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Production Tool

Alternative handling tools for moving grow-finish pig cadavers

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Summary

The National Pork Board provides recommendations for humane handling tools and non-ambulatory pig handling methods. However, there are limited published studies that evaluate the efficacy of handling tools for on-farm manual movement of grow-finish non-ambulatory or cadaver pigs. A sked, deer sled, and modified deer sled were studied as handling tools for non-ambulatory grow-finish pigs. Handling tools were tested on-farm using pig cadavers (59-134 kg) to evaluate effectiveness based on employee effort and opinion. Our results support the sked and deer sled as effective handling tools to move grow-finish pigs, while the modified deer sled was ineffective.

Keywords: swine, caretakers, grow-finish pig, handling tools, non-ambulatory pigs

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Resumen - Herramientas de manipulación alternativas para mover cadáveres de cerdos de crecimiento y finalización

El Consejo Nacional de Cerdos ofrece recomendaciones de herramientas de manejo humanitario y métodos de manejo no ambulatorios. Sin embargo, existen pocos estudios publicados que evalúen la eficacia de las herramientas de manipulación para el movimiento manual de cerdos no ambulatorios o cadáveres en crecimiento y finalización en la granja. Se estudió una camilla, un trineo de ciervo y un trineo de ciervos modificado como herramientas de manejo para cerdos no ambulatorios en crecimiento y engorda. Las herramientas de manejo se probaron en la granja utilizando cadáveres de cerdo (59-134 kg) para evaluar la efectividad en función del esfuerzo y la opinión de los empleados. Nuestros resultados respaldan la camilla y el trineo de ciervos como herramientas de manejo efectivas para mover cerdos de crecimiento, mientras que el trineo de ciervos modificado no fue efectivo.

Résumé - Équipements de manutention alternatifs pour déplacer les cadavres de porcs en période de croissance-finition

Le National Pork Board fournit des recommandations pour l'utilisation d'équipements de manutention et des méthodes de manutention humanitaires de porcs non-ambulatoires. Toutefois, il y a un nombre limité d'études publiées qui évaluent l'efficacité des équipements de manutention lors d'utilisation à la ferme pour déplacer des porcs non-ambulatoires en période de croissance-finition ou des cadavres. Un traîneau de type sked, un traîneau à chevreuil et un traîneau à chevreuil modifié furent étudiés comme équipement de manutention pour des porcs non-ambulatoires en période de croissance-finition. Les équipements de manutention furent testés à la ferme en utilisant des cadavres de porcs (59-134 kg) afin d'évaluer l'efficacité basée sur l'effort déployé par les employés et les opinions. Nos résultats suggèrent que le traîneau sked et le traîneau à chevreuil sont des équipements efficaces de manutention pour déplacer des porcs en période de croissance-finition, alors que le traîneau à chevreuil modifié était inefficace.

Non-ambulatory pigs can occur any time on-farm due to injury, illness, or fatigue, and caretakers may be required to move non-ambulatory pigs into or out of pens, alleys, and load out areas.[1] Recommendations for swine handling are provided through the Pork Quality Assurance Plus and Transport Quality Assurance programs.[2,3] Building on these programs, the Common Swine Industry Audit (CSIA) allows packers and companies to verify that on-farm practices are in compliance with animal welfare standards, which includes humane swine handling. Willful acts of abuse and neglect are prohibited and are partially defined as "[d]ragging of conscious animals by any part of their body except in the rare case where a non-ambulatory animal must be moved from a life-threatening situation."[4] If witnessed on farm, it will result in an automatic audit failure. The CSIA recommends that non-ambulatory pigs can be moved using a drag-mat. One study by Akin et al[5] investigated the use of a wean-to-finish mat to move finisher pig cadavers. The researchers assessed factors including ease of use, durability, cost, force required to drag the handling

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tool carrying three sizes of pig cadavers a typical distance in the barn, the resulting impact on employee heart rate, and overall employee satisfaction. They concluded that this mat was not suitable for manually moving non-ambulatory grow-finish pigs, and that further mat modifcations could improve ease of movement and postioning to keep the pig secured. Therefore, the objective of this project was to test a sked, deer sled, and modified deer sled (MDS) as handling tool options for non-ambulatory grow-finish pigs.

Materials and methods

All research was approved by Iowa State University Institutional Review Board for Human Subject Research (Approval No. 18-003). On-farm testing was accomplished using a pig cadaver model rather than live animals for ethical reasons. Therefore, Institutional Animal Care and Use Committee approval was not needed.

