted, the design of the second being conditional on the results of the first.

Experiment 1

Animals and housing

The time taken to lie down was investigated in 32 Large White × Landrace sows (Masterbreeders, Tring, UK), housed in two different dry-sow housing systems at the Cambridge Veterinary School's Pig Welfare Unit. Behaviour was studied when all the sows were of a similar age (seventh to eighth parity) and stage of gestation (mean 55·3 (s.e. 4·3) days after service). They were slaughtered approximately 6 months after the behavioural measurements. The sows were housed in two adjacent building sections of identical design externally, but each modified internally to accommodate one of the two systems.

(1) Stalls (no. = 8). The sows were housed in individual stalls consisting of metal tubular frames bolted to a raised partially slatted floor. The stalls were 2·0 m long × 0·6 m wide × 1·0 m high.

(2) A large group with an Electronic Sow Feeder (ESF) system (no. = 24 from a group of 38 including 14 non-experimental animals). This system consisted of an area 16·6 m × 5·5 m divided into a strawed lying area and an unstrawed dunging area, with an ESF station situated in one corner.

The general management was similar in both systems. The ambient temperature was increased in the stall house in cold conditions but was similar in the two building sections in warmer weather. All sows were given a commercial diet (Pigbreed 16 — BOCM Pauls, Ipswich, UK) containing (g/kg) 160 crude protein, 50 fibre, 9·5 calcium and 5·8 phosphorus and giving 13 MJ/kg digestible energy. The quantity of diet varied in the same way for all sows from 2·0 kg/day to 7·5 kg/day, depending on body condition and stage of gestation or lactation. The sows housed in the large group also had access to straw. All sows were routinely weighed on entry to the farrowing house and at weaning, over each parity, and were always returned to the same dry-sow system from 4 weeks after service to 1 week prior to farrowing. The service accommodation comprised of large, individual strawed pens.

Experimental procedures

The sows were measured to determine body length from crown to tailhead, height to the point of shoulder and width across shoulders and were weighed prior to the behavioural measurements. The movements of the stall-housed sows were recorded remotely using a static camera (Panasonic WV-CD110AE) linked to a video-recorder (Panasonic AG-6720A) set to record in real time (25 frames per s). Those of the group-housed sows were recorded manually using a hand-held camcorder (Panasonic GN300), again recording in real time, from an aerial observation platform situated in the house.

The sequence of movements during lying down has been described previously by Baxter and Schwaller (1983) and was taken as follows. *Stage 1.* One front foot is lifted and placed onto the floor so that the sow drops to a half-kneeling position. The second is then lifted, placed onto the floor, and the sow drops into a full kneel. *Stage 2.* The sow may pause before movement continues. *Stage 3.* The sow slides one knee forward along the floor and rotates the upper part of her body to bring a shoulder and side of head to rest on to the floor. *Stage 4.* Again, the sow may pause before movement continues. *Stage 5.* The sow lowers her hindquarters and rotates slightly causing the rear legs to slide sideways. The hindquarters then drop so that the upper thigh of one leg lands on the floor.

Stall-housed sows cannot lie down freely and have to lean against the sides of the stall. Group-housed sows, however, can lie down in two different ways. On the majority of occasions, lying down is carried out with the assistance of an aid, usually a wall, but sometimes the recumbent body of another sow. On other occasions, sows lie down unaided in the open. The lying down sequence of each of the stall-housed sows was video-recorded four times and that of group-housed sows eight times, four times against a wall and four times in the open. This number of lying events per sow was chosen on the basis of a preliminary investigation and was determined to be a sufficient number of samples per sow to give a 'real' average. Only undisturbed lying events were included in the analysis and lying events which were disturbed by external factors, such as the extreme proximity of other sows, sudden noises or human activity, were discarded. The average durations were then calculated for each separate stage of movement and for the whole behavioural sequence, following frame-by-frame analysis of the tapes.

Approximately 6 months later, the sows were weighed and physical dimensions were again measured. Six stall-housed sows and seven of the 24 group-housed sows were slaughtered on-farm by lethal injection of pentobarbitone. After slaughter, 14 individual locomotor muscles, five from the left forelimb and nine from the left hindlimb, were dissected out. The muscles which were removed, reasons for choice and experimental procedure have been detailed previously (Marchant and Broom, 1996).

