Title: Providing humane on-farm handling tools to move non-ambulatory grow-finish pigs – **#17-030 IPPA**

Investigator: Dr. A. Johnson

Institution: Iowa State University

Date Submitted: May 1, 2019

Industry Summary:

The National Pork Board (NPB) provides swine handling recommendations and humane handling tools to move both ambulatory and non-ambulatory pigs through their Pork Quality Assurance program (PQA) and Transport Quality Assurance program (TQA; NPB, 2016, 2017). Building on these educational programs, the Common Swine Industry Audit (CSIA) requires for humane handling under Willful Acts of Abuse or Neglect; Movement of non-ambulatory pigs. The CSIA specifically notes, "*Dragging of conscious animals by any part of their body except in the rare case where a non-ambulatory animal must be moved for a life threatening situation. Non-ambulatory pigs may be moved by using a drag mat* (NPB, 2019)." If an auditor witnesses a concious non-ambulatory pig being dragged by any body part, the farm will automatically fail the audit (Johnson et al., 2013). There is limited scientific knowledge in the literature that provides producers with effective handling tools for moving a non-ambulatory grow-finish pig on-farm that accounts for caretaker safety and pig welfare. Two objectives were defined to meet this goal: 1) determine durability, caretaker physiology, movement ease, overall time, and caretaker preference for sked, deer sled, modified deer sled, and wean-to-finish mat when moving 18 grow-finish pig cadavers on-farm, 2) evaluate durability, pig physiology and behavior, and overall time for the sked, revised deer sled, and ice fishing sled when moving 18 non-ambulatory grow-finish pigs on-farm.

Our results from this project showed:

- This modified wean-to-finish mat is not a suitable handling tool for manually moving grow-finish pig cadavers and we suggest that it will also not be suitable for moving non-ambulatory grow-finish pigs on a commercial farm
- This modified deer sled is not a suitable handling tool for manually moving grow-finish pig cadavers and we suggest that it will also not be suitable for moving non-ambulatory grow-finish pigs on a commercial farm
- This version of the sked and deer sled are suitable handling tools for manually moving grow-finish pig cadavers on a commercial farm
- This version of the sked, revised deer sled and ice fishing sled are suitable handling tools for manually moving non-ambulatory grow-finish pigs on a commercial farm

Keywords: Audits, caretakers, handling tools, non-ambulatory grow-finish pigs, welfare

Scientific Abstract:

Through the National Pork Board, the U.S. pork industry provides recommendations on humane handling tools and acceptable non-ambulatory pig handling. While these recommendations are useful, there is a lack of published evidence regarding humane handling tool options for moving non-ambulatory pigs. The objectives of this proposal were to (1) to evaluate four handling tools to move grow-finish pig cadavers and (2) to evaluate the most promising handling tools from objective one using non-ambulatory grow-finish pigs.

Objective One: To evaluate four handling tools to move grow-finish pig cadavers

Phase one: A wean-to-finish mat was modified to 1.8 m length x 60.9 cm width. Six caretakers were asked to move three commercial crossbred pigs (135, 118, 68 kg) that were selected from the hospital pen and euthanized according to company protocols, which were consistent with industry guidelines. Two empty pens were designated as the start (home pen) and end (hospital pen), corresponding to distance that a non-ambulatory pig would need to be humanely moved on a commercial farm. Outcomes included duration to move pig cadavers, differences in caretaker heart rate (bpm) and oxygen saturation (%), and caretakers' subjective effort score (1 = very difficult to 5 = very easy). Data were analyzed using a mixed model method (PROC MIXED) for parametric data. Employee was the experimental unit. The statistical design was a complete randomized design with the statistical model including the fixed effect of employee (n = 6) and cadaver (n = 3). Time to move the cadaver onto the MAT did not differ between

employees (*P* = .87) or cadavers (*P* = .30). No employee was able to complete the entire task, such that none of the cadavers were moved into the hospital pen using the MAT. Only one employee was able to move all cadavers into the alleyway (37.3 ± 12.7 s); two employees were able to move the heavier and lighter cadaver into the alleyway (68 kg: 11 ± 5.7 s; 135 kg: 39.5 ± 34.6 s). Force was measured only once and at the furthest location reached for each cadaver task. Employees did not differ for force used (*P* = .40). Less force was used for the lightest cadaver (68 kg: 88.5 ± 8.7 kgf; 118 kg: 145.6 ± 8.7 kgf; 135 kg: 165.2 ± 8.7 kgf; *P* = .0003). Employees did not differ in heart rate or oxygen saturation (*P* ≥ .05). Similarly, heart rate and oxygen saturation did not differ between employees moving cadavers (*P* > .05). Employees agreed that moving the MAT in the home pen was very difficult, and the three employees who were able to move the MAT out of the pen into alley scored it as very difficult even with the lightest cadaver. Even though very durable, all employees felt strongly that the MAT would not easily move a non-ambulatory market-weight pig and would not recommend this MAT to other employees for moving a non-ambulatory market-weight pig.

Phase two: Three skeds were purchased and modified to each have final dimension of 1.9 m length x 91.4 cm width. Three deer sleds were not modified, but each had dimensions of 1.8 m length × 91.8 cm width. Three modified deer sleds were modified to each have final dimensions of 1.8 m length × 50.8 cm width. Four caretakers were asked to move fifteen commercial crossbred pig cadavers (59 to 134 kg) that were selected from the hospital pen and euthanized according to company protocols, which were consistent with industry guidelines. Two empty pens were designated as the start (home pen) and end (hospital pen), corresponding to distance that a non-ambulatory pig would need to be humanely moved on a commercial farm. The same outcomes from phase one were collected. Data were analyzed using mixed model methods (PROC MIXED) for parametric data. The statistical design was a complete randomized design with the statistical model including the fixed effect of employee (n = 4), handling tool (n = 3) and farm (n = 3) with cadaver (kg) as a linear covariate. Employee within farm was included as a random effect in the model. Total duration was affected by handling tool and farm (*P* < .001). Total duration was affected by cadaver, such that 0.64 s increase occurred with each one kg increase in weight (*P* < .0001). Modified deer sled was quicker to move than sked and deer sled (*P* < .0001). Employee was not a source of variation (*P* = .24). Exertion force at the end of the alley was affected by handling tool, farm and cadaver, such that 0.23 kgf increase occurred with each one kg increase in weight (*P* < .01). More force was required to move cadavers on sked then deer sled or modified deer sled. Employee was not a significant source of variation (*P* = .38). Change in heart rate after moving the cadaver from home- to hospital pen was affected by the handling tool used (P = .04). Change in heart rate was greater with sked than modified deer sled (*P* = .01); deer sled did not differ from sked or modified deer sled. Change in heart rate was affected by cadaver, such that 0.22 bpm increase occurred with one kg change in cadaver weight ($P < .0001$). Employee and farm were not sources of variation ($P > .05$). Change in oxygen saturation after moving the cadaver from home pen to hospital pen was not affected by handling tool, cadaver weight, employee, or farm ($P > .05$). The sked was the most durable with only a rip and crease and the deer sled was the least durable with multiple creases and holes. Overall, employees recommended the sked and deer sled as suitable handling tools to move non-ambulatory pigs, whereas the modified deer sled would not be recommended as a suitable handling tool due to no-restraints.

Objective two: To evaluate the most promising handling tools from objective one using non-ambulatory grow-finish pigs

Phase three: Three handling tools (sked, revised deer sled and ice fishing sled) were evaluated as suitable handling tools to move non-ambulatory grow-finish pigs. The sked was modified to have a final dimension of 1.9 m length x 91.4 cm width. The revised deer sled was modified to affix restraint straps and a polypropylene rope for a handle with final dimension of 1.8 m length × 91.8 cm width. The ice fishing sled was modified to affix restraint straps and a polypropylene rope for a handle with final dimension of 109 cm length x 58 cm width x 27 cm height. 18 commercial crossbred genetic line pigs (average BW of 99.9 ± 25.3 kg) were randomly assigned to one handling tool. Two empty pens were designated as the start (home pen) and end (hospital pen), corresponding to distance that a non-ambulatory pig would need to be humanely moved on a commercial farm. Each pig was moved to the start pen. A lidocaine epidural block was administered to each pig in order to induce a non-ambulatory state. Once confirmed non-ambulatory by a swine veterinarian, two production well-being employees positioned the pig onto the handling tool and moved them. Outcomes included duration to move from start- to end pen (s) that covered a distance of 20.6 m, change in pig temperature (ºC), taken with an Infrared gun on the ventral plane, pig respiration rate (bpm), pig vocalization score (0 = none to 2 = continuous grunts/calls) and struggle score (0 = none to 2 = continuous movement of legs and/or head). Change in pig temperature- and respiration rate and handling tool duration data were analyzed using mixed model methods (PROC MIXED) for parametric data with fixed effect of farm (n = 1), handling tool (n = 3), and sex of pig (M/F) with pig weight (kg) as a linear covariate. Pig vocalization and struggle score data were analyzed using PROC FREQUENCY and CHI SQUARE to observe the distribution of vocalization and struggle scores by handling tool. Total duration was affected by pig weight ($P = 0.014$). Handling tool and sex were not sources of variation ($P > 0.10$). There were no associations between handling tools and pig vocalization and struggle scores when moving non-ambulatory pig from home pen floor onto the handling tool, securing pig onto the handling tool, and moving the handling tool and pig from start pen to end pen ($P > 0.10$). Change in pig temperature (ºC) and respiration rate (bpm) was not affected by handling tool, sex or pig weight ($P > .05$). The ice fishing sled was the most durable with no creases, rips or holes. The sked and deer sled both had a total of two creases.