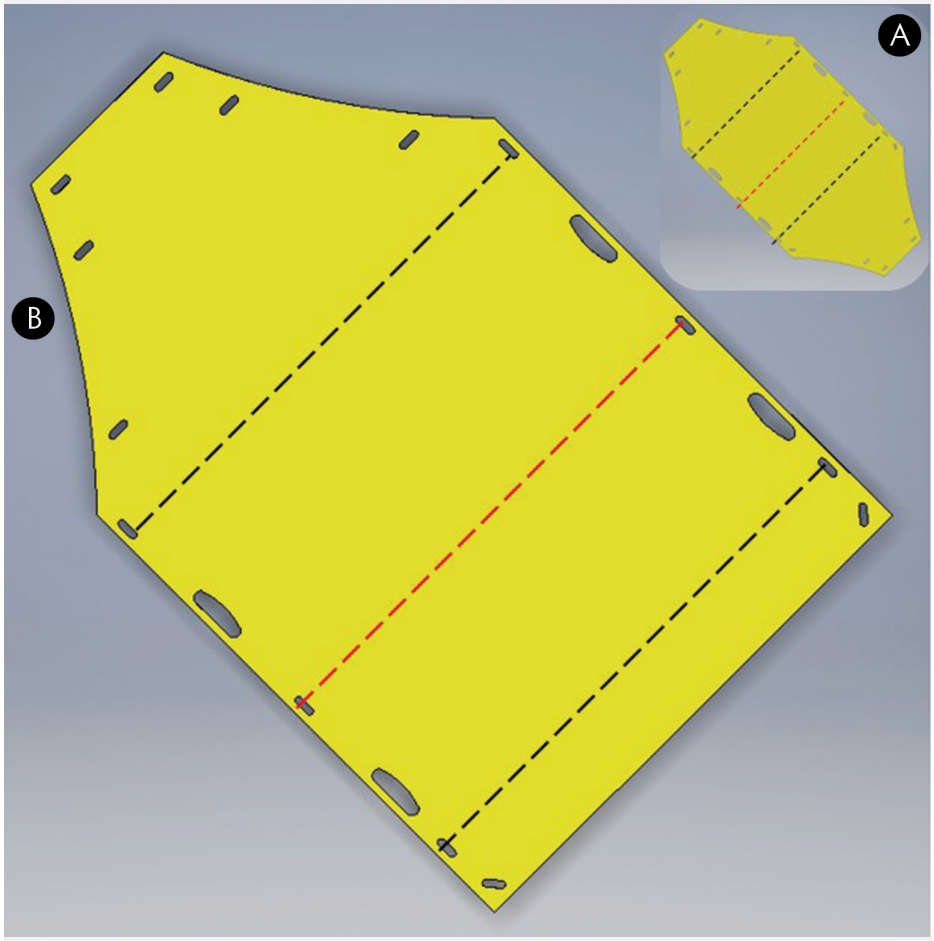
Handling tools and modifications

Three identical HMH Skeds (sk-250; Skedco) were purchased. Each sked weighed 5.0 kg, measured 2.4 m long × 91.4 cm wide × 0.3 cm deep and were made of medium-density polyethylene plastic (Figure 1A). Modifications were performed to reduce the length to make transitioning between the pens and alleyways possible. For each sked, all straps were removed except 3 side release plastic buckle restraint straps (5.08 cm wide polypropylene straps) used to secure the cadaver to the 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 long × 91.4 cm wide (Figure 1B). Each sked cost $327 with $0 for modifications.

Six identical Magnum Deer Sleigh'r Game Sleds were purchased from Sportman's Guide (Item No.: 138755). Each deer sled weighed 2 kg, measured 1.8 m long × 91.8 cm wide × 0.2 cm deep, and was made of slick polymer construction. Three of the deer sleds had 2 strings (1.83 m × 0.76 cm) 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 (Figure 2).

Three of the deer sleds were further modified to reduce the width to fit inside alleys. On each MDS, the final width was 50.8 cm and was achieved by removing 20.3 cm from each side. The final MDS dimensions were 1.8 m long × 50.8 cm wide (Figure 3). Each deer sled cost $30 plus modification costs of $0.90 for a total cost of $30.90 per deer sled.

Figure 1: The HMH sked rescue system was modified to move grow-finish pig cadavers from the home pen to the hospital pen. A) Original sked dimensions were 2.4 m long × 91.4 cm wide × 0.3 cm deep. B) All straps were removed except 3 side release plastic buckle restraint straps (5.08 cm polypropylene straps). 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 long × 91.4 cm wide.