Statistical analysis
The two mean values for the time taken for group-housed sows to lie down are related whilst the mean value for the time taken for stall-housed sows to lie down is unrelated. This renders ANOVA, Kruskal-Wallis and Friedman two-way ANOVA tests invalid. Therefore, initial comparisons between housing systems on the individual stage times and total time taken to lie down were carried out using Mann-Whitney U tests on the average values for the stall-housed sows *versus* the overall average values for group-housed sows. The comparison between the two different forms of lying down for the group-housed sows was then carried out using a Wilcoxon signed-ranks test.

Multiple regression was used to examine the strength of association between time taken to lie down and body length, height, breadth, weight and proportional muscle weights, using a step-wise procedure. The small number of animals for which proportional muscle weight data was available presented difficulties in analysis with the high number of partial correlations calculated increasing the likelihood that a type I error would occur. Therefore, the partial F value for inclusion of a variable into the model (F-to-enter) was set for significance at the $P = 0{\cdot}01$ level, although we acknowledge the increased possibility of a type II error occurring and the rejection of a potentially interesting relationship.

Experiment 2

General
The results from experiment 1 indicated that sows housed in stalls had more difficulty when lying down than did loose-housed sows. However, because of the small sample size, and the fact that the sows studied had been housed in confinement for longer than is usual on commercial units, the study was repeated on confined sows housed in a commercial stall-house. Although we were unable to obtain muscle data, other factors, such as parity, stage of gestation, and genotype were investigated in relation to time taken to lie down and time taken to stand up.

Animals and housing
Experiment 2 was carried out on 30 sows which were a mixture of 'Tribred' × Landrace (Landrace-cross — no. = 10), and 'Tribred' × Hampshire (Hampshire-cross — no. = 20). The 'Tribred' line was bred using a three-way rolling cross programme and consisted of approximately 0·25 Large White, 0·25 Landrace and 0·50 Hampshire genes. Thus, Landrace-cross sows contained approximately 0·625 Landrace, 0·25 Hampshire and 0·125 Large White genes whilst Hampshire-cross sows contained approximately 0·75 Hampshire, 0·125 Landrace and 0·125 Large White genes. The Hampshire blood line had been introduced to allow the sows to be crossed with Large White terminal sires to produce progeny which could be reared outdoors. All sows were among 72 sows housed in a single building containing a permanent stall system with partially slatted floor and no straw, on a 400-sow commercial unit. The stalls were 2·2 m long × 0·6 m wide × 1·0 m high. The sows were of varying age (first to eighth parity) but similar stage of gestation (mean 55·7 (s.e. 2·5) days after service). All sows were given a commercial ration containing (g/kg) 152 crude protein, 51 fibre, 10·0 calcium and 6·9 phosphorus and giving 13 MJ/kg digestible energy.

Experimental procedures
The sows were measured to determine body length from crown to tailhead, height to the point of shoulder and width across shoulders. The sows were recorded using a static camera (Panasonic WV-CD 110AE) attached to a video recorder (Panasonic AG-6720A) set to record in normal time mode (25 frames per s). Each sow was recorded for a total of 8 h, and the average durations of individual stages and total times taken to lie down and stand up for each sow, were calculated using frame-by-frame analysis. The division of lying down into individual stages was the same as for the previous experiment. In this study, standing up was also measured. The sequence of movements during standing up has also been described by Baxter and Schwaller (1983) and occurs as follows. *Stage 1*. The sow rises up onto her foreknees and pushes up with her forelimbs one after the other, rising to a sit. *Stage 2*. The sow may pause before continuing movement. *Stage 3*. The sow lifts her entire hindquarters off the floor, into a full standing position, in a single motion.

Unlike the lying down behaviour, no use is made of any vertical surfaces even in close confinement. The stage of gestation and time spent in the housing system were calculated from the computerized herd records.