In conclusion, the modified wean-to-finish mat and modified deer sled are not suitable handling tools for moving non-ambulatory grow-finish pigs. Whereas, the sked, deer sled, revised deer sled and ice fishing sled are suitable handling tools for moving non-ambulatory grow-finish pigs' on-farm.

Introduction:

The National Pork Board (NPB) provides guidance about humane swine handling through the Pork Quality Assurance Plus (PQA) and Transport Quality Assurance programs (TQA; NPB, 2016, 2017). Building on these educational programs, the Common Swine Industry Audit (CSIA) was designed as an assurance program to meet company and customer needs (NPB, 2019), and includes requirements for humane swine handling. Willful acts of abuse and neglect are strictly prohibited critical elements of the CSIA, that can result in automatic audit failure as described "*[d]ragging of conscious animals by any part of their body except in the rare case where a non-ambulatory animal must be moved for a life threatening situation. Non-ambulatory pigs may be moved by using a drag mat* (NPB, 2019)". This audit point has provoked discussion among swine extension agents, producers and veterinarians. Discussion has included, what defines a "life-threatening" situation? Would an auditor and the producer agree on life threatening? If moved, is it in compliance with CSIA? Do drag mats work? Preliminary work concluded that a rubber farrowing mat was unsatisfactory as a drag mat for finisher pigs because it was too heavy, the pig kept sliding off and it tore very easily. These findings suggest there is an opportunity to identify other handling tools that consider practical logistics, worker safety and non-ambulatory market-weight pig welfare. Non-ambulatory pigs can occur on-farm due to injury, illness or fatigue during day-to-day operations and during loading and unloading from transport trailers. Hence, employees may be required to move non-ambulatory pigs into or out of pens, alleys and load out areas. To ensure pig and caretaker safety, it is important to have facilities with wide enough alleys and pen openings, appropriate and durable handling equipment, and correctly trained employees (Doonan et al 2003).

References:

Doonan G, Appelt M, and Corbin A. 2003. Non-ambulatory livestock transport: The need for consensus. *Canadian Veterinary Journal 44*: 667-672.

Johnson AK, Gesing LM, Ellis M, McGlone JJ, and Berg E. 2013. Farm and pig factors affecting welfare

during the marketing process. *Journal of Animal Science* 91: 2481-2491.
NPB. National Pork Board. 2016. Pork Quality Assurance Plus. Version 3 Handbook. Available at: https://d3fns0a45gcg1a.cloudfront.net/sites/all/files/documents/PQAPlus/V3.0/BinderMaterial/Tab%202/1%20PQAhandbook.pdf. Accessed 1 January 2018.
NPB. National Pork Board. 2017. Transport Quality Assurance. Version 6 Handbook. Available at: https://d3fns0a45gcg1a.cloudfront.net/sites/all/files/documents/TQA/2017-Version6/TQA.V6_Handbook.pdf. Accessed 14 September 2017.
NPB. National Pork Board. 2019. Common Swine Industry Audit. Available at: http://d3fns0a45gcg1a.cloudfront.net/sites/all/files/documents/CommonSwineIndustryAudit/CSIA-English.pdf. Accessed 5 February 2019.

Objectives:

1) To evaluate three handling tools to move non-ambulatory market pigs.
2) To evaluate three handling tools to move conscious non-ambulatory market weight pigs during pre-sort and load out under commercial conditions in terms of pig welfare handling efficiency and worker safety.

Materials & Methods:

Objective One: To evaluate four handling tools to move grow-finish pig cadavers

Phase One and Two

All research was approved by Iowa State University Institutional Review Board for Humans Subject Research (Approval #18-003). Due to ethical considerations, on-farm testing was accomplished using pig cadavers; Institutional Animal Care and Use Committee approval was not needed.

Phase One: Wean-to-finish mat

Wean-to-finish mat and modifications

Four wean-to-finish mats were purchased from Hog Slat (SKU: 544187F, Humboldt, IA, USA). The mats weighed 23.1 kg, measured 1.8 m length x 1.2 m width x 1.3 cm depth, and were made of Nyracord rubber. Modifications were performed to reduce mat width, improve stability and to affix handles to create a modified wean-to-finish mat. These modifications took approximately 45 min to complete for each mat. Modifications consisted of cutting a mat down its length to produce two separate drag mats. To add stability to each wean-to-finish mat, two PVC trim boards (55.9 cm length x 8.9 cm width x 2.5 cm height) were centered and attached 12.7 cm from the top of the mat on the upper and lower surfaces. The

PVC trim boards were affixed using two carriage bolts (1.3 x 7.6 cm), flat washers (1.3 cm), and hex nuts (1.3 cm-13 thread size) and four exterior wood screws (8 x 5.1 cm) were drilled into the PVC trim boards. To affix handles two holes were drilled into the PVC trim boards and a 2.7 m polypropylene rope was inserted and knotted on the upper surface. The final modified wean-to-finish mat (MAT) dimensions were 1.8 m length x 60.9 cm width (Table 1).

Table 1. Before and after wean-to-finish mat modifications

Before	**After**
1.8 m length x 60.9 cm width	**1.8 m length x 1.2 m width**
	

Animals, facilities and pig cadaver tasks

The study was conducted on a commercial grow-finish site in Central Iowa. Three commercial crossbred pigs were selected from the hospital pen by the company veterinarian and euthanized according to company protocols, which were consistent with industry guidelines (AASV, 2016). Prior to euthanasia, body weights were collected using a weigh scale (Raytec WayPig 300; AGRIsales Inc., Ceresco, NE) and rounded up to whole numbers; pig cadavers weighed 68 kg, 118 kg and 135 kg. For the pig cadaver tasks, two empty pens were designated as the start (home pen) and end (hospital pen), corresponding to distance that a non-ambulatory pig would need to be humanely moved on a typical commercial farm. The pens were fully slatted (slat width 12.7 cm × slot width 2.5 cm). The distance between the home pen and hospital pen was 57.9 m, and was comprised of partially slatted with a concrete center (115.8 m × 30.3 cm) alley. Each pig cadaver was positioned inside the home pen, 2.8 m from the alleyway gate, 2.3 m in from the right pen divider and oriented with the head towards the alleyway. At the start of each pig cadaver task, the employee was asked to roll the pig cadaver onto the MAT and move it from home pen to hospital pen. For all employees, the cadaver tasks were performed using the heaviest to the lightest pig cadavers.

Employee enrollment

One female and five males were enrolled in the study by the company veterinarian. On the study day, each employee was asked to complete a demographics questionnaire in the farm office before completing the cadaver tasks using the MAT. From the surveys, employees ranged from 23 to 30 years old, weighed 160.2 to 195.6 cm, height 64.5 to 133.8 kg and had 1 to 20 years of on-farm experience. The six English-speaking employees were members of the production well-being team, the engineering team and the farm manager.

Peak exertion force and duration of cadaver tasks

A FGV-HXY High Capacity Digital Force Gauge (Nidec-SHIMPO America Corporation, Itasca, IL, USA) was attached to the MAT handle to record force (kgf) applied by the employee while moving the cadaver. Each employee held his or her arms with the force gauge positioned at waist height and pulled for five continuous seconds. Peak exertion force was performed in two locations (1) in the alleyway immediately outside the home pen and (2) inside the hospital pen. Time to complete pig cadaver tasks was measured at three time points (s): 1) Duration to roll pig cadaver from home pen floor onto the MAT. 2) Duration to move MAT and pig cadaver from home pen into alleyway, defined as the MAT being entirely inside the alley and oriented towards the hospital pen. 3) Duration to move MAT and pig cadaver along the alleyway and into the hospital pen, defined as MAT being entirely inside the hospital pen.

Employee physiologic measures

One researcher collected each employee's physiologic measures at two different time points: (1) baseline resting levels in the home pen and (2) post exertion levels collected immediately after moving each cadaver. A pulse oximeter (Pulse Oximeter 50DL; Clinical Guard, Atlanta, GA, USA) was placed onto the employee's index finger to collect heart rate (bpm) and oxygen saturation (%). Consistent with other studies (Berkeley Wellness, 2010; Dray, 2017), a minimum 5-min resting period was enforced between each cadaver task to allow physiologic measures to return to baseline levels.