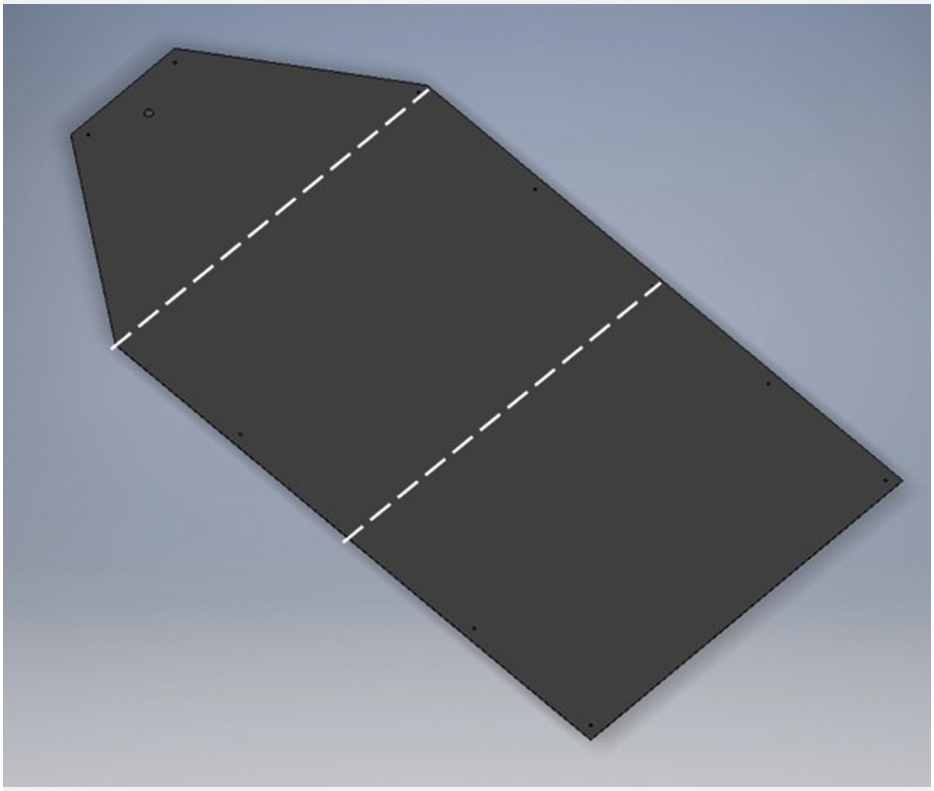
Animals and facilities

The study was conducted on 3 commercial grow-finish sites in central Iowa. Fifteen commercial crossbred pigs were selected from the hospital pen by the company veterinarian. The fifteen compromised pigs were identified as euthanasia candidates and euthanized according to company protocols, which were consistent with industry guidelines.[6] Prior to euthanasia, pigs were able to individually walk to a weigh scale (Raytec WayPig 300; AGRIsales Inc) where body weights were collected and rounded up to the nearest tenth; mean (SD) body weight was 89.1 (5.3) kg (range: 59-134 kg). Pig weight determined pig order for movement by handling tool. The weight order was rotated on each farm so that the heaviest or lightest cadaver was not always pulled first.

Handling tool securing process

A pig cadaver was rolled onto the sked so it was in lateral recumbency with the back aligned inside the sked's edge to ensure the entire cadaver remained on the sked. The cadaver was secured by 3 buckle restraints. This methodology was also used for placement on the sled with the exception that the cadaver was secured by knotting one string end in the first hole, moving the string across the cadaver and knotting the other end in the first hole on the opposite side. The same knotting process was completed with a second string using the third hole. As for the MDS, no restraints were added to secure the pig cadaver.

Figure 2: The deer sled used to move grow-finish pig cadavers from the home pen to the hospital pen. The sled dimensions were 1.8 m long × 91.8 cm wide × 0.2 cm deep. One string was placed across the pig cadaver and the ends tied to the first hole on both sides. A second string was placed across the pig cadaver and the ends tied to the third hole on both sides. A 1.4 m polypropylene rope was inserted and knotted on the front of the deer sled as a handle for employees.