Statistical analysis
The behaviour of standing up was seen to take two forms which differed in duration. The first form (or category 1) was seen in response to a stimulus, such as a sudden noise or a person entering the building, and the sow would go from lying to standing very quickly. The second form (or category 2) was seen during normal posture changes and was spontaneous, i.e. would occur without prior external stimulation. These two categories could be clearly distinguished on the basis of the length of stage 2. Where stage 2 lasted less than 2 s, the behaviour was categorized as category 1; when longer than this, the behaviour was categorized as category 2.

Comparisons between genotypes of average times to lie down and stand up were carried out using Mann-Whitney *U* tests. Comparisons between categories of standing up within the same group of sows were carried out using Wilcoxon signed-rank tests. Relationships between times and body dimensions, stage of gestation, genotype and parity were carried out using step-wise regression. As the sample size (no. = 30) was larger than that of the previous experiment, the significance of the F to-enter value was set at $P < 0{\cdot}05$.

Results

Experiment 1

Stall-housed sows took significantly longer to lie down and to carry out each individual stage of lying down than group-housed sows (Table 1). Group-housed sows lying down in the open took significantly longer to lie down and to carry out stages 2 and 5 of the sequence than group-housed sows lying down against a wall (Table 1).

When comparisons of body dimensions and weight were carried out, there were no significant differences ($P > 0{\cdot}05$) between stall-housed sows and group-housed sows in the height to point of shoulder (840 (s.e. 10) mm *v.* 829 (s.e. 6) mm respectively), width across the shoulders (404 (s.e. 13) mm *v.* 416 (s.e. 5) mm respectively), body weight during behaviour measurements (224 (s.e. 6) kg *v.* 234 (s.e. 4) kg respectively), or body weight at slaughter (228 (s.e. 5) kg *v.* 240 (s.e. 4) kg respectively). However, stall-housed sows tended to be shorter than group-housed sows (1524 (s.e. 26) mm *v.* 1573 (s.e. 12) mm respectively, $P = 0{\cdot}052$), even though they were the same age and from the same genetic stock.

Table 1 *Comparison of individual stage times and total time taken (s) to lie down in seconds, for sows in stalls and groups*

	Stall sows (no. = 8) All lying events		Group sows (no. = 24) All lying events		Mann-Whitney *U*		Group sows (no. = 24) Lying in the open		Group sows (no. = 24) Lying against a wall		Wilcoxon signed-rank	
	Mean	s.e.	Mean	s.e.	z	P	Mean	s.e.	Mean	s.e.	z	P
Stage 1	3·01	0·62	1·98	0·10	−2·05	0·041	2·22	0·18	1·74	0·12	−1·92	0·056
Stage 2	7·44	2·86	2·01	0·24	−3·48	<0·001	3·09	0·44	0·93	0·23	−3·63	<0·001
Stage 3	2·09	0·15	1·18	0·09	−3·74	<0·001	1·12	0·13	1·24	0·11	−0·39	0·700
Stage 4	5·23	1·05	2·34	0·42	−2·96	0·003	2·61	0·60	2·06	0·48	−0·77	0·440
Stage 5	2·66	0·31	1·79	0·14	−2·61	0·009	2·04	0·21	1·53	0·14	−1·99	0·047
Total	20·42	3·47	9·28	0·61	−3·57	<0·001	11·07	0·88	7·48	0·75	−2·82	0·004

There were many significant differences between housing systems in absolute muscle weights and muscle weights expressed as a proportion of total body weight with, in all cases, stall-housed sows having lighter muscles than group-housed sows, similar results to those reported previously (Marchant and Broom, 1996).

Step-wise regression analysis was then carried out to examine the strength of association between the times taken to lie down and various body measurements; weight at time of slaughter, length, height, breadth and the proportional weights of the 14 locomotor muscles. With the significance level of F-to-enter set at $P < 0{\cdot}01$, few significant associations are found.