Employee MAT tool evaluation and durability

During each resting period, employees were asked to complete a survey which evaluated the MAT. The MAT was moved three times per employee resulting in 18 completed surveys. Comments were also solicited for each question to collect qualitative data. Durability of the MAT was evaluated by one researcher for presence of holes, rips and creases at the conclusion of each pig cadaver task. If observed, these were counted, measured (cm) and photographed.

Statistical Analysis

The handling tool survey was evaluated by simple means and standard deviation of six employees. Whereas, handling tool durability was evaluated by counting and measuring holes, rips and creases after movement from home pen to hospital pen. Two new variables were created for employee heart rate and oxygen saturation;

Change in employee heart rate (bpm) = hospital pen heart rate – baseline resting heart rate

Change in employee oxygen saturation (%) = hospital pen post exertion oxygen saturation – baseline resting oxygen saturation

The distribution of the peak exertion force, duration, change in employee heart rate- and oxygen saturation data were evaluated using the PROC UNIVARIATE procedure (SAS v 9.2, SAS Inst., Inc., Cary, NC). Data met the assumption of normality and were analyzed using a mixed model method (PROC MIXED) for parametric data. Employee was the experimental unit. The statistical design was a complete randomized design with the statistical model including the fixed effect of employee (n = 6) and pig cadaver (n = 3). A $P \leq .05$ was considered significant and PDIFF option was used to separate means when fixed effects were significant sources of variation.

Results

Peak Exertion force and duration of cadaver tasks

Since employees were unable to move pig cadavers into the hospital pen, peak force was measured only once and at the furthest location reached for each pig cadaver task. Employees did not differ for peak force used (P = .40). Average peak exertion force (±SE) was 60.4 ± 14.2 kgf, and ranged from 36.5 to 85.2 kgf. Less force was used for the lightest cadaver (68 kg: 88.5 ± 8.7 kgf; 118 kg: 145.6 ± 8.7 kgf; 135 kg: 165.2 ± 8.7 kgf; P = .0003). Time to move the pig cadaver onto the MAT did not differ between employees (P = .87) or pig cadavers (P = .30). Average duration (range) to move pig cadavers onto MAT was 5.7 ± 4.6 s (2 to 13 s; 135 kg), 7.5 ± 3.6 s (3 to 13 s; 118 kg) and 3.7 ± 1.9 s (2 to 7 s; 68 kg). No employee was able to complete the entire task, such that none of the pig cadavers were moved into the hospital pen using the MAT. The average duration for failed attempts was 9.0 s. Only one employee was able to move all pig cadavers into the alleyway (37.3 ± 12.7 s); two employees were able to move the heavier and lighter cadaver into the alleyway (68 kg: 11 ± 5.7 s; 135 kg: 39.5 ± 34.6 s).

Employee physiologic measures

Employees did not differ in heart rate or oxygen saturation ($P \geq .05$). Similarly, heart rate and oxygen saturation did not differ between employees moving pig cadavers ($P > .05$). Average duration (range) for change in employee heart rate was 49.0 ± 13.1 bpm (35 to 71 bpm; 135 kg), 38.8 ± 12.7 bpm (19 to 53 bpm; 118 kg), and 39.5 ± 8.8 bpm (29 to 52 bpm; 68 kg). Change in employee oxygen saturation was 0.8 ± 1.3 % (0 to 3 %; 135 kg), -0.5 ± 1.0 % (-2 to 1 %; 118 kg), and -0.2 ± 0.75 % (-1 to 1 %; 68 kg).

Employee MAT tool evaluation and durability

Employees agreed that moving the MAT in the home pen was very difficult, and the three employees who were able to move the MAT out of the pen into alley scored it as very difficult even with the lightest pig cadaver. Employees commented that the MAT was stiff and lacked movement ease. These comments support the researchers' casual observations of employee frustration during their performance of the pig cadaver tasks. Rolling pig cadavers onto the MAT was ranked as neutral or easy in 9 of 18 surveys (50.0%). In the home pen, positioning pig cadavers onto the MAT was ranked as easy (72.2%). In the alley, repositioning pig cadavers onto the MAT was ranked as neutral (31.3%) or difficult (31.3%). Three employees ranked the MAT size as difficult, and commented that the MAT was awkward to carry throughout the barn and was a little too wide to fit in the alley (two employees). All employees ranked the MAT weight as difficult or very difficult and commented that the MAT itself was too heavy to move, a problem that increased with the addition of a pig cadaver (three employees). All employees felt strongly that the MAT would not easily move a non-ambulatory market-weight pig and would not recommend this MAT to other employees for moving a non-ambulatory market-weight pig.

Discussion:

Field expertise associated with moving non-ambulatory pigs has resulted in several guidance documents. The American Meat Institute (Grandin and AMI, 2013) recommends using slide boards, sleds and cripple carts to move non-ambulatory pigs within meat processing plants. Similarly, the Transport Quality

Assurance program (NPB, 2017) recommends stretchers, sleds, hand carts and specialized skid loaders for moving non-ambulatory pigs. When non-ambulatory pigs occur on farms, the Pork Quality Assurance Plus program (NPB, 2016) recommends using plastic sleds or drag mats. There are no other science-based publications validating different handling tool options for moving non-ambulatory pigs. It is important to test potential on-farm handling tools for ease of use, employee safety (Hill et al., 2007) and pig welfare (Ritter et al., 2009; Johnson et al., 2013). A positive of this mat was the durability during the moving tasks and the cost to buy and modify (approx. $100). A pitfall with this mat was its starting weight. A lighter mat (e.g., a polyethylene wean-to-finish mat weighing 7.7 kg). Different modifications to this wean-to-finish mat could improve movement ease, for example adding a surface on the underside of the mat that reduces friction and adding buckle restraint straps to keep the pig secure. Therefore, other mats could be a better option and should be investigated

References

AASV. American Association of Swine Veterinarians. On-Farm Euthanasia of Swine: Recommendations for the Producers. 2016. Available at: https://www.aasv.org/documents/2016EuthRec-EN.pdf. Accessed 25 September 2018.

Berkeley Wellness. Your Heart Beat and Your Health. 2010. Available at: http://www.berkeleywellness.com/fitness/exercise/article/your-heart-beat-and-your-health. Accessed 17 June 2018.

Dray T. How Long After Working Out Does Your Heart Rate Return to Base? 2017. Available at: https://www.livestrong.com/article/448974-how-long-after-working-out-does-your-heart-rate-return-to-base/. Accessed 15 June 2018.

Grandin T and American Meat Institute Animal Welfare Committee. Recommended Animal Handling Guidelines & Audit Guide: A Systematic Approach to Animal Welfare. Rev 1. 2013;1-121.

Hill J, Berry N, and Johnson AK. Handling and loadout of the finisher pig. Available at: http://porkgateway.org/resource/handling-and-loadout-of-the-finisher-pig/. Pork Information Gateway Factsheet. Published April 2007. Accessed 1 January 2018.

Johnson AK, Gesing LM, Ellis M, McGlone JJ, and Berg E. Farm and pig factors affecting welfare during the marketing process. Journal of Animal Science. 2013;91:2481-2491. doi:10.2527/jas.2012-6114.

NPB. National Pork Board. Pork Quality Assurance Plus. 2016. Version 3 Handbook. Available at: https://d3fns0a45gcg1a.cloudfront.net/sites/all/files/documents/PQAPlus/V3.0/BinderMaterial/Tab%202/1%20PQAhandbook.pdf. Accessed 1 January 2018.

NPB. National Pork Board. Transport Quality Assurance. Version 6 Handbook. 2017. Available at: https://d3fns0a45gcg1a.cloudfront.net/sites/all/files/documents/TQA/2017-Version6/TQA.V6_Handbook.pdf. Accessed 14 September 2017.

NPB. National Pork Board. Common Swine Industry Audit. 2019. Available at: http://d3fns0a45gcg1a.cloudfront.net/sites/all/files/documents/CommonSwineIndustryAudit/CSIA-English.pdf. Accessed 5 February 2019.

Ritter MJ, Ellis M, Berry NL, Curtis SE, Anil L, Berg E, Benjamin M, Butler D, Dewey C, Driessen B, DuBois P, Hill JD, Marchant-Forde JN, Matzat P, McGlone J, Mormède P, Moyer T, Pfalzgraf K, Salak-Johnson J, Siemens M, Sterle J, Stull C, Whiting T, Wolter B, Niekamp SR, and Johnson AK. Review: Transport Losses in Market Weight Pigs: I. A Review of Definitions, Incidence, and Economic Impact. Professional Animal Science. 2009;25:404-414.

