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Providing periodic exercise to stall-housed gestating sows influences only the total number of live-born piglets in older parity sows

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Abstract

The 2014 Canadian Pig Code of Practice includes a recommendation to provide stall-housed gestating pigs with periodic exercise. The objective of this study was to evaluate the effects of periodic exercise on sow performance and placental and piglet characteristics. Sows ($n = 180$) were assigned to one of three gestation treatments: stall-housed sows (Control: C), stall-housed sows given weekly exercise (Exercise: E—10 min of walking per week), and group-housed sows (Group: G). Sows were distributed among three parity groups: young (parity 0–1), mid (parity 2–4), and old (parity 5–7). Old C sows had a higher number of total born than G sows, and E sows were intermediate; mid G sows had a higher total born than E and C sows ($P = 0.023$). Old E and G sows had similar numbers of total live-born piglets, which were higher than in old C sows ($P = 0.033$). Periodic exercise did not influence placental and piglet characteristics in the current study. In conclusion, periodic exercise benefited only the reproductive performance of older parity sows, increasing the number of live-born piglets in E and G sows compared to C sows.

Key words: stall (gestation), stress (gestational), exercise (periodic), pig, placenta, performance (reproductive)

Résumé

Le Code canadien de pratique pour les soins et la manipulation des porcs comprend une recommandation d'offrir de l'exercice périodique aux porcs en gestation logées en stalles. L'objectif de cette étude était d'évaluer les effets de l'exercice périodique sur la performance des truies ainsi que les caractéristiques du placenta et des porcelets. Les truies ($n = 180$) ont été assignées à l'un de trois traitements lors de la gestation : truies logées en stalles (C; groupe témoin [« control »]), truies logées en stalles avec exercice hebdomadaire (E; 10 minutes de marche par semaine), truies logées en groupe (G). Les truies ont été distribuées selon trois groupes de parité : jeune (parité 0 à 1), moyenne (parité 2 à 4), et vieille (parité 5 à 7). Les vieilles truies C avaient un plus grand nombre de nés total que les truies G, et les truies E montraient un nombre intermédiaire; et les truies G moyennes avaient un plus grand nombre de nés total que les truies E et C ($P = 0{,}023$). Les vieilles truies E et G avaient un nombre semblable de porcelets nés vivants; ce nombre était plus élevé que chez les vieilles truies C ($P = 0{,}033$). Dans la présente étude, l'exercice périodique n'a pas eu d'influence sur les caractéristiques du placenta ni des porcelets. En conclusion, l'exercice périodique était avantageux seulement pour la performance reproductive des truies à plus grandes parités, augmentant le nombre de porcelets nés vivants dans les groupes E et G de truies par rapport aux truies du groupe C. [Traduit par la Rédaction]

Mots-clés : stalle (gestation), stress (gestationnel), exercice (périodique), porc, placenta, performance (reproductive)

Introduction

To address societal concerns about the welfare of stall-housed gestating sows, the 2014 Code of Practice for the Care and Handling of Pigs required that as of 2024, mated female pigs should be provided greater freedom of movement (NFACC 2014). The Code states that meeting this recommendation should be achieved by implementing group gestation housing in all newly built barns, and by providing sows in stall barns built prior to 2014, with opportunities for a greater freedom of movement, such as periodic exercise. Previous research has shown that stall-housed gestating pigs are motivated to exit their stall (Tokareva et al. 2021), and also that low levels of periodic exercise in gestating sows can alter piglets' response to behavioural stress tests (Tokareva et al. 2022). However, exercising sows in commercial barns would result in significant costs for the producers through additional labour, as sows would need to be exercised one at a time to prevent aggressive interactions. For example, exercising individual sows for 10 min/week, a herd with 550 gestating sows would require approximately 92 h of labour each week to exercise each sow and also additional time to move the sows out of their stalls when they are not used to this. Periodic exercise could be a more viable option if the costs of exercising could be offset by improvements in sow productivity. Earlier studies have identified that more intensive exercise regimes (exercising at least three times/week for at least 30 min) impact sow reproductive physiology through changes in umbilical blood flow (Harris et al. 2013) and improve sow performance by increasing piglet birth weight and reducing piglet mortality (Schenck et al. 2008), but the impact of low-level periodic exercise on sow reproductive function is unknown.