The total time taken for group-housed sows to lie down against a wall (no. = 7) was not significantly associated with any of the body measurements although the time taken to complete stage 1 was associated with length ($F_{1,5} = 16{\cdot}3$, $P = 0{\cdot}01$, $R^2 = 0{\cdot}75$), the time to complete stage 4 was associated with the proportional weight of the *biceps brachii* ($F_{1,5} = 17{\cdot}5$, $P < 0{\cdot}01$, $R^2 = 0{\cdot}78$) and the time to complete stage 5 was associated with the proportional weight of the *deltoideus* ($F_{1,5} = 24{\cdot}21$, $P < 0{\cdot}01$, $R^2 = 0{\cdot}83$).

The total time taken for group-housed sows to lie down in the open (no. = 7) was significantly associated with the proportional weight of the *extensor carpi radialis* ($F_{1,5} = 54{\cdot}0$, $P < 0{\cdot}001$, $R^2 = 0{\cdot}92$). Also, the time taken to complete stage 1 was associated with the proportional weight of the *soleus/gastrocnemius* ($F_{1,5} = 16{\cdot}3$, $P = 0{\cdot}01$, $R^2 = 0{\cdot}75$), the time to complete stage 4 with the proportional weight of the *extensor carpi radialis* ($F_{1,5} = 66{\cdot}8$, $P < 0{\cdot}001$, $R^2 = 0{\cdot}93$).

The time taken for stall-housed sows (no. = 6) to complete stage 2 was associated with the proportional weight of the *brachialis* ($F_{1,5} = 51{\cdot}5$, $P < 0{\cdot}001$, $R^2 = 0{\cdot}93$). The total time taken for stall-housed sows to lie down was not significantly associated with any of the body measurements with the significance level of F-to-enter set at $P < 0{\cdot}01$. However, with the significance level of F-to-enter set at $P < 0{\cdot}05$, there was a strong association with body length ($F_{1,4} = 10{\cdot}164$, $P = 0{\cdot}033$, $R^2 = 0{\cdot}72$). When a simple regression of body length and total time taken to lie down was carried out, using data from all stall-housed animals (no. = 8), the association was significant at the $P < 0{\cdot}01$ level ($F_{1,6} = 15{\cdot}1$, $P = 0{\cdot}008$, $R^2 = 0{\cdot}72$).

Experiment 2

Lying down

There were no significant differences ($P > 0{\cdot}05$) between Hampshire-cross sows and Landrace-cross sows in body length (1503 (s.e. 14) mm *v.* 1521 (s.e. 29) mm respectively), body height (792 (s.e. 7) mm *v.* 779 (s.e. 9) mm respectively), body width (401 (s.e. 6) mm *v.* 411 (s.e. 7) mm respectively), parity (2·8 (s.e. 0·3) *v.* 3·2 (s.e. 0·8) respectively), or stage of gestation (56 (s.e. 3) days *v.* 54 (s.e. 4) days respectively). The average time taken for all sows to lie down, was 18·4 s. Landrace-cross sows took significantly longer than Hampshire-cross sows to complete stage 3 and tended to take longer to complete stage 2 and to lie down overall (Table 2).

Table 2 *Comparison of mean individual stage times and total time taken (s) to lie down between stall-housed sows of different genotypes*

Stage times	Hampshire-cross sows (no. = 20)		Landrace-cross sows (no. = 10)			
	Mean	s.e.	Mean	s.e.	z	P
1	1·61	0·08	1·78	0·19	−0·462	0·644
2	7·20	0·79	10·80	1·74	−1·800	0·071
3	1·27	0·07	1·74	0·19	−2·200	0·028
4	5·06	0·66	5·18	1·01	−0·220	0·826
5	1·77	0·17	1·85	0·15	−0·920	0·356
Total time	16·81	1·42	21·58	2·23	−1·69	0·090

The total time taken for all sows (no. = 30) to lie down was significantly associated with body length and height. The times taken to complete stages 1, 2, 3 and 4 were also associated with body length (see Table 3). Within genotype, the total time taken to lie down was more strongly associated with body length in Landrace-cross sows than in Hampshire-cross sows (see Figure 1).