Phase two: Sked, deer sled and modified deer sled

Materials & Methods:

Handling tools

Three identical skeds were purchased from Skedco (SKU: sk-250, Tualatin, Oregon, USA). The skeds (SKED) weighed 5.0 kg, measured 2.4 m length × 91.4 cm width × 0.3 cm depth, and made of medium-density polyethylene plastic. Modifications were made to reduce the length to make transitioning between the pens and alleyways possible. For each sked, all straps were removed except three 5.08 cm side release plastic buckle restraint straps (5.08 cm width polypropylene straps) used to secure pig cadaver to sked. Across the width on the foot-end, a 31.1 cm line was drawn and a hacksaw was used to cut across the line. The final sked dimensions were 1.9 m length × 91.4 cm width (Table 2).

Three identical Magnum Deer Sleigh'r Game Sleds were purchased from Sportman's Guide (Item Number: 138755, Minneapolis, MN, USA). The deer sleds (SLED) weighed 2 kg, measured 1.8 m length × 91.8 cm width × 0.2 cm depth, and was made of slick polymer. Two strings (1.83 m × 0.76 cm) were provided by the manufacturer to secure the animal to the sled. A handle was created by inserting and knotting a 2.4 m polypropylene rope on the upper surface (Table 2).

Additionally, three identical Magnum Deer Sleigh'r Game Sleds were purchased from Sportman's Guide (Item Number: 138755, Minneapolis, MN, USA). Modifications were made to reduce the width to fit inside alleys. On each deer sled, the final width was 50.8 cm and was achieved by removing 20.3 cm from each side. A handle was created by inserting and knotting a 2.4 m polypropylene rope on the upper surface. The final MDS dimensions were 1.8 m length × 50.8 cm width (Table 2).

Table 2. Handling tools before and after modifications

	Before	
Sked	**Deer sled**	**Modified deer sled**
2.4 m length × 91.4 cm width	1.8 m length × 91.8 cm width	1.8 m length × 91.8 cm width
		
	After	
1.9 m length × 91.4 cm width	1.8 m length × 91.8 cm width	1.8 m length × 50.8 cm width
		

Animals, facilities and pig cadaver tasks

The study was conducted on three commercial grow-finish sites in Central Iowa. Fifteen commercial crossbred pigs were selected from the hospital pen by the company veterinarian and euthanized according to company protocols, which were consistent with industry guidelines (AASV, 2016). Prior to euthanasia, body weights were collected using a weigh scale (Raytec WayPig 300; AGRIsales inc., Ceresco, NE) and rounded up to the nearest tenth; average pig cadaver BW 89.1 ± 5.3 kg. Pig weight determined movement order by handling tool. The weight order was rotated on each farm so a weight class (light, medium, heavy) was never consistently first, second or last. For the pig cadaver tasks, two empty pens were designated as the start (home pen) and end (hospital pen; distance 58.8 m), corresponding to distance that a non-ambulatory pig would need to be humanely moved on a typical commercial farm. Each pig cadaver was positioned inside the home pen 2.9 m from alleyway gate and 2.3 m in from the right pen divider for farm one. 3.5 m from alleyway gate and 2 m in from the right pen divider for farm two. 3.6 m from alleyway gate and 2 m in from the right pen divider for farm three. Pig cadaver was oriented with the head towards the alleyway at all farms. At the start of each pig cadaver task, employee was asked to roll the pig cadaver onto the handling tool (sked, deer sled and modified deer sled) and move it from home- to hospital pen.

Employee enrollment

Four male employees were enrolled in the study by the company veterinarian. On the study day, each employee was asked to complete a demographics questionnaire in the farm office before completing pig cadaver tasks using the three handling tools. They ranged in age of 23 – 60 years old, height 180.3 – 195.6 cm, weight 83.9 – 113.4 kg and on-farm experience of 1 – 30 years. The four English-speaking employees were comprised members of the production well-being team and the engineering team.

Peak exertion force and duration of pig cadaver tasks

A FGV-HXY High Capacity Digital Force Gauge (Nidec-SHIMPO America Corporation, Itasca, IL, USA) was attached to the handling tool handle to record force (kgf) applied by the employee while moving the pig cadaver. Each employee held his or her arms with the force gauge positioned at waist height and pulled for five continuous seconds. Pig cadaver tasks were performed in two locations (1) in the alleyway immediately outside of the home pen and (2) inside the hospital pen. Time to complete pig cadaver tasks were measured at four time points (s): 1) Duration to roll pig cadaver from home pen floor onto the handling tool (TOD). 2) Duration to secure pig cadaver on the handling tool (TTS). 3) Duration to move handling tool and pig cadaver from home pen into the alleyway, defined as the handling tool being entirely inside the alley and oriented towards the hospital pen (TTA). 4) Duration to move handling tool and pig cadaver along the alleyway and into the hospital pen, defined as handling tool being entirely inside the hospital pen (MUA).

Employee physiologic measures

One researcher collected each employee's physiologic measures at two different time points: (1) baseline resting levels in the home pen and (2) post exertion levels collected immediately after moving each pig cadaver. A pulse oximeter (Pulse Oximeter 50DL; Clinical Guard, Atlanta, GA, USA) was placed onto the employee's index finger to collect heart rate (bpm) and oxygen saturation (%). Consistent with other studies (Berkeley Wellness, 2010; Dray, 2017), a minimum 5-min resting period was enforced between each pig cadaver task to allow physiologic measures to return to baseline levels.

Employee handling tool evaluation and durability

During each resting period, employees were asked to complete a survey which evaluated the handling tools. The handling tools were moved three times per employee resulting in 180 completed surveys (60 surveys per handling tool). Comments were also solicited for each question to collect qualitative data. Durability of the handling tools were evaluated by one researcher for presence of holes, rips and creases at the conclusion of each pig cadaver task. If observed, these were counted, measured (cm) and photographed.

Statistical Analysis

The handling tool survey was evaluated by simple means and standard deviation of four employees. Handling tool durability was evaluated by counting and measuring holes, rips and creases after movement from home pen to hospital pen. Two new variables were created for employee heart rate and oxygen saturation;

Change in employee heart rate (bpm) = hospital pen heart rate – baseline resting heart rate

Change in employee oxygen saturation (%) = hospital pen post exertion oxygen saturation – baseline resting oxygen saturation

The distribution of the peak exertion force, handling tool duration, change in employee heart rate- and oxygen saturation difference data were evaluated using the PROC UNIVARIATE procedure (SAS v 9.2, SAS Inst., Inc., Cary, NC). Data met the assumption of normality and were analyzed using mixed model methods (PROC MIXED) for parametric data. The statistical design was a complete randomized design with the statistical model including the fixed effect of employee (n = 4), handling tool (n = 3) and farm (n = 3) with pig cadaver (kg) as a linear covariate. Employee within farm was included as a random effect in the model. A $P \leq .05$ was considered significant and PDIFF option (SAS v 9.2, SAS Inst., Inc., Cary, NC) was used to separate means when fixed effects were a significant source of model variation.

Results:

Duration of pig cadaver tasks

Total duration was affected by handling tool and farm ($P < .001$; Figures 1 and 2). Total duration was affected by pig cadaver, such that 0.64 s increase occurred with each one kg increase in weight ($P < .0001$). MDS was quicker to move than SKED and SLED. Average total durations were as follows: SKED [67.1 ± 3.0 s] vs SLED [107.5 ± 3.0 s, $P < .0001$]; SLED vs MDS [63.0 ± 3.0 s, $P < .0001$]. Employee was not a source of variation ($P = .24$).

Figure 1. Total duration of cadaver tasks by handling tools. [ab]Means across the figure with no common superscript are significantly different (P < .05).