Employee enrollment

Four English-speaking male employees were enrolled in the study by the company veterinarian. The employees comprised members of the production well-being team and the engineering team. These employees were selected as a convenience sample, which took into consideration limited biosecurity risk, represented typical employees within a wean-to-finish production system, and were physically fit enough to work within a wean-to-finish barn. Employees had mean (SD) age of 37 (16.1) years (range: 23-60 years), height of 185 (7.1) cm (range: 180.3-195.6 cm), weight of 99.8 (14.7) kg (range: 83.9-113.4 kg), and on-farm experience of 16.5 (12.1) years (range: 1-30 years). On the day of the study, each employee was asked to complete a demographics questionnaire prior to completing the cadaver movement using the handling tools.

Cadaver movement

Two empty pens were designated as the home pen (start) and hospital pen (end). Facility details are described in Table 1.

Each cadaver was positioned inside the home pen 2.9 m from the alleyway gate and 2.3 m from the right pen divider for farm 1. For farm 2, each cadaver was positioned 3.5 m from the alleyway gate and 2 m from the right pen divider. For farm 3, each cadaver was positioned 3.6 m from the alleyway gate and 2 m from the right pen divider. Pig cadavers were oriented with the head towards the alleyway at all farms. At the start of each cadaver movement, the employee was asked to roll the cadaver onto the handling tool (sked, sled, or MDS) and move it from the home pen to the hospital pen.

Time to complete cadaver tasks was measured at 4 time points by one researcher using a stopwatch: 1) Duration to roll cadaver from home pen floor onto the handling tool. 2) Duration to secure cadaver on the handling tool. 3) Duration to move handling tool and cadaver from home pen into the alleyway, defined as the handling tool being entirely inside the alley and oriented towards the hospital pen. 4) Duration to move handling tool and cadaver along the alleyway and into the hospital pen, defined as handling tool being entirely inside the hospital pen.

Peak force

An FGV-HXY High Capacity Digital Force Gauge (Nidec-SHIMPO America Corporation) was attached to the handling tool handle to record peak force applied by the employee while moving the cadaver. Each employee held his arms with the force gauge positioned at waist height and pulled for 5 continuous seconds. Peak force was collected during cadaver movement in 2 locations: in the alleyway immediately outside of the home pen and inside the hospital pen.

Employee physiologic measures

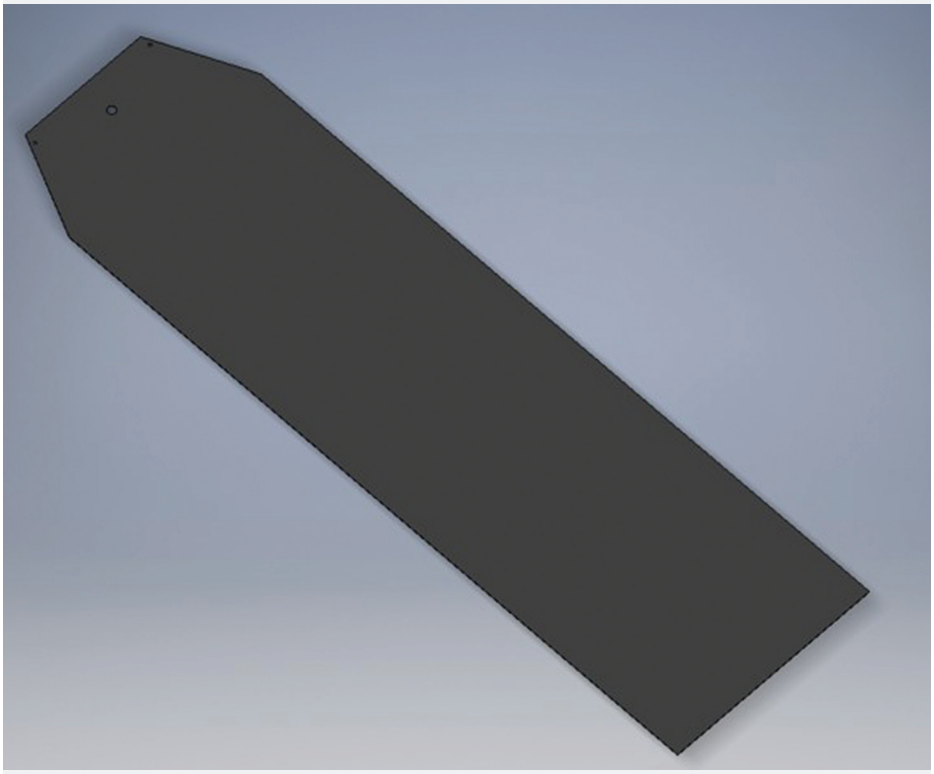
One researcher collected each employee's physiologic measures at 2 different time points: baseline resting levels in the home pen and post exertion levels collected immediately after moving each cadaver. A pulse oximeter (Pulse Oximeter 50DL; Clinical Guard) was placed onto the employee's index finger to collect heart rate and oxygen saturation. Consistent with other studies,[7,8] a minimum 5-minute resting period was provided between movement of each cadaver to allow physiologic measures to return to baseline levels.