Evaluating both prenatal and postnatal piglet survival measures, which reflect the intrauterine and extrauterine environment (Baxter et al. 2008), provides a more refined approach to assessing the effects of periodic exercise on sow productivity. For example, previous research in humans suggests that most stillbirths are related to placental dysfunction, which is associated with fetal growth restriction (Smith and Fretts 2007). Medical research has also found evidence of a positive influence of exercise on fetoplacental growth, resulting in faster placental development and improved placental function (Clapp et al. 2000). While the existing body of literature on the effects of periodic exercise on prenatal and postnatal survival in swine is limited, there is some evidence that providing a greater freedom of movement to gestating sows through housing them in groups in early gestation can improve sow conception rates and piglet prenatal survival, as demonstrated by the decreased number of stillborn piglets in sows mixed after weaning in comparison to the sows mixed at 5 weeks post breeding (Brown 2015). Similarly, Connor (2018) found a tendency for reduced numbers of stillborns in sows grouped at weaning, in comparison to the sows mixed into static groups 7 to 8 days after weaning, and at 4 weeks after breeding. It was also found that housing gestating sows in groups increased chances of piglet postnatal survival, as determined by higher piglet birth weight compared to sows housed in gestation stalls (Bates et al. 2003). However, group housing not only provides sows with more opportunities for movement but also freely permits social interaction between sows and improves sow resting behaviour, which collectively could contribute to improved prenatal and postnatal survival measures found in previous studies (Bates et al. 2003; Brown 2015; Connor 2018). Therefore, care needs to be taken when interpreting the findings of studies focused on sows housed in group systems. There is a lack of studies providing a comprehensive comparison of the measures of prenatal and postnatal piglet survival in relation to the level of exercise received by sows during gestation.

The objectives of this study were to determine the effects of providing periodic exercise to stall-housed sows during gestation on their reproductive performance, placental development, and piglet viability, with comparisons to stall-housed sows receiving no exercise, and sows housed in groups.

Materials and methods

All experimental procedures were reviewed and approved by the University of Saskatchewan Animal Care Committee (AUP No. 20170057), which is regulated by the Canadian Council of Animal Care (CCAC 2009). This study was conducted at the Prairie Swine Centre, Saskatoon, Canada between February and November 2019.

Animals and housing

A total of 180 bred PIC Camborough 42 sows (parities 0–7, mean parity ± standard deviation [SD]: 2.42 ± 1.76) were studied. On day 7–10 post breeding, sows were moved from breeding stalls to free-access stall gestation pens (Egebjerg INN-O-STALL® free access stalls, Egebjerg International A/S, Nykøbing Sjælland, Denmark) and remained in the pens until day 107–110 of gestation. Each free-access stall pen contained 32 free access stalls (each 2.1 m long × 0.65 m wide), with 16 stalls on adjacent sides of the pen, and a 3.0 m wide fully slatted loafing area in between (Rioja-Lang et al. 2013). Each free-access stall pen was divided with an opaque plastic central divider, so there were two lanes of eight stalls on each side of the pen. One replicate block consisted of 12 experimental animals selected within 1 breeding week, and a total of 15 replicate blocks were formed. For each experimental animal, body condition score (BCS) on a scale of 1 to 5 (1 = thin, 5 = fat) was recorded. Animals were fed approximately 2.2 kg of a standard sow gestation ration once daily at 0700 h, and each free access stall and central loafing area were equipped with nipple water drinkers.

Experimental sows were moved to individual farrowing crates on day 107–110 of pregnancy. The farrowing crates were equipped with electronic sow feeders (Jyga Technologies, Saint-Lambert-de-Lauzon, QC, Canada) and nipple drinkers. The farrowing rooms were illuminated by natural sunlight and artificial lightning provided between 0700 and 1500 h; on the days of farrowing data collection, the artificial lightning was provided for 24 h. Farrowing was allowed to occur naturally, with limited intervention by trained personnel if a piglet birth interval was longer than 3 h, and research staff were present for data collection. One day before the expected date of farrowing, rubber mats were placed in the farrowing crates behind the sows for the purpose of collecting placentas. The mats were regularly washed and replaced with clean dry mats as needed and were left in the crates until the end of farrowing. The piglets had access to a heated area at the front of the farrowing pen, which was inaccessible to the sow. Cross-fostering was performed within treatment groups and within 2 days of age in accordance with the barn practices to maintain the litter size of 14 piglets per sow, and the numbers of piglets fostered on the sow and fostered off the sow were recorded. Husbandry procedures were performed by trained barn staff on the piglets, including teeth clipping (at 1-day postpartum), tail docking, iron injections, ear notching, and castrations (at 3 days of age). Weaning of piglets was performed at approximately 28 days of age.

Treatments

After moving to gestation pens, sows were randomly assigned to one of three treatment groups (four sows per treatment per replicate block, $n = 180$ sows, 60 sows per treatment): sows housed in stalls throughout gestation (Control: C); stall-housed sows given weekly exercise throughout gestation (Exercise: E); sows housed in static groups of four throughout gestation (Group: G). Experimental animals were blindly selected from the list of available sows and then assigned to treatments based on their parity. Efforts were made to balance treatments by parity, and all treatments were represented within the same gestation pen. The pen design with a central divider allowed housing of two replicates within each pen. The individual sow was the experimental unit.