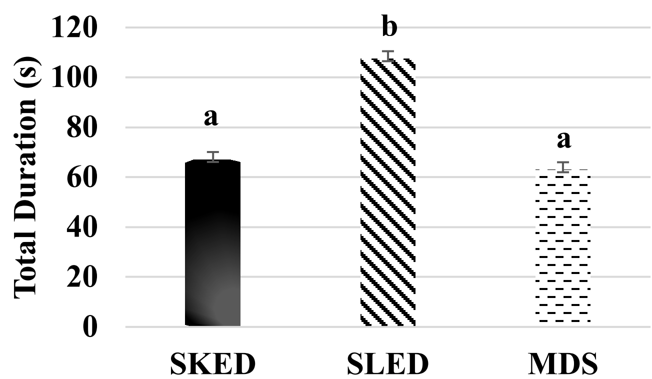
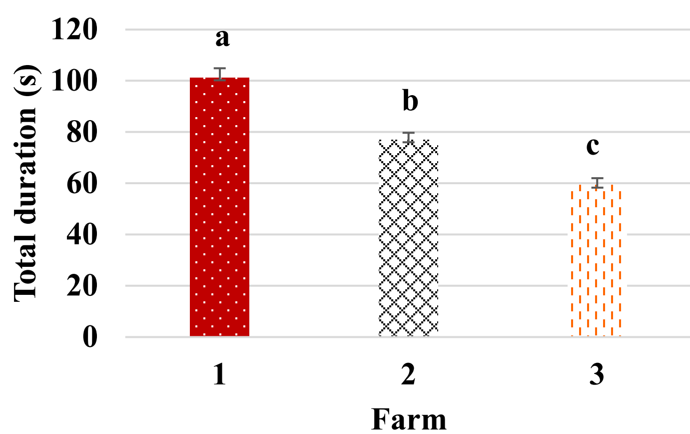


Figure 2. Total duration of cadaver tasks by farm. [ab]Means across the figure with no common superscript are significantly different (P < .05)



Peak exertion force

Peak exertion force at the start of the alley was affected by handling tool, farm and pig cadaver, such that 0.25 kg increase occurred with each one kg increase in weight ($P < .001$; Figure 3 and 5). More force was required to move pig cadavers on the SKED than SLED or MDS. Average peak exertion force (±SE) at the start of alley were as follows: SKED [26.4 ± 0.6 kgf] vs SLED [20.1 ± 0.6 kgf, $P < .0001$]; SKED vs MDS [20.9 ± 0.6 kgf, $P < .0001$]. Employee was not a source of variation ($P = .05$). Exertion force at the end of the alley was affected by handling tool, farm and pig cadaver, such that 0.23 kgf increase occurred with each one kg increase in weight ($P < .01$; Figure 4 and 6). More force was required to move pig cadavers on SKED then SLED or MDS. Average peak exertion force (±SE) in hospital pen were as follows: SKED [23.5 ± 0.6 kgf] vs SLED [18.0 ± 0.6 kgf, $P < .0001$]; SKED vs MDS [19.7 ± 0.6 kgf, $P < .0001$]. Employee was not a significant source of variation ($P = .38$).

Figure 3. Peak exertion force at the start of alley (SOA) by handling tools. [ab]Means across the figure with no common superscript are significantly different (P < .05)

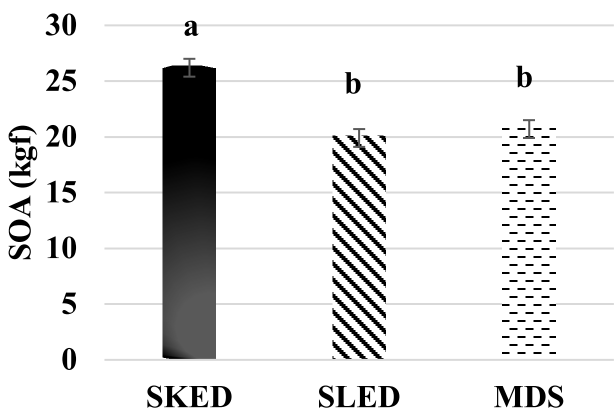


Figure 4. Peak exertion force at the end of alley (EOA) by handling tools. [ab]Means across the figure with no common superscript are significantly different (P < .05)

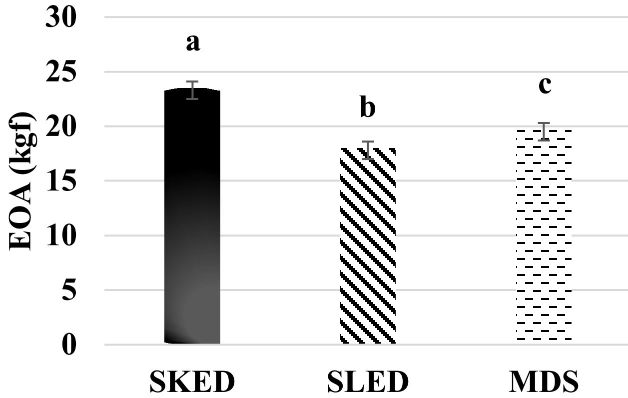


Figure 5. Peak exertion force at the start of alley (SOA) by farm. [ab]Means across the figure with no common superscript are significantly different (P < .05)

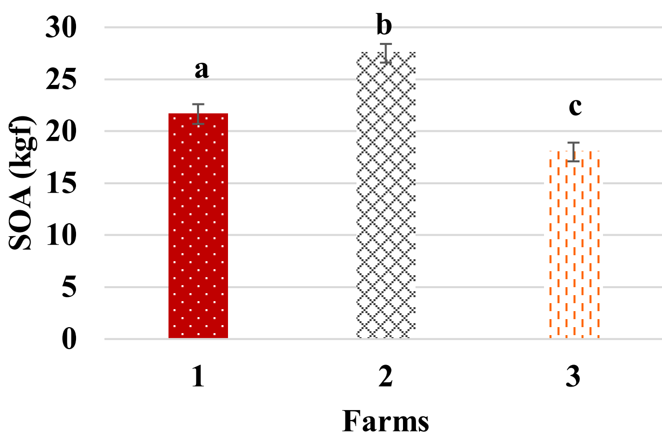
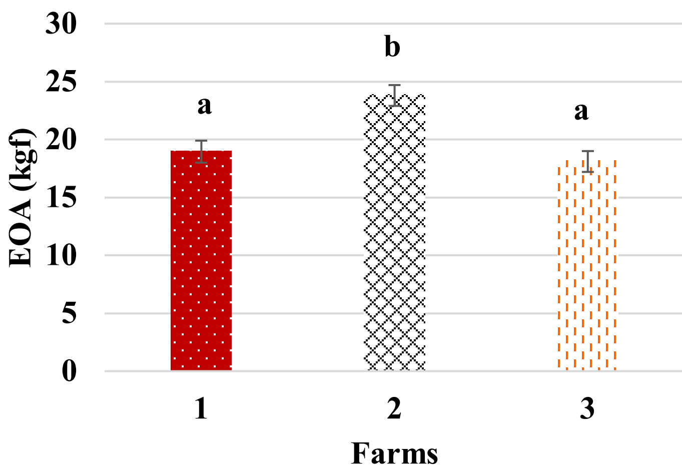


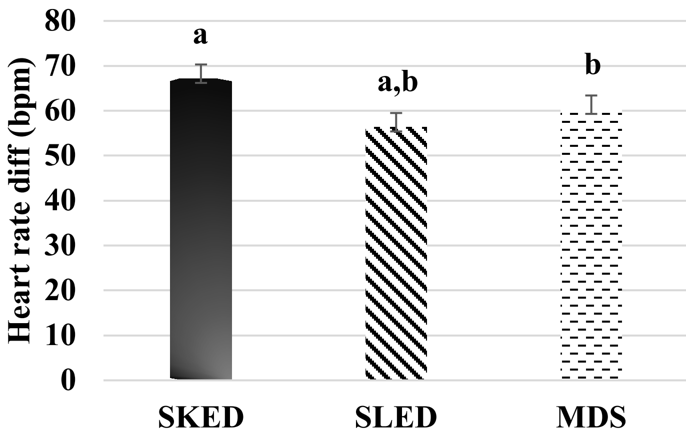
Figure 6. Peak exertion force at the end of alley (EOA) by farm. [ab]Means across the figure with no common superscript are significantly different (P < .05)



Employee physiologic measures

Change in heart rate after moving the pig cadaver from home- to hospital pen was affected by the handling tool used (P = .04; Figure 7). Change in heart rate was greater with SKED than MDS (*P* = .01); SLED did not differ from SKED or MDS. Average (±SE) and range of change in employee heart rate were as follows: SKED [62.7 ± 3.1 bpm (12 – 91 bpm)], MDS [56.4 ± 3.1 bpm (15 – 104 bpm,)] and SLED [60.3 ± 3.1 bpm (20 – 92 bpm)]. Change in heart rate was affected by pig cadaver, such that 0.22 bpm increase occurred with one kg change in pig cadaver weight (*P* < .0001). Employee and farm were

Figure 7. Change in employee heart rate by handling tools. [ab]Means across the figure with no common superscript are significantly different (P < .05)



Change in oxygen saturation after moving the cadaver from home pen to hospital pen was not affected by handling tool, pig cadaver weight, employee, or farm (*P* > .05).

Employee handling tool evaluation

Surveys were obtained from all four employees for all pig cadaver tasks. Employees ranked rolling pig cadavers onto the MDS as very easy (32 of 60 scores), whereas SKED (32 of 60 scores), SLED (33 of 60 scores) were ranked as easy. Securing cadavers onto SKED was very easy (31 of 60 scores), whereas SLED was ranked easy (20 of 60 scores). The MDS did not include restraints and therefore was not ranked. In the comments section, employees suggested replacing the SLED's string restraints with buckle restraints used on the SKED. Additionally, employees recommended buckle restraints for the MDS.