Employee evaluation and handling tool durability

During each resting period, employees were asked to evaluate the handling tools using the survey described in Table 2. On each farm, the handling tool was moved 3 times per employee resulting in the handling tool survey being completed 180 times (60 surveys per handling tool). Comments were also solicited for each question to collect qualitative data.

Durability of handling tools were evaluated by one of the researchers for presence of holes, rips, and creases at the conclusion of each cadaver movement. If observed, these were counted, measured, and photographed.

Figure 3: The modified deer sled (MDS) used to move grow-finish pig cadavers from the home pen to the hospital pen. The deer sled was modified by removing 20.3 cm from each side. The final MDS dimensions were 1.8 m long × 50.8 cm wide × 0.2 cm deep. A 1.4 m polypropylene rope was inserted and knotted on the front of the MDS as a handle for employees.



Statistical analysis

The handling tool survey was evaluated by simple means and standard deviation of four 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, cadaver movement duration, change in employee heart rate, and change in employee oxygen saturation were evaluated using the PROC UNIVARIATE procedure (SAS v 9.2, SAS Institute, Inc). 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 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 was used to separate means when fixed effects were a significant source of variations.

Results

Duration of cadaver movement

Total duration was affected by handling tool and farm ($P < .001$; Table 3). Total duration was affected by cadaver, such that a 0.64 second increase occurred with each 1 kg increase in weight ($P < .001$). The MDS was quicker to move than the sked and sled. Mean (SE) total durations were 67.1 (3.0) seconds for sked, 107.5 (3.0) seconds for sled, and 63.0 (3.0) seconds for MDS ($P < .001$). Employee was not a source of variation ($P = .24$).

Duration to move the cadaver onto the handling tool was affected by cadaver, such that a 0.05 second increase occurred with each 1 kg increase in weight ($P < .001$; Table 3). Handling tool, farm, and employee were not sources of variation ($P > .05$). Duration to secure the cadaver was affected by handling tool and cadaver such that a 0.15 second increase occurred with each 1 kg increase in weight ($P < .01$). Farm and employee were not sources of variation ($P > .05$). Duration to move from home pen into the alley was affected by farm and cadaver such that a 0.16 second increase occurred with each 1 kg increase in weight ($P < .01$). Handling tool and employee were not sources of variation ($P > .05$). Duration to move from the alley into the hospital pen was affected by handling tool, farm, and cadaver such that a 0.33 second increase occurred with each 1 kg increase in weight ($P < .001$). Employee was not a source of variation ($P = .86$). When moving through the alley, farm 1 took twice as long (55 seconds) to move cadavers using all handling tools than farm 2 (29 seconds) and farm 3 (21 seconds). The deer sled was the fastest (38 and 19 seconds) to move through the alley on farms 1 and 3 respectively, followed by the sked (40 and 21 seconds) and MDS (63 and 23 seconds). On farm 2, the sked was the fastest to move through the alley (24 seconds) followed by the deer sled (30 seconds) and MDS (34 seconds).

Peak force

At the start of the alley peak force was affected by handling tool, farm, and cadaver such that a 2.3 N increase in peak force occurred with each 1 kg increase in weight ($P < .001$; Table 4). The sked had a higher coefficient of friction than the sled or MDS. Mean (SE) peak force at the start of the alley was 256.3 (7.1) N for the sked, 202.2 (7.1) N for the sled, and 205.3 (7.1) N for the MDS ($P < .001$). Employee was not a source of variation ($P = .09$). At the end of the alley peak force was affected by handling tool, farm, and cadaver such that a 2.2 N increase occurred with each 1 kg increase in weight ($P < .01$). More force was required to move cadavers on the sked than the sled or MDS. Mean (SE) exertion force in the hospital pen was 228.3 (5.8) N for the sked, 181.1 (5.8) N for the sled, and 191.5 (5.8) N for the MDS ($P < .001$). Employee was not a significant source of variation ($P = .27$).