Sows in the C treatment remained locked in the gestation stalls during gestation. Sows in the E treatment were also locked in stalls throughout gestation, but were removed for exercise once a week. To provide exercise, E sows were backed out of their stalls, moved out of the gestation pen by a handler using a pig board if needed, and walked in a loop twice around the alleyways surrounding half of the gestation room. Exercising was performed between 1100 and 1300 h on the same day every week. The distance walked by sows during one exercise session was approximately 160 m. Sows were encouraged to keep moving by the handler through vocal signals, and, if needed, use of a pig board or light taps from the hand. Sows were exercised one at a time. Sows in the G treatment were manually locked out of the free access stalls for 6–7 h a day, to enforce a group housing situation, remaining in the group loafing area, which measured 3.0 m by 5.35 m (4.01 m^2/sow) with concrete slatted flooring, and having access to both the stalls and the group area the rest of time. If sows were not locked out of the free-access stalls in the day, a proportion of sows would remain in the stalls for the majority of the time by choice. Locking animals out of stalls ensured that group-housed sows experienced a group scenario where social interactions took place. Group sows were locked in the stalls once a week, during the period of exercising E sows.

Sow performance measurements

Total litter size (total of live-born, stillborn, and mummified piglets), as well as the numbers of live-born and stillborn piglets separately, were recorded for all sows. For the purpose of statistical analysis, sows were assigned to one of three parity groups: young (parity 0–1), mid (parity 2–4). and old parity sows (parity 5–7). The distribution of sows belonging to different treatments and parity groups was as follows: Young C: $n = 17$; Mid C: $n = 27$; Old C: $n = 9$; Young E: $n = 12$; Mid E: $n = 36$; Old E: $n = 9$; Young G: $n = 20$; Mid G: $n = 32$; Old G: $n = 6$. Whether piglets were stillborn (not moving during farrowing and following birth) was determined from video footage and live observations of farrowing conducted by research staff or trained barn staff. Body weight and crown-rump length of live-born piglets were recorded at birth. Ponderal index (PI) and body mass index (BMI) measures were adapted from Baxter et al. (2008) and determined for each live-born piglet. PI was calculated as birth weight (kg)/(crown-rump length (m))^3; BMI was calculated as birth weight (kg)/(crown-rump length (m))^2.

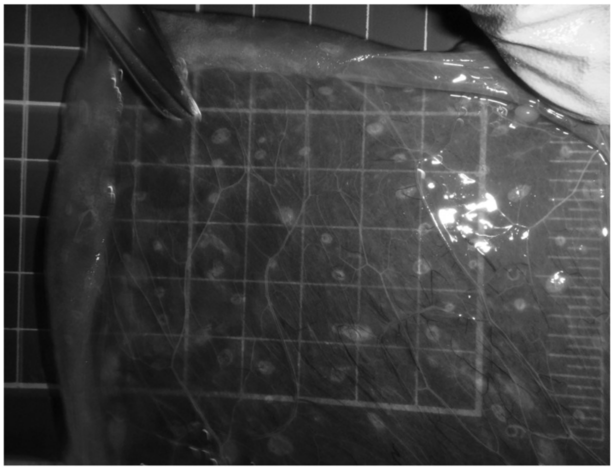
At weaning, the number of piglets weaned from each experimental sow was recorded, and live-born piglet mortality percentage was calculated using an adjusted equation adapted from Mack et al. (2014): live-born piglet mortality (%) = ((adjusted number of live-born piglets post fostering − number of piglets weaned)/adjusted number of live-born piglets post fostering) × 100, where the adjusted number of live-born piglets post fostering was determined as: number of live-born piglets + number of piglets fostered on the sow − number of piglets fostered off the sow.

Placental characteristics

Placentas from 36 sows (12 sows/treatment) were collected from the rubber mats immediately upon farrowing and stored at 4 °C for up to 24 h until dissection could be performed. The distribution of sows belonging to different treatments and parity groups was as follows: Young C: $n = 4$; Mid C: $n = 4$; Old C: $n = 4$; Young E: $n = 3$; Mid E: $n = 8$; Old E: $n = 1$; Young G: $n = 3$; Mid G: $n = 8$; Old G: $n = 1$. The sows were randomly selected from six replicates (two sows/treatment/replicate). The placentas were dissected and evaluated according to procedures adapted from van Rens et al. (2002) and Baxter et al. (2008). Placental dissections were performed by two trained technicians: one technician counted areolae and weighed placentas, and another technician prepared placentas for dissection and took all other measurements. Placentas were carefully washed and each individual placenta was separated. The umbilical cord, necrotic tips, and amnion and amniotic fluids were removed, and only the allantochorion was evaluated. Placental vascularization was evaluated macroscopically on a scale from 1 (white, fragile and thin placenta with little blood within the major blood vessels and capillaries) to 5 (deep red, thick, and resistant to tearing placenta with the presence of blood within the major blood vessels and capillaries). For a full description of the placental vascularization scoring system refer to Baxter et al. (2008). The width and length of each placenta were recorded, and then the placenta was cut across its length at the anti-mesometrial side and spread out. Parts of the upper and lower allantochorion, equidistant between the centre and the edge, were placed on a board with ruler markings, and areolae visible macroscopically within 5 × 5 cm quadrants on both upper (Quadrant 1) and lower (Quadrant 2) parts of allantochorion were counted (Fig. 1). Areolae were presented as white opaque circles and ellipses on the allantochorionic surface (Brambel 1933). Afterwards, the weight of each placenta was recorded.