Table 3 *Step-wise regression equations showing significant relationships between times taken (s) to lie down and variables (length, width, height, parity and stage of gestation) for sows housed in stalls*

Y	Equation and factors used	R^2	P	Residual s.d.
Stage 1	−2·7 + 0·03 length	0·222	<0·01	0·40
Stage 2	−61·0 + 0·05 length	0·546	<0·001	3·06
Stage 3	−3·8 + 0·003 length	0·287	<0·01	0·40
Stage 4	−22·0 + 0·02 length	0·194	<0·05	2·66
Stage 5	—	—	—	—
Total time	−89·3 + 0·07 length	0·574	<0·001	4·56
	−115·8 + 0·07 length + 0·63 height	0·637	<0·001	4·29

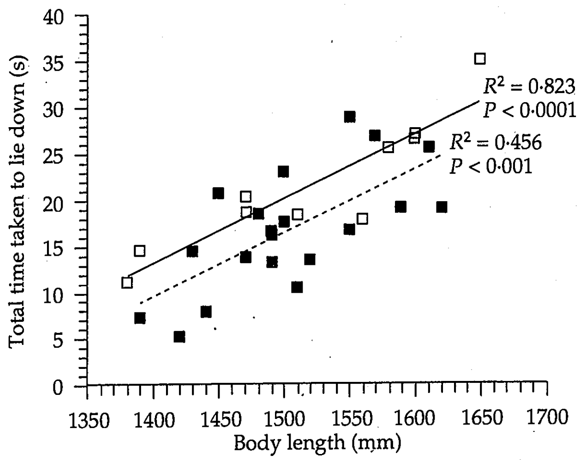

Figure 1 Relationship between total time taken to lie down (s) and body length (mm) for stall-housed sows of different genotypes: —□— Landrace-cross sows, - - ■ - - Hampshire-cross sows.

Standing up

Nineteen of the 30 sows carried out both categories of standing up behaviour. There were significant differences between categories in duration of all stages and in total time taken to stand up (see Table 4). Between genotypes, Landrace-cross sows took significantly longer than Hampshire-cross sows to complete stage 2 when standing up quickly (0·71 (s.e. 15) s and 0·35 (s.e. 0.11) s respectively, $P < 0{\cdot}05$). There was a significant association between total duration of category 1 standing and body length ($F_{1,23} = 5{\cdot}22$, $R^2 = 0{\cdot}185$, $P < 0{\cdot}05$) when both genotypes were combined, but not when genotypes were considered separately.

Discussion

Experiment 1

The results show that sows confined in stalls took significantly longer than group-housed sows to complete each individual stage of lying down and the whole behaviour. Possible factors contributing to this difference are: (1) chronic effects of the housing system, i.e. lifetime effects of the differences in ability to exercise; (2) floor type, i.e. straw *versus* no straw; and (3) acute effects of housing system, i.e. effects of physical restriction.

Table 4 *Comparison of mean times taken (s) for sows to stand up during different categories of standing (both genotypes combined)*

Stage times	Category 1 (no. = 19)		Category 2 (no. = 19)			
	Mean	s.e.	Mean	s.e.	z	P
1	1·42	0·10	2·29	0·11	–3·66	0·001
2	0·52	0·12	54·31	13·66	–3·82	0·001
3	1·00	0·07	1·19	0·05	–2·01	0·044
Total time	2·94	0·22	57·79	13·65	–3·82	0·001

There were chronic effects of the housing system, with stall-housed sows having smaller locomotor muscles in proportion to total body weight than group-housed sows. Sows with lower proportional muscle weights may have had less muscular control over their lying down movements. In the majority of cases where times were correlated with proportional muscle weights, the relationship was positive, with time taken increasing as muscle weight increased, indicating greater muscular control. Therefore, if the lower proportional muscle weights did influence the difference between stall and group-housed sows in total time to lie down, it is likely that any affect would be in the opposite direction to that seen. Together with the differences in locomotor muscle weights, the stall-housed sows tended to have shorter bodies than the group-housed sows, even though they were from the same genetic stock. This may indicate the importance of exercise for the growth and development of muscle and bone to its full genetic potential, as the animals were assigned to their respective dry-sow systems as gilts and continued to grow in the housing systems.