Table 1: Buildings and production specifications of central Iowa commercial grow-finish sites where handling tools were evaluated to move grow-finish pig cadavers

	Farm		
Specification	**1**	**2**	**3**
Site capacity, No. of pigs	5350	2400	2400
Barn capacity, No. of pigs	1783	2400	2400
Projected market weight, kg*	127	127	127
No. of barns	3	1	1
Rooms per barn	1	2	2
Barn width, m	12.5	15.5	15.5
Barn length, m	115.8	118.3	118.3
Pen width, m	3.06	2.6	2.7
Pen depth, m	5.8	7.03	7.2
Pens per barn	64	78	78
Space allowance, m^2	0.6	0.7	0.7
No. pigs per pen	20-30	20-30	20-30
Pen flooring	Fully slatted	Fully slatted	Fully slatted
Slat width, cm	12.7	15.2	15.2
Slot width, cm	2.5	2.5	2.5
Alley flooring	Partially slatted	Partially slatted	Partially slatted
Alley width, cm	53.3	63.5	66
Alley concrete center, cm	30.3	13.9	15.2
Gate width, cm	82.6	85.1	86.4
Gate length, m	2.7	2.7	2.7
Distance of cadaver movement, m	57.9	59.2	59.2

* Projected pig market weight ranged between 125 and 136 kg.

Employee physiologic measures

Change in heart rate after moving the cadaver from the home to hospital pen was affected by the handling tool used ($P = .04$). Change in heart rate was greater with the sked than MDS ($P = .01$); change in heart rate with the sled did not differ from the sked or MDS. Mean (SE) and range of change in employee heart rate was 62.7 (3.1) bpm for the sked (12-91 bpm), 56.4 (3.1) bpm for the MDS (15-104 bpm), and 60.3 (3.1) bpm for the sled (20-92 bpm). Change in heart rate was affected by cadaver such that a 0.22 bpm increase occurred with 1 kg change in cadaver weight ($P < .001$). Employee and farm were not sources of variation ($P > .05$). Change in oxygen saturation after moving the cadaver from the home pen to hospital pen was not affected by handling tool, cadaver weight, employee, or farm ($P > .05$).

Employee evaluation and handling tool durability

Surveys were obtained from all 4 employees for all cadaver movements (Tables 5 and 6). Employees ranked rolling cadavers onto the MDS as very easy (32 of 60 scores), whereas sked (32 of 60 scores) and sled (33 of 60 scores) were ranked as easy. Securing cadavers onto the sked was very easy (31 of 60 scores), whereas the 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 the buckle restraints used on the sked. Additionally, employees recommended buckle restraints for the MDS.

Employees ranked positioning cadavers onto the MDS in the home pen and in the alley as very easy (home pen: 28 of 60 scores; alley: 23 of 60 scores). 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 the 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. The 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

Table 2: Employee handling tool survey*

Questions†					
1) Rate the HT for:					
a) Rolling cadaver from home pen floor onto HT	5	4	3	2	1
b) Securing cadaver onto HT	5	4	3	2	1
2) Positioning ease of cadaver onto HT‡:					
a) Home pen	5	4	3	2	1
b) Alley	5	4	3	2	1
3) Rate the HT for:					
a) Moving HT in home pen towards pen gate	5	4	3	2	1
b) Moving HT out of home pen and into alley	5	4	3	2	1
c) Moving HT down the alley to hospital pen	5	4	3	2	1
4) Rate the HT for:					
a) HT size to move cadaver§	5	4	3	2	1
b) HT weight to move cadaver¶	5	4	3	2	1
5) Do you think the HT could easily be used to move a NA market-weight pig		Yes		No	
6) Would you recommend this HT to other producers to move a NA market-weight pig		Yes		No	

* During each resting period, employees were asked to evaluate the handling tools (sked, deer sled, and modified deer sled) using the handling tool survey. Each employee (n = 4) filled out 3 surveys, one per cadaver (n = 15), over 3 farm sites for a total of 180 surveys completed.
† Survey responses were scored on a 5-point scale (5 = very easy, 4 = easy, 3 = neutral, 2 = difficult, and 1 = very difficult) for questions 1 through 4. Questions 5 and 6 were scored as Yes or No.
‡ Positioning defined as cadaver head positioned toward handle and legs/body centered on the mat.
§ Handling tool size defined as whether the length and width affected movement ease.
¶ Handling tool weight defined as whether the weight affected movement ease.
HT = handling tool; NA = non-ambulatory.

the width, which periodically caught on penning during movement. However, the sked