Placental surface area was calculated by multiplying placental width by placental length. An estimate of the total number of areolae per placenta was calculated as (placental surface area (cm^2)/total surface area of Quadrants 1 and 2 (cm^2)) × total number of areolae in Quadrants 1 and 2. Areolae density was calculated as total number of areolae per placenta/placental surface area (cm^2). Placental efficiency was

Fig. 1. Dissected placenta on a board with ruler markings. White opaque circles and ellipses on the allantochorionic surface represent areolae.



determined for each sow individually as average piglet birth weight (g)/average placental weight (g).

Piglet viability data collection

Sows and their piglets were continuously filmed using a camcorder (Vixia HF R800, Canon Canada Inc., Brampton, ON, Canada) starting from one day before the expected date of farrowing until 3 h after the end of farrowing (when the last placenta was expulsed), and after behavioural events such as standing and reaching the teat (adapted from Baxter et al. 2008) were performed by each piglet at least one time. Piglet viability measures including farrowing duration (the time between the birth of the first and the last piglets), farrowing duration per piglet (farrowing duration/total number of piglets born (live-born + stillborn + mummies)), latency to stand, and latency to reach the teat were transcribed from the video footage for 24 C sows, 28 E sows, and 36 G sows by a single trained observer blind to the treatments. The original aim was to record farrowing from at least 36 sows per treatment, but it was not possible due to multiple camera failures. The sows were randomly selected across 11 replicates, with the numbers of sows per replicate being not equal due to camera failures. The distribution of sows belonging to different treatments and parity groups was as follows: Young C: $n = 8$; Mid C: $n = 13$; Old C: $n = 3$; Young E: $n = 5$; Mid E: $n = 18$; Old E: $n = 5$; Young G: $n = 8$; Mid G: $n = 24$; Old G: $n = 4$.

Statistical analysis

Data were analysed using the statistical package SAS 9.4 (SAS Institute, Cary, NC, USA). The significance level was set at $P < 0.05$, and results with $P < 0.10$ were considered as statistical trends. Residuals of all dependent variables were examined for normality and homogeneity of variances, and the data were transformed as necessary; the least-square means (LSMEANS) of fixed effects with Tukey's adjustment were used to account for multiple comparisons. The fit statistics of models were checked through the Akaike's information criterion corrected (AICC) and Bayesian information criterion (BIC) to ensure the best-fit model was achieved. Results are presented as the mean and SEM from the raw (untransformed) data.

The description of statistical models used for different dependent variables is presented in Table 1. Collinearity between farrowing duration and farrowing duration per piglet was explored prior to inclusion in the same model. The live-born piglet mortality percentage was calculated from the adjusted number of live-born piglets post fostering and was converted to the proportion.

In total, 11 sows were removed from the trial and their data were not included in the final analysis: three of these sows were removed due to illness (two control and one group sow) and eight sows aborted (five control, two exercise, and one group sow). Performance data were missing for one sow. Additionally, piglets for which farrowing assistance was provided were excluded from the piglet viability analysis, and sows which received farrowing assistance were not included in the farrowing duration data. For the main effects, *P*-values and *F*-values are included, and adjusted *P*-values are presented for post hoc comparisons.

Results

Sow performance

There was an interactive effect of gestation treatment and parity group on total litter size ($F_{[4,156]} = 2.92$, $P = 0.023$) and the number of live-born piglets ($F_{[4,155]} = 2.70$, $P = 0.033$). Gestation treatment predominantly influenced the performance of older parity sows: old parity C sows had larger litters than G sows, and E sows were intermediate (Fig. 2). Within mid parity sows: G sows had larger litters than both E and C sows, which did not differ (Fig. 2).

Old C sows had a lower number of live-born piglets than old E sows, with old G sows being intermediate (Fig. 3). Within C treatment: old C sows had a significantly lower number of live-born piglets than young ($P = 0.002$) and mid C sows ($P = 0.008$), which were no different. There were no other treatment and parity group interactions on the total litter size and number of live-born piglets.