A sow lying down on bare concrete could either be quicker, by slipping, or take longer, by trying to avoid slipping, than when lying down on straw. It could be argued that floor type is likely to have the largest influence on time taken to lie down when the sow lies down in the open with complete freedom of movement and that without straw, the total time taken would be highly variable with an increased unpredictability of movement. In both the stall and group-housed animals, the time taken to lie down was fairly consistent within individuals. Where the time taken to lie down was much longer or shorter than the average, it was exclusively influenced by the external factors mentioned previously and these lying events had not been included in the analysis. However from the results of this study, it is not possible to discount floor type as a factor affecting the differences between housing systems in time taken to lie down.

Within the stalls, the total time taken to lie down was strongly associated with body length. This result, combined with the fact that total time to lie down was longer than for sows given freedom of movement, suggests that the stalls may restrict the sows' movements during lying down and that the degree of restriction may increase as sow body length increases. Within the group-housing system, the sows took longer to lie down in the open than to lie down against a wall. The results show that time taken to lie down in the open was positively correlated with the proportional weights of certain individual muscles. More muscular control is needed when lying down in the open and although this study has implicated only two muscles that are crucial for the control of lying down (*extensor carpi radialis* and *soleus/gastrocnemius*), there are very likely to be other muscles involved which were not among the 14 muscles selected for the dissection and analysis. The fact that sows more frequently chose to lie down against a wall, may highlight a potential lack of ability to control this sequence of movements, probably as a consequence of genetic selection for increased back length.

Experiment 2

The sows in this study took an average of 18·4 s to lie down. This is comparable with the stall-housed sows in experiment 1. When the genotypes were compared, Landrace-cross sows took significantly longer to complete stage 3 than Hampshire-cross sows. Time taken to complete stage 2 and total time taken to lie down also tended to be longer for Landrace-cross sows. These differences cannot be explained in terms of body dimensions, but may be due to differences in muscular conformation. The results confirm the findings of experiment 1, in that total time taken to lie down was strongly associated with body length for sows housed in confinement. This relationship was strongest for the Landrace-cross sows (see Figure 1). There was also a strong association between body length and all stages of movement except stage 5. It is likely that, once initiated, stage 5 is largely involuntary, has no element of muscular control and is not significantly influenced by any of the variables investigated in this experiment.

The existence of two distinguishable forms of standing up is interesting. Baxter and Schwaller (1983) included the recorded duration of standing in a small number of sows, and their results clearly showed differences in the duration of stage 2, ranging from 0 to 106 s. Baxter (1981, 1984) also described standing up in detail, but did not differentiate between normal standing up, and standing up as an alarm response. When comparing the two categories of standing up, all stages of movement were significantly shorter when the sow stood in response to a stimulus.

There was a significant association between body length and total time taken to stand up but only when standing up quickly. Going from sitting to standing requires a large forward movement and the extent of the restriction of dynamic spatial requirements would appear to be the major factor determining the time taken to stand up quickly. The duration of standing up slowly was independent of any of the factors examined in this study. When compared by genotype, Landrace cross sows took significantly longer to complete stage 2 than Hampshire-cross sows when standing up quickly.

General

Overall, the results suggest that without any spatial restriction, the time taken for sows to lie down will be largely determined by the weight, in proportion to total body weight, of certain muscles involved in the control of movement. It may be hypothesized that similar relationships between muscle proportions and time taken will exist when a sow stands up quickly without spatial restriction, as in this case the movement is totally dependent on muscular action working against gravity. Sows housed in close confinement over long term do have lower proportional muscle weights (Marchant and Broom, 1996), and this may influence how the sow would lie down in an open environment. Schmid and Hirt (1993) have demonstrated that sows housed in a restrained housing system whilst growing, subsequently chose to lean against a wall on 77% of occasions when lying down in an open environment, compared with only 3% of occasions for sows previously loose-housed during growth.

Once placed into commercial gestation stalls, the total time taken to stand up quickly and to lie down is associated with body length, suggesting an increasing difficulty in carrying out the movement due to increasing spatial restriction. Taylor *et al.* (1988) reported that pregnant gilts introduced into stalls and tethers soon reduced the number of times they stood up and lay down compared with loose-housed gilts, and suggested that this was probably due to the difficulty of carrying out these movements. However, as in our study, there were differences in floor type between confined and loose-housed treatments, which may be an influencing factor.