In the home pen and in the alley, positioning cadavers onto MDS the employees ranked this task as very easy (home pen: 28 of 60 scores; alley: 23 of 60 scores). Whereas, the employees ranked the SKED (home pen: 33 of 60 scores; alley: 30 of 60 scores) and SLED (home pen: 33 of 60 scores; alley: 27 of 60 scores) as easy to position. Employees commented on the importance of centering the cadaver head by the handle to limit risks of catching head and limbs on penning when moving down the alley. The SLED (31 of 60 scores) and MDS (30 of 60 scores) were ranked as very easy to move from home- to the hospital pen, while SKED (35 of 60 scores) was ranked as easy. Employees recommended adding a flexible PVC tube section to the SLED and MDS polypropylene rope handle to prevent the rope from pinching employees' hands during movement. MDS size (44 of 60 scores) and weight (45 of 60 scores) were ranked as very easy. The SLED size (30 of 60 scores) and weight (35 of 60 scores) were ranked as easy. The SKED's size was ranked as neutral (27 of 60 scores) and employees commented on the width, which periodically caught on penning during movement. However, the SKED's weight was ranked as easy (35 of 60 scores).

Handling tool durability

The SKED was the most durable with only a rip (2.5 cm length x 1.3 cm width) on the side of one SKED after the 11th drag. The SLED was the least durable handling tool with multiple creases ranging from 1.3 cm – 11. cm in length, rips 2.5 cm – 35.6 cm in length, and holes 2.5 cm – 34.3 cm in length and approximately 0.6 cm in width. The holes, rips, and creases were not large enough to discard the handling tool or cause safety issues to the employee.

Discussion:

There are several guidance documents to help know how to move non-ambulatory pigs. The American Meat Institute (Grandin and AMI, 2013) recommends using slide boards, sleds and cripple carts to move non-ambulatory pigs within meat processing plants. Similarly, the Transport Quality Assurance program (NPB, 2017) recommends stretchers, sleds, hand carts and specialized skid loaders for moving non-ambulatory pigs. When non-ambulatory pigs occur on farms, the Pork Quality Assurance Plus program (NPB, 2016) recommends using plastic sleds or drag mats. There are no other science-based publications validating different handling tool options for moving non-ambulatory pigs. These handling tools can be bought online and are relatively economical to modify (approximately $327, $31, and $31 USD). Handling tool duration (s) would change between farm sites due to barn layout, differing alleyway width and length, pen and alley flooring, percentage of dry vs wet manure covering the alley floor. When moving up the alley, farm site one took twice as long to move all handling tools: farm one [55 s] vs farm two [29 s] vs farm three [21 s]. When breaking this down further by handling tools per farm, on farm one sked [40 s], deer sled [38 s] and modified deer sled [63 s]. Farm two was sked [24 s], deer sled [30 s] and modified deer sled [34 s]. Lastly, farm three was sked [21s], deer sled [19 s] and modified deer sled [23 s]. The difference could be explained by the smaller alley width in farm one, which could affect handling tool movement ease. The decrease in alley width could cause the pig cadaver limbs and head to catch in penning when moving from home- to hospital pen. It is suggested when conducting future research on handling tools for the grow-finish pig, one important measure to collect is the amount of manure on the pen and alley floor as this could factor into movement ease. Researchers should also look at whether the peak force changed based on where the handler as positioned. For example, if the handle was held more at shoulder height (75 degree angle) versus being pulled at waist height (45 degree angle). As well as, whether differing of employee weight and height and differing handling tool handle lengths could affect the force used. Interestingly throughout the handling tool survey, modified deer sled was ranked similarly to the sked and deer sled. However, when employees reached the final two questions of the handling tool survey of whether the modified deer sled could easily move a non-ambulatory pig and recommending modified deer sled to producers all employees responded no. Employees responded that without restraint straps the modified deer sled would not be preferred handling tool to move non-ambulatory pigs. Therefore, it was recommended that restraint straps be added onto the modified deer sled. After conclusion of the study, the researcher was interested if inclusion of restraint straps would make a difference in moving the cadaver. Restraints similar to the skeds were affixed to the modified deer sled and taken on-farm to be tested on a cadaver. The researcher observed that even with restraints, the pig cadaver continually slid off the backside and had to be repositioned multiple times. Therefore, even with inclusion of restraints the modified deer sled would not be a suitable handling tool to move a non-ambulatory pig. Future research studies should test whether different cadaver positioning on handling tools could affect movement ease. For example, positioning pig cadaver with hind end closest to the handle vs pig cadaver head closest to handle and cadaver in lateral recumbence vs. cadaver laying on back with limbs in the air. Handling tools should be tested on varying farm site layouts as movement ease could differ between farm sites and handling tools. Finally, these handling tools should be tested to simulate if a pig becomes non-ambulatory in the alley or chute.

References

AASV. American Association of Swine Veterinarians. On-Farm Euthanasia of Swine: Recommendations for the Producers. 2016. Available at: https://www.aasv.org/documents/2016EuthRec-EN.pdf. Accessed 25 September 2018.

Berkeley Wellness. Your Heart Beat and Your Health. 2010. Available at: http://www.berkeleywellness.com/fitness/exercise/article/your-heart-beat-and-your-health. Accessed 17 June 2018.

Dray T. How Long After Working Out Does Your Heart Rate Return to Base? 2017. Available at:

https://www.livestrong.com/article/448974-how-long-after-working-out-does-your-heart-rate-return-to-base/. Accessed 15 June 2018.
Grandin T and American Meat Institute Animal Welfare Committee. Recommended Animal Handling Guidelines & Audit Guide: A Systematic Approach to Animal Welfare. Rev 1. 2013;1-121.
Hill J, Berry N, and Johnson AK. Handling and loadout of the finisher pig. Available at: http://porkgateway.org/resource/handling-and-loadout-of-the-finisher-pig/. Pork Information Gateway Factsheet. Published April 2007. Accessed 1 January 2018.
Johnson AK, Gesing LM, Ellis M, McGlone JJ, and Berg E. Farm and pig factors affecting welfare during the marketing process. Journal of Animal Scinece. 2013;91:2481-2491. doi:10.2527/jas.2012-6114.
NPB. National Pork Board. Pork Quality Assurance Plus. 2016. Version 3 Handbook. Available at: https://d3fns0a45gcg1a.cloudfront.net/sites/all/files/documents/PQAPlus/V3.0/BinderMaterial/Tab%202/1%20PQAhandbook.pdf. Accessed 1 January 2018.
NPB. National Pork Board. Transport Quality Assurance. Version 6 Handbook. 2017. Available at: https://d3fns0a45gcg1a.cloudfront.net/sites/all/files/documents/TQA/2017-Version6/TQA.V6_Handbook.pdf. Accessed 14 September 2017.
Ritter MJ, Ellis M, Berry NL, Curtis SE, Anil L, Berg E, Benjamin M, Butler D, Dewey C, Driessen B, DuBois P, Hill JD, Marchant-Forde JN, Matzat P, McGlone J, Mormède P, Moyer T, Pfalzgraf K, Salak-Johnson J, Siemens M, Sterle J, Stull C, Whiting T, Wolter B, Niekamp SR, and Johnson AK. Review: Transport Losses in Market Weight Pigs: I. A Review of Definitions, Incidence, and Economic Impact. Professional Animal Science. 2009;25:404-414.

Objective two: To evaluate the most promising handling tools from objective one using non-ambulatory grow-finish pigs

Phase three*: *To test a sked, revised deer sled, and ice fishing sled as humane handling tools for moving non-ambulatory grow-finish pigs

Materials & Methods:

All research was approved by Iowa State University Institutional Animal Care and Use Committee (Approval #18-319).

Handling tool modifications

A HMH sked rescue system was purchased from Skedco (SKU: sk-250, Tualatin, Oregon, USA). The sked (SKED) weighed 5.0 kg, measured 2.4 m length × 91.4 cm width × 0.3 cm depth, and made of medium-density polyethylene plastic. Modifications were made to reduce the length to make transitioning between the pens and alleyways possible. All straps from the sked were removed except three 5.08 cm side release plastic buckle straps (5.08 cm polypropylene straps) used to secure pig to sked. Across the width on the foot-end, a 31.1 cm line was drawn and a hacksaw was used to cut across the line. The final sked dimension was 1.9 m length × 91.4 cm width.