The interaction of treatment and parity group tended ($F_{[4,158]} = 2.22$, $P = 0.069$) to affect the number of stillborn piglets. Old parity C sows had more stillborns than E sows ($P = 0.013$), with G sows being intermediate. However, given that the main effect of the model showed only a tendency, the difference between old parity C sows and old parity E sows was also interpreted as a tendency (Fig. 4). Old C sows tended to have more stillborn piglets than young and mid C sows, which did not differ. There were no other treatment and parity group interactions on the number of stillborn piglets.

There was no effect of treatment or interactive effect of treatment and parity group on piglet birth weight. However, sow parity group influenced piglet birth weight: mid parity sows had significantly heavier piglets than young and old parity sows, which did not differ (Young: 1.43 ± 0.03, Mid: 1.51 ± 0.03, Old: 1.38 ± 0.04; mean $\pm$ SEM, kg; $F_{[2,157]} = 5.21$, $P = 0.007$).

There was no effect of treatment on PI, BMI, and live-born piglet mortality (Table S1), as well as no effect of parity group

Table 1. Description of statistical models used for sow performance (total litter size, number of live-born pilgets, number of stillborn piglets, piglet PI, piglet BMI, live-born piglet mortality), placental parameters (placental surface area, areolae density, total areolae number, placental weight, placental efficiency, and placental vascularization), and piglet viability (farrowing duration, farrowing duration per piglet, piglet latency to stand, and piglet latency to reach the teat).

Variable	Model used	Fixed effects	Random effects	Covariates	Transformation
Sow performance					
Total litter size	Mixed linear regression	Treatment, parity group, treatment × parity group	Replicate	Not included	Square root
Number of live-born piglets	Mixed linear regression	Treatment, parity group, treatment × parity group	Replicate	Total litter size	Square root
Number of stillborn piglets	Poisson regression	Treatment, parity group, treatment × parity group	Replicate	Total litter size	Non-transformed
Piglet birth weight	Mixed linear regression	Treatment, parity group, treatment × parity group	Replicate	Total litter size	Non-transformed
Piglet PI	Mixed linear regression	Treatment, parity group, treatment × parity group	Replicate	Not included	Square root
Piglet BMI	Mixed linear regression	Treatment, parity group, treatment × parity group	Replicate	Not included	Square root
Live-born piglet mortality	Mixed linear regression	Treatment, parity group, treatment × parity group[a]	Replicate	Adjusted number of live-born piglets post fostering	Arcsine square root
Placental parameters					
Placental surface area	Mixed linear regression	Treatment	Replicate	Total litter size, piglet birth weight	Square root
Areolae density	Mixed linear regression	Treatment	Replicate	Total litter size, piglet birth weight	Non-transformed
Total areolae number	Mixed linear regression	Treatment	Replicate	Total litter size, piglet birth weight	Square root
Placental weight	Mixed linear regression	Treatment	Replicate	Total litter size, piglet birth weight	Square root
Placental efficiency	Mixed linear regression	Treatment	Replicate	Total litter size	Square root
Placental vascularization	Poisson regression	Treatment	Replicate	Total litter size, piglet birth weight	Non-transformed
Piglet viability					
Farrowing duration	Mixed linear regression	Treatment	Replicate	Total litter size, piglet birth weight	Log
Farrowing duration/piglet	Mixed linear regression	Treatment	Replicate	Total litter size, piglet birth weight	Log
Piglet latency to stand	Mixed linear regression	Treatment	Replicate	Farrowing duration, farrowing duration/piglet, total litter size, piglet birth weight	Square root
Piglet latency to reach the teat	Mixed linear regression	Treatment	Replicate	Farrowing duration, farrowing duration/piglet, total litter size, piglet birth weight	Log

Note: PI, ponderal index; BMI, body mass index. [a]effect removed from the final model due to being non-significant.

and no interactive effect of treatment and parity group on PI and BMI. Parity group tended to affect live-born piglet mortality, with sows from the old parity group tending to have a higher proportion of dead piglets than young or mid sows, which did not differ (Young: 0.11 ± 0.02, Mid: 0.11 ± 0.01, Old: 0.15 ± 0.03; mean ± SEM; $F_{[2,159]} = 2.45$, $P = 0.089$).

Placental parameters and piglet viability

Placental development variables (Table S2), such as placental surface area, areolae density, total number of areolae, placental weight, placental efficiency, and placental vascularization did not differ between treatments. Similarly, piglet viability measures (Table S3) such as farrowing duration, farrowing duration per piglet, latency to stand, and latency to reach the teat were not significantly different across treatments.