The two kinds of commercial gestation stalls used in the experiments did not allow the sow sufficient space to lie down easily. The space requirement of sows during posture-changing has been investigated by Baxter and Schwaller (1983) and Curtis *et al.* (1989). Both found that the majority of farrowing crates available in the UK and US were designed around the static space requirements of the animals and did not take into account the amount of space required during standing up and lying down. During these behaviours, there is a degree of sideways, forwards and backwards motion outside the bounds of the static requirements.

With these dynamic space requirements taken into account, the vast majority of gestation stalls and farrowing crates are too small in width and length, to allow standing and lying to be carried out without spatial restriction. The problems of spatial restriction will become worse as the mature sow size continues to increase. Mature sizes of 300+ kg are becoming more common (Whittemore, 1994) rendering more and more existing stall systems inadequate and having consequences for future building design. Restriction during movement may impose severe biomechanical stress on the sow (Baxter, 1981), which may be a factor causing the higher incidence of lameness seen in sows housed in confinement (Bäckström, 1973; Tillon and Madec, 1984). However again, the fact that most confinement systems are operated without straw and most loose-housed systems are straw-based will be an important factor influencing lameness incidence.

The hindrance of muscular control by spatial restriction also has implications for farrowing system design. In a loose farrowing system, sows will carry out pre-lying behaviour and lie down carefully (Blackshaw and Hagelsø, 1990). This will reduce the likelihood of piglet deaths due to crushing but only if the sow has adequate muscular control. Stall-housed sows have smaller proportional muscle weights than group-housed sows and thus, would have a reduced ability to lie down in a controlled way if placed in an open farrowing system. The ability to stand quickly is also important in the farrowing house, when the sow may need to respond to a trapped piglet's squeals. Cronin and Cropley (1991) reported that all gilts in their study, which had recently farrowed in crates, stood quickly in response to tactile and auditory stimuli presented as they carried out stage 1 of lying down. However, Hutson *et al.* (1991) using sows ranging from first to ninth parity report a very variable response to the same stimuli which they proposed was due to genetic variation. These apparent differences could be more due to the size of the sow and the degree of restriction imposed by the crate. Gilts would be lighter, smaller, more mobile and less spatially restricted than ninth parity sows and thus, more able to get up quickly.

Conclusions

The time taken for sows in gestation stalls to stand up quickly and lie down increases as body length increases. This may be due to increasing spatial restriction. Lying down in an unrestricted environment is under muscular control and the degree of control depends on the proportion of the muscles involved to total body weight. The proportion of a muscle to body weight has a genetic basis but is influenced by dry-sow environment. The factors affecting lying down and standing up should be considered when designing dry-sow and farrowing accommodation as inappropriate design may affect the welfare of the sow and her litter.

Acknowledgements

We would like to thank Phil Maltby and Paul Carter for their care and attention in looking after the pigs at Cambridge and David Overton for allowing us access to his commercial system. We also thank Dr H. Bradshaw and an anonymous referee for comments on an earlier draft of this paper. JNM was funded by a UK Ministry of Agriculture, Fisheries and Food studentship.

References

Bäckström, L. 1973. Environment and animal health in piglet production. *Acta Veterinaria Scandinavica* **41:** (suppl.) 1-240.

Baxter, M. R. and Schwaller, C. 1983. Space requirements for sows in confinement. In *Farm animal housing and welfare* (ed. S. H. Baxter, M. R. Baxter and J. A. C. MacCormack). *Current topics in veterinary medicine and animal science, vol. 24,* pp. 181-194. Martinus Nijhoff, The Hague.

Baxter, S. H. 1981. Welfare and the housing of the sow and suckling pigs. In *The welfare of pigs* (ed. W. Sybesma). *Current topics in veterinary medicine and animal science, vol. II,* pp. 276-311. Martinus Nijhoff, The Hague.

Baxter, S. H. 1984. *Intensive pig production: environmental management and design.* Granada, London.