A Magnum Deer Sleigh'r Game Sled was purchased from Sportman's Guide (Item Number: 138755, Minneapolis, MN, USA). The revised deer sled (RDS) weighed 2 kg, measured 1.8 m length × 91.8 cm width × 0.2 cm depth, and was made of slick polymer. Modifications were made to affix new restraints to assist in securing the pig and a polypropylene rope was added to serve as a handle. Two grommets (3.8 cm) were installed on both sides of deer sled. One grommet was inserted 50 cm from the top and 2.5 cm in from the width. Second grommet was inserted 55 cm down from the first grommet and 2.5 cm in from the width. Process is repeated on the deer sleds opposite side. Two 5.08 cm side release plastic buckle restraint straps (5.08 cm polypropylene straps) were affixed to the grommets to secure pig to the deer sled. A 3.7 m polypropylene rope was inserted through three pieces, 20.3 cm each, of braided vinyl tubing. The first top handle was created and then two additional handles were added underneath (30.5 cm apart) to provide employees with handle length options when moving pigs. The handle was inserted and knotted on the upper surface. Final RDS dimension was 1.8 m length × 91.8 cm width.

An Otter Pro Sled Mini was purchased from Otter Outdoors (SKU: 200817, Maple Lake, MN, USA). The ice fishing sled (IFS) weighed 3.6 kg, measured 109 cm length x 58 cm width x 27 cm height and was made of polyethylene construction. Modifications were made to affix new restraints to assist in securing and the addition of a polypropylene rope as a handle. Two holes were drilled on both sides of the outer lips. First hole was drilled 40.6 cm down from the top of IFS. Second hole was drilled 81.3 cm down from the IFS's top. Two 5.08 cm side release plastic buckle restraint straps (5.08 cm polypropylene straps) were affixed to holes. Two additional holes were drilled into the front of IFS using a 1.27 cm spade bit to increase the size of the pre-existing holes. A 2.7 m polypropylene rope was inserted through a section of 25.4 cm braided vinyl tubing. The handle was knotted at the front, upper surface (Table 3).

Table 3. Handling tools before and after modifications

	Before	
Sked	**Deer sled**	**Ice fishing sled**
2.4 m length × 91.4 cm width	1.8 m length × 91.8 cm width	109 cm length x 58 cm width x 27 cm height

		
After		
1.9 m length × 91.4 cm width	1.8 m length × 91.8 cm width	109 cm length x 58 cm width x 27 cm height
		

Animals, facilities and non-ambulatory pig movement tasks

The study was conducted on a commercial grow-finish site in Central Iowa. Eighteen commercial cross bred genetic line pigs were selected from the general population by the company veterinarian. Body weights were collected using a weigh scale (Raytec WayPig 300; AGRIsales inc., Ceresco, NE) and rounded to the nearest whole number, average BW of 100 ± 25.3 kg. Once a pig was weighed, they were individually marked (before released into the start pen. For the non-ambulatory pig movement tasks, two empty pens were designated as the start (home pen) and end (hospital pen), distance 20.6 m. This corresponded to the distance that a non-ambulatory pig would need to be humanely moved on a typical commercial farm.

Epidural procedure

The Swine Medicine Education Center staff and veterinarians at Iowa State University's College of Veterinary Medicine completed the epidural procedures. Each pig was restrained with a pig snare while standing. In addition to the individual snaring the pig, three personnel were utilized to administer the epidural: one supported the pig with a sort board on its side to prevent lateral swaying or evasive movement during injection, a second to administer the epidural, and a third to hand supplies to the individual administering the epidural. The site of injection for epidural was the lumbosacral space, located by palpating the cranial edge of the tuber coxae and finding the point perpendicular to that location on midline of the dorsum of the pig. The location was prepared by shaving the hair on the pig's back. The location was infiltrated with a local anesthetic agent (2% lidocaine) prior to insertion of the spinal needle. An 18-gauge x 8.9 cm spinal needle (BD Franklin Lakes, New Jersey) was inserted at the prepared location between the last lumbar and first sacral vertebrae. The stylet was removed and a 12-mL syringe filled with 2% lidocaine was attached to the needle for administration of the anesthetic agent. As the lidocaine was injected, if resistance was noted, the pressure on the syringe was released and the spinal needle was repositioned before administration of the full dose. After administration, the needle was withdrawn from the pig and the hog snare was removed. The epidural procedure took six min; the analgesia was present within 20 min and lasted approximately two hours.

Employee enrollment

One female and one male production well-being employees were enrolled in the study. The female employee was 30 years of age, 160.2 cm tall and weighed 63.5 kg with 10 years of experience. The male employee was 60 years of age, 180.3 cm tall and weighed 90.7 kg with 20 years of experience.

Duration of non-ambulatory pig movement tasks

Time to complete non-ambulatory pig movement tasks were measured at three time points (s): 1) Duration to move non-ambulatory pig from start pen floor onto the handling tool (TOD). 2) Duration to secure non-ambulatory pig inside the handling tool (TTS). 3) Duration to move handling tool and non-ambulatory pig from start pen to end pen, defined as handling tool being entirely inside the end pen (TSE).

Non-ambulatory pig vocalization score and struggle score

One researcher collected the pig's vocalization and struggle scores throughout the non-ambulatory pig movement tasks. Vocalization score was scored the following: (0) none, (1) intermittent grunts/calls and (2) continuous grunts/calls. Struggle score was scored the following (0) none, (1) intermittent movement of legs and/or head and (2) continuous movement of legs and/or head.

Pig temperature and respiration rate

One researcher collected each pig's temperature and respiration rate at two different time points: (1) pig baseline [defined as pig is in the start pen, before the epidural procedure begins] and (2) non-ambulatory pig endpoint [defined as after pig has been unloaded from handling tool and laying on the end pen floor]. Pig temperature (ºC) was collected via an InfraRed Gun (Extech Dual Laser InfraRed Thermometer; Boston, MA, USA) aimed at the pig's ventral plane. Pig respiration rate (defined as one inhalation and one exhalation) was counted over 15 s on the flank of the pig then times by four to get breaths per min (bpm).

Pig assessment

A pig assessment was completed pre- and post-movement, which included the number of scratches (defined as injuries to the skin that goes into the skin but does not go all the way though and may include redness and inflammation; NPB 2016), bruises (defined as injury appearing as an area of discolored skin on the body), open mouth breathing (defined as breathing with mouth open / panting), muscle tremors (defined as pigs began shaking), and skin discoloration (defined as skin become reddish/purple color; Gesing et al 2010). Pre-movement no pigs had any of the aforementioned measures or displayed signs of distress. Post movement, four non-ambulatory pigs displayed muscle tremors in their front limbs.

Handling tool durability

Durability of each handling tool was evaluated by one researcher for presence of holes, rips and creases at the conclusion of each handling tool movement. If observed, these were counted and measured (cm).

Statistical Analysis

Pig assessment was evaluated by noting number of scratches, bruises, open mouth breathing, muscle tremors and skin discoloration. Handling tool durability was evaluated by counting and measuring holes, rips and creases after movement from start pen to end pen Two new variables were created for pig temperature and respiration rate;

Change in pig temperature (ºC) = end pen non-ambulatory pig temperature – baseline pig temperature

Change in pig respiration rate (bpm) = end pen non-ambulatory pig respiration rate – baseline pig respiration rate

The distribution of the change in pig temperature- and respiration rate difference, handling tool duration and pig vocalization and struggle scores were evaluated using the PROC UNIVARIATE procedure (SAS v 9.2, SAS Inst., Inc., Cary, NC). Change in pig temperature- and respiration rate and handling tool duration data met the assumption of normality and were analyzed using mixed model methods (PROC MIXED) for parametric data. The statistical design was a complete randomized design with the fixed effect of farm (n = 1), handling tool (n = 3), and sex of pig (M/F) with pig weight (kg) as a linear covariate. Pig vocalization and struggle score data were analyzed using PROC FREQUENCY and CHI SQUARE to observe the distribution of vocalization and struggle scores by handling tool. A $P \leq 0.05$ was considered significant and PDIFF option (SAS v 9.2, SAS Inst., Inc., Cary, NC) was used to separate means when fixed effects were a significant source of model variation.

Results:

Duration of non-ambulatory pig movement tasks

Total duration was affected by pig body weight ($P = 0.014$). Handling tool and sex were not sources of variation ($P > 0.10$). Average total handling tool duration (range) were as follows: SKED [127.47 ± 20.88 s (96 – 207 s)], RDS [161.28 ± 20.83 s (76 – 264 s)] and IFS [124.41 ± 20.05 s (64 – 184 s)].

Non-ambulatory pig vocalization score and struggle score

There were no associations between handling tools and pig vocalization and struggle scores when moving non-ambulatory pig from home pen floor onto the handling tool, securing pig onto the handling tool, and moving the handling tool and pig from start pen to end pen ($P > 0.10$).