Discussion

In the current study, the effects of providing periodic exercise to pregnant stall-housed sows on sow reproductive performance, placental characteristics, and piglet viability measures were investigated. Out of 17 investigated parameters (seven of them were related to sow performance, six to placental characteristics, and four to piglet viability) only two

Fig. 2. Total born (mean number of piglets ± SEM) for sows, stall-housed throughout the gestation (Control, $n = 53$), stall-housed sows exercised for 10 min once per week (Exercise, $n = 57$) and sows housed in groups from insemination to farrowing (Group, $n = 58$), belonging to young (parity 0–1; $n = 49$), mid (parity 2–4, $n = 95$), and old (parity 5–7, $n = 24$) parity groups. Brackets connect treatments with differences, $^*P < 0.05$.

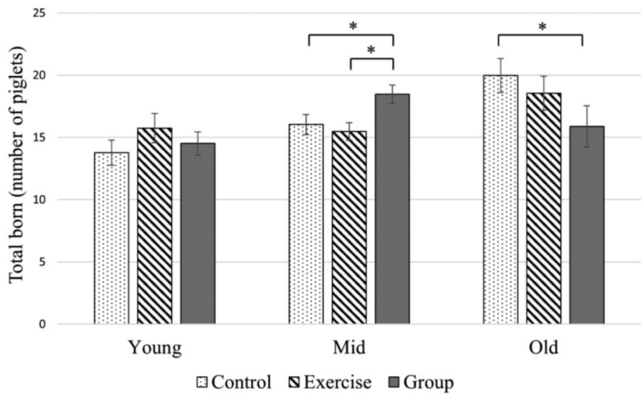
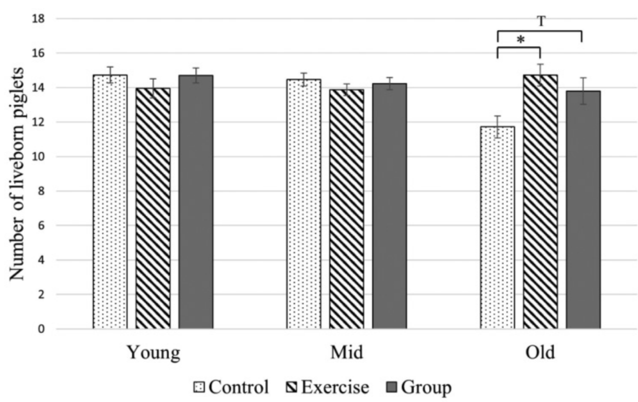


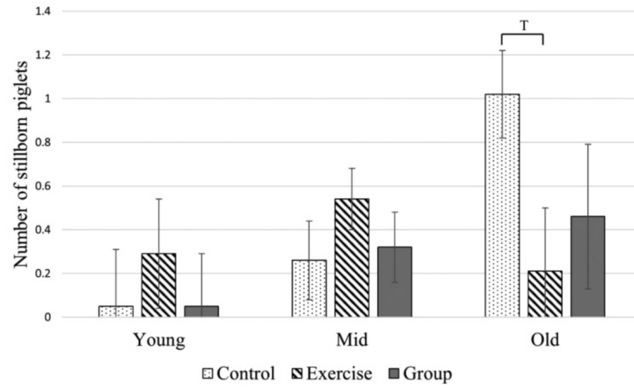
Fig. 3. Number of live-born piglets (mean ± SEM) for sows stall-housed throughout the gestation (Control, $n = 53$), stall-housed sows exercised for 10 min once per week (Exercise, $n = 57$) and sows housed in groups from insemination to farrowing (Group, $n = 58$), belonging to young (parity 0–1; $n = 49$), mid (parity 2–4, $n = 95$), and old (parity 5–7, $n = 24$) parity groups. Brackets connect treatments with differences, $^*P < 0.05$; T: tendency, $P = 0.067$.



significant findings were obtained, and both were related to older sows (total born and number of live-born piglets). Additionally, in the mid parity group, periodically exercised sows were not different to control sows in terms of their litter size, and both had smaller litters than group-housed sows. These finding suggests that periodic exercise may not be suited to improve litter size in the most common age group of sows, and the results obtained from the old parity group need to be interpreted with caution as this group included the lowest number of animals in comparison to young and mid parity groups.

In terms of sow welfare, providing periodic exercise offers relatively limited benefits in comparison to group hous-

Fig. 4. Number of stillborn piglets (mean ± SEM) for sows stall-housed throughout the gestation (Control, $n = 53$), stall-housed sows exercised for 10 min once per week (Exercise, $n = 57$) and sows housed in groups from insemination to farrowing (Group, $n = 58$), belonging to young (parity 0–1; $n = 49$), mid (parity 2–4, $n = 95$), and old (parity 5–7, $n = 24$) parity groups. Brackets connect treatments with differences, T: tendency, $P = 0.069$.



ing. For example, periodic exercise cannot meet sow needs for control over their environment and being able to select the duration, location, and frequency of exercising. Additionally, opportunities to perform social behaviour in periodically exercised sows remain limited. A transition to group housing addresses concerns over limited free movement and restricted social contact.