Blackshaw, J. K. and Hagelsø, A. M. 1990. Getting-up and lying-down behaviours of loose-housed sows and social contacts between sows and piglets during day 1 and day 8 after parturition. *Applied Animal Behaviour Science* **25:** 61-70.

Brambell Committee. 1965. *Report of technical committee to enquire into the welfare of animals kept under intensive husbandry systems.* Her Majesty's Stationery Office, London.

Cronin, G. M. and Cropley, J. A. 1991. The effect of piglet stimuli on the posture changing behaviour of recently farrowed sows. *Applied Animal Behaviour Science* **30:** 167-172.

Curtis, S. E., Hurst, R. J., Widowski, T., Shanks, R., Jensen, A., Gonyou, D., Bane, A., Muehling, A. and Kesler, R. 1989. Effects of sow-crate design on health and performance of sows and piglets. *Journal of Animal Science* **67:** 80-93.

Edwards, S. A. and Malkin, S. J. 1986. An analysis of piglet mortality with behavioural observations. *Animal Production* **42:** 470 (abstr.).

Edwards, S. A., Smith, W. J., Fordyce, C. and MacMenemy, F. 1994. An analysis of the causes of piglet mortality in a breeding herd kept outdoors. *Veterinary Record* **135:** 324-327.

English, P. R. and Morrison, V. 1984. Causes and prevention of piglet mortality. *Pig News and Information* **5:** 369-376.

English, P. R. and Wilkinson, V. 1982. Management of the sow and litter in late pregnancy and lactation in relation to piglet survival and growth. In *Control of pig production* (ed. D. J. A. Cole and G. R. Foxcroft), pp. 479-506. Butterworths, London.

Hutson, G. D., Wilkinson, J. L. and Luxford, B. G. 1991. The response of lactating sows to tactile, visual and auditory stimuli associated with a model piglet. *Applied Animal Behaviour Science* **32:** 129-137.

Krohn, C. C. and Munksgaard, L. 1993. Behaviour of dairy cows kept in extensive (loose-housing/pasture) or intensive (tie stall) environments. II. Lying and lying-down behaviour. *Applied Animal Behaviour Science* **37:** 1-16.

Marchant, J. N. and Broom, D. M. 1996. Effects of dry sow housing conditions on muscle weight and bone strength. *Animal Science* **62:** 105-113.

Marchant, J. N., Broom, D. M. and Corning, S. 1996. The effects of sow maternal behaviour on piglet mortality in an open farrowing system. *Animal Science* **62:** 675 (abstr.).

Marchant, J. N. and Rudd, A. R. 1993. Differences in heart rate response at feeding between stall-housed and group-housed sows. *Animal Production* **56:** 423 (abstr.).

Ministry of Agriculture, Fisheries and Food. 1990. *Codes of recommendation for the welfare of livestock.* Her Majesty's Stationery Office, London.

Petherick, J. C. 1983. A biological basis for the design of space in livestock housing. In *Farm animal housing and welfare* (ed. S. H. Baxter, M. R. Baxter and J. A. C. MacCormack). *Current topics in veterinary medicine and animal science, vol. 24,* pp. 103-120. Martinus Nijhoff, The Hague.

Schmid, H. and Hirt, H. 1993. Influence of domestication and housing conditions on the behaviour of lying down in sows. In *Proceedings of the international congress on applied ethology* (ed. M. Nichelmann, H. K. Wierenga and S. Braun), pp. 458-462. K.T.B.L., Darmstadt, Germany.

Taylor, L., Friend, T. and Smith, L. A. 1988. Effects of housing on in situ postures of gestating gilts. *Applied Animal Behaviour Science* **19:** 265-272.

Tillon, J. P. and Madec, F. 1984. Diseases affecting confined sows. Data from epidemiological observations. *Annales de Recherches Vétérinaires* **15:** 195-199.

Whittemore, C. T. 1994. Causes and consequences of change in the mature size of the domestic pig. *Outlook on Agriculture* **23:** 55-59.

(*Received* 9 *November* 1995—*Accepted* 13 *June* 1996)