Pig temperature and respiration rate

Change in pig temperature (ºC) and respiration rate (bpm) was not affected by handling tool, sex or pig body weight ($P > .05$). Average (±SE) and range for change in pig temperature were as follows: SKED [1.03 ± 1.67 ºC (-6.50 – 5.50 ºC)], RDS [1.64 ± 1.71 ºC (0.72 – 3.94 ºC)] and IFS [2.48 ± 1.58 ºC (-1.78 –

5.50 ºC)]. Average (±SE) and range for change in pig respiration rate were as follows: SKED [10.29 ± 3.95 bpm (4 – 16 bpm)], RDS [6.96 ± 4.04 bpm (0 – 24 bpm)] and IFS [10.68 ± 3.74 bpm (-4 – 32 bpm)].

Handling tool durability

The IFS was the most durable with no creases, rips or holes. The SKED had a total of two creases. The first crease occurred during the first pull and was 1.27 in length. The second crease occurred during the sixth (final) pull and was 7.62 cm in length. The RDS had a total of two creases. The first crease occurred during the third pull and was 2.54 cm in length. The second crease occurred during the fourth pull and was 20.32 cm in length.

Discussion:

These handling tools can be bought online and are relatively economical to modify (approximately $327, $144 and $69 USD). Initially, a researcher observed finishing pigs leaving the farm and being loaded onto trailers. These observations occurred over five farms and over a two week period. After observing 6,370 finisher pigs, the researcher only collected one naturally occurring non-ambulatory pig (0.002%). To add context, the current swine industry non-ambulatory rate is 0.4% (Ritter et al., 2009). Using the observed number of 6,370 pigs' times the non-ambulatory rate of 0.4%, the researcher should have identified approximately 26 non-ambulatory pigs over the two weeks. The researchers decided that this research methodology was ineffective. Hence, a non-ambulatory pig biomedical model was created. The epidural procedure affected the motor functions of the hind limbs and resulted in recumbency, therefore, mimicking a non-ambulatory pig. After viewing vocalization and struggle score results, we question if the epidural procedure affected these scores. Epidural anesthesia refers to the sensory, motor and autonomic blockade produced by epidural administration of local anesthetics. Lidocaine was used in the study as the local anesthetic and administered into the lumbosacral epidural space, which produces a rapid desensitization of the caudal portions of the abdominal cavity, inguinal area, hind limbs, tail and perineum (Cruz et al 1997). Studies on horses (Natalini 2010), dogs (Steagall et al 2017), cattle, buffalo and camels (Ismail 2016) have shown the effectiveness of spinal sensory blocks for pain control on the chronically ill and during surgical procedures. Naturally occurring non-ambulatory pigs may have become overwhelmed by the accumulation of stressors and collapsed, but still have sensory function in their hind legs. Pigs used in the study may have had less of a vocalization and struggle reaction when employees were attempting to load and move the pigs on the handling tools due to little to no sensation in their hind limbs. More research needs to be completed on whether these handling are as effective in moving naturally occurring non-ambulatory pigs. After study completion, the researcher asked two employees for their opinions of each handling tool used to move non-ambulatory pigs from start- to end pen. When loading the non-ambulatory pigs, both employees commented on how the sked's thicker material made loading easier compared to the other two handling tools. The revised deer sled's flimsiness made loading more difficult. As the non-ambulatory pigs were loaded onto the revised deer sled, some pigs struggled and in turn bend the material causing the employees to have to stop loading and readjust both the handling tool and pig. The ice fishing sled was the most difficult handling tool to load the non-ambulatory pigs and two employees are especially needed for both employee and pig safety. They commented on even though the ice fishing sled was tipped on its side, it was still difficult to maneuver pigs up into the ice fishing sled, especially with the pigs that struggled. These comments can be validated when looking at the average duration to move the non-ambulatory pig into the handling tools: sked [12 s] vs revised deer sled [26 s] vs ice fishing sled [37 s]. When moving the non-ambulatory pigs from the start pen to the end pen, employees commented that the sked's stiff material would sometimes catch on gates, causing readjustments of the sked, which prevented a smooth forward transition. Depending on the angle of entry, the sked was at times difficult to turn the corners of the alley way into the end pen and vice versa. Additionally, both employees really liked the placement of the sked's handle and commented that the sked pulled more evenly than the revised deer sled. For the revised deer sled, employees commented that since the material was easier to manipulate, they could tighten the restraints around the pig make a cocoon like structure. This allowed the employees to safely secure the pigs' limbs and head inside, minimizing the risk of limbs/head catching in the gates. Lastly, employees commented on the ice fishing sled had the smoothest transition when moving from the start pen to the end pen. Although, both employees commented on the smaller size of the ice fishing sled could be problem especially with the heavier and/or longer pigs. These comments can be validated when comparing the average duration to move from the start pen to the end pen: sked [113 s] vs revised deer sled [117 s] vs ice fishing sled [55 s]. It is important to test potential on-farm handling tools for ease of use, employee safety (Hill et al., 2007) and pig welfare (Ritter et al., 2009; Johnson et al., 2013).

References

Cruz ML, Luna SPL, Clark RMO, Massone F and Castro GB. 1997. Epidural anesthesia using lignocaine, bupivacaine or a mixture of lignocaine and bupivacaine in dogs. Veterinary Anaesthesia and Analgesia 24: 30-32.

Gesing LM, Johnson AK, Selsby JT, Feuerbach C, Hill H, Faga M, Whiley A, Bailey R, Stalder KJ, PAS and Ritter MJ. 2010. Effects of Presorting on Stress Responses at Loading and Unloading and the Impact on Transport Losses from Market-Weight Pigs. The Professional Animal Scientist 26: 603-610.

Hill J, Berry N and Johnson AK. 2007. Handling and loadout of the finisher pig. Available at: http://porkgateway.org/resource/handling-and-loadout-of-the-finisher-pig/. Pork Information Gateway Factsheet. Accessed 1 January 2018.

Ismail ZB. 2016. Epidural analgesia in cattle, buffalo, and camels. Veterinary World 9: 1450-1455.

Johnson AK, Gesing LM, Ellis M, McGlone JJ, and Berg E. 2013. Farm and pig factors affecting welfare during the marketing process. Journal of Animal Science 91: 2481-2491.

Natalini CC. 2010. Spinal anesthetics and analgesics in the horse. Veterinary Clinics of North America: Equine Practice 26: 551–564

NPB. National Pork Board. 2016. Pork Quality Assurance Plus. Version 3 Handbook. Available at: https://d3fns0a45gcg1a.cloudfront.net/sites/all/files/documents/PQAPlus/V3.0/BinderMaterial/Tab%202/1%20PQAhandbook.pdf. Accessed 1 January 2018.

Steagall P, Simon BT, Teixeira Neto FJ and Luna S. 2017. An Update on Drugs Used for Lumbosacral Epidural Anesthesia and Analgesia in Dogs. Frontiers in veterinary science 4: 68.

Ritter MJ, Ellis M, Berry NL, Curtis SE, Anil L, Berg E, Benjamin M, Butler D, Dewey C, Driessen B, DuBois P, Hill JD, Marchant-Forde JN, Matzat P, McGlone J, Mormède P, Moyer T, Pfalzgraf K, Salak-Johnson J, Siemens M, Sterle J, Stull C, Whiting T, Wolter B, Niekamp SR, and Johnson AK. 2009. Review: Transport Losses in Market Weight Pigs: I. A Review of Definitions, Incidence, and Economic Impact. The Professional Animal Scientist 25: 404-414.

Conclusion:

The overall goal was to provide the swine industry with humane on-farm handling tools to move non-ambulatory pigs through two objectives: 1) to evaluate three handling tools to move non-ambulatory market pigs and 2) to evaluate three handling tools to move conscious non-ambulatory market weight pigs during pre-sort and load out under commercial conditions in terms of pig welfare handling efficiency and worker safety.

- Conclusion one: Modified wean-to-finish mat was not a suitable handling tool for manually moving grow-finish pig cadavers as a model for moving non-ambulatory grow-finish pigs.
- Conclusion two: The modified deer sled is not a suitable handling tool for manually moving grow-finish pig cadavers as a model for moving non-ambulatory grow-finish pigs.

- Conclusion three: This version of the sked and deer sled are suitable handling tools for manually moving grow-finish pig cadavers as a model for moving non-ambulatory grow-finish pigs.
- Conclusion four: This version of the sked, revised deer sled and ice fishing sled are suitable handling tools for manually moving non-ambulatory grow-finish pigs on a commercial farm.

Finally, Table 4 provides a ranking of six handling tools to move grow-finish pig cadavers and non-ambulatory pigs on commercial farms.

Table 4. Ranking of six handling tools to move grow-finish pigs on commercial farms

Handling Tool	Modification time (minutes)	Total cost ($)	Total duration (seconds) ‡	Ranking
Cadavers				
Sked	2	4	3	**1**
Deer sled	1	1	2	**2**
Modified deer sled	3	1	1	**3**
MAT	4	3	4	**4**
Live, non-ambulatory pigs				
Sked	1	3	2	**1**
Revised deer sled	3	2	3	**2**
Ice fishing sled	2	1	1	**3**