Providing exercise to gestating sows for 10 min once per week rather than transition to group housing systems would bring not only welfare implications, but also practical difficulties. Exercising sows for 10 min per week showed that a herd with 550 gestating sows would require approximately 92 h of additional labour per week. Modelling the economic consequences of this additional labour, providing periodic exercise to sows would increase the cost of production by $2.00 per hog produced to slaughter (Tokareva et al. 2020). However, if exercise was provided only to parity 5 and older sows, assuming that they represent 26.5% of the herd, it would actually decrease the overall cost of production by $0.16. However, this approach would ignore welfare implications for young and mid parity sows, and selectively providing a greater freedom of movement was not intended by the Code of Practice requirement. Additionally, exercising older sows in commercial barns might take more than 10 min per sow per week; older sows might have locomotory problems that additionally make it not always feasible to move them. For further research, it could be more beneficial to use a significantly larger sample size with similar numbers of sows in all parity groups for all investigated parameters, or to focus the study on mid parity sows that represent the highest proportion of sows in commercial herds.

Providing stall-housed sows with access to a low level of exercise once per week throughout gestation affected mainly the reproductive performance of older parity sows, increasing live-born and tending to reduce stillborns, and also affected the total litter size, which suggests that freedom of movement plays a role in sow reproductive performance. Sows housed in groups, on the one hand, showed similar benefits that could be explained by having access to exercise in group housing system. On the other hand, the observed benefits could also be due to other positive aspects of group housing, such as having control over their environment and improved social behaviour. Previous research suggests that sows in groups that have control over their environment may voluntarily receive more exercise than sows that were periodically exercised in the current study. Marchant-Forde and Marchant-Forde (2004) reported that pregnant gilts housed in straw-bedded group pens spent approximately 5% of their time walking in the first week of gestation, with the percentage of time spent walking decreasing over the following 9 weeks and remaining around 2% for the last 6 weeks of gestation. These results correspond to 72 min and 29 min of walking daily, accordingly. Assuming that the average walking speed of gilts in the study of Marchant-Forde and Marchant-Forde (2004) corresponded to the speed of sows in the current study (160 m/10 min), it can be estimated that daily travel distance for those gilts was between 464 m and 1152 m, or from 3248 m to 8064 m weekly. Similar estimated daily travel distances (between 400 m and 800 m) were reported by Schenck et al. (2008) for multiparous gestating sows housed in groups at different stocking densities. Attaining this level of exercise in stall-housed sows and having sows walk a distance of 3248 m would require over 3 h of labour per sows each week. This could not be achievable in commercial practice and illustrates further that group housing is a much better approach to providing freedom of movement.

The productivity results presented for the group-housed sows in the current study have been found repeatedly in previous literature: group-housed sows were found to have a higher number of live-born piglets and a greater total litter size in comparison to the sows housed in stalls during gestation (Seguin et al. 2006; Lammers et al. 2007; Tan 2015). In contrast, group-housed sows were found to have fewer stillborns than stall-housed sows (Lammers et al. 2007; Weng et al. 2009; Chapinal et al. 2010; Brown 2015). Schenck et al. (2008) showed that stall-housed gilts receiving periodic exercise at levels higher than those used in the current study did not demonstrate any difference in the total litter size and numbers of live-born and stillborn piglets in comparison to gilts, stall-housed throughout gestation, which is in agreement with the results of the current study for the young parity group.

There are a few possible explanations for improved productivity in sows receiving exercise. For example, the increase in the number of live-born piglets and decrease in the number of stillborn piglets in sows having access to a greater freedom of movement could be related to higher muscular weight (Marchant and Broom 1996*a*) and improved cardiovascular fitness (Marchant et al. 1997) in these animals. These parameters were previously demonstrated to reduce the farrowing duration and piglet birth interval (Ferkett and Hacker 1985; Fraser et al. 1997), which could decrease the incidence of neonatal asphyxia and result in higher piglet survival (Lammers et al. 2007). However, in the current study, sows from different treatments did not differ in the duration of parturition and farrowing duration per piglet; hence, the physiological mechanisms that could result in changes to reproductive performance were not revealed.

The lack of impact of the level of access to a greater freedom of movement on piglet mortality is in agreement with the results of Harris et al. (2006), who did not find any difference in piglet mortality between gilts stall-housed throughout gestation and gilts housed in small groups. In contrast, Anil et al. (2005) reported a significantly lower piglet mortality rate in sows housed in group pens with electronic sow feeders (ESF) in comparison to stall-housed sows. Karlen et al. (2007) also reported a higher number of piglets weaned from sows group-housed on deep litter in comparison to sows housed in conventional stalls. Similarly, Schenck et al. (2008) reported higher piglet mortality in stall-housed gilts compared to gilts that received exercise 5 days per week at low (610 m per week) and high (1525 m per week) levels. The abovementioned findings could be associated with the decreased time taken to lie down by exercised sows, which could reduce the chance of piglets moving under the sow after the onset of the descent of her body to the ground (Marchant and Broom 1996*b*). This effect could be observed due to improved sow mobility resulting in more controlled posture changes linked to increased overall fitness and hence more muscle control as the result of exercise (Harris et al. 2013). The levels of exercise used in the current study were much lower in terms of both frequency and duration than in the study of Schenck et al. (2008) and lower than the levels of exercise accessible to group-housed sows. The levels of exercise received by group-housed sows have been shown to be greater than when sows were given forced exercise in the maximum exercise treatment in the same study of Schenck et al. (2008), which might be a reason of the lack of observed differences between treatments.

Such measures of piglet viability, as farrowing duration, farrowing duration per piglet, piglet latency to stand, and piglet latency to reach the teat were not influenced by sow gestation treatment in the current study, which is in agreement with the study of Harris et al. (2013), who reported no differences in piglet birth interval and the length of parturition across stall-housed throughout gestation and exercised gilts. These results were obtained possibly because the levels of exercise received by periodically exercised and group-housed sows in the current study and in the study of Harris et al. (2013) were not sufficient to measurably improve farrowing kinetics through enhancing uterine and overall muscular fitness. Given that both piglet birth weight and piglet vigour were identified as crucial survival factors in previous literature (Baxter et al. 2008), piglet vigour results are in agreement with piglet birth weight results in the current study and suggest that piglets from all treatments had similar survivability.

Piglet birth weight did not differ across treatments, which is consistent with previously reported findings for stall-housed sows compared to periodically exercised sows (Schenck et al. 2008; Harris et al. 2013) and sows housed in groups (Broom et al. 1995; Salak-Johnson et al. 2007).

Although the presence of intrauterine crowding leading to intrauterine growth restriction (IUGR) is expected in multiparous species, there was no IUGR effect observed in the current study, based on the values of piglet PIs and BMIs. Low PIs and BMIs are considered to be indicators of severe IUGR and lower piglet survivability (Amdi et al. 2013). However, in the current study these indices did not differ across treatments, and the obtained values of BMI were higher than those defined as indicative of mild IUGR in the study of Amdi et al. (2013). Based on this information, it can be concluded that the observed increase in litter size in older sows due to providing a greater freedom of movement at the levels used in this study did not cause IUGR.

In the current study, no differences in placental traits between treatments were observed. Previous human medical research suggests that exercise has positive effects on fetoplacental growth resulting in faster placental development that improves the placental function (Clapp et al. 2000). One of the main functions of the placenta is delivering nutrients to the developing fetus, and this function is largely determined by the size of the placenta (its weight and surface area), placental efficiency, and level of placental blood supply (van Rens et al. 2005). Placental efficiency has previously been shown to be positively correlated with placental and endometrial RNA content, placental protein content, and endometrial RNA to DNA ratio, indicating cellular transcriptional activity potentially related to increased nutrient uptake or angiogenesis (Wilmoth et al. 2011). Additionally, areolae density and the total number of areolae were demonstrated to be important indicators of piglet prenatal and postnatal survival (Baxter et al. 2008).

The placental results obtained in the current study might be due to a few reasons: first, the levels of exercise applied in the current study could be too low to influence placental parameters. Second, the sample size might have been too small to detect potentially small differences. Additionally, there is a possibility that measurements of areolae density were unable to fully distinguish all areolae in the maternal–fetal interface due to the macroscopic nature of the analysis. A larger sample size and focusing on group-housed sows receiving unlimited access to exercise, as well as collecting additional measures might be needed to demonstrate the mechanisms by which providing a greater freedom of movement can impact placental development.

Our findings suggest that providing pregnant sows with 10 min of exercise once a week did not bring any measurable benefits in terms of placental development and farrowing kinetics in comparison to sows housed in group settings and stalls. Periodic exercise did not improve most of the investigated parameters, only more live born piglets were found in periodically exercised and group-housed older parity sows compared to older parity control sows; therefore, periodic exercise cannot be recommended.

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Data availability

Dr. Yolande Seddon (yolande.seddon@usask.ca) and Dr. Mariia Tokareva (mariia.tokareva@usask.ca) have access to the primary research data. Please contact Dr. Seddon or Dr. Tokareva to access the data.

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Competing interests

The authors declare there are no competing interests.

Supplementary material

Supplementary data are available with the article at https://doi.org/10.1139/cjas-2021-0087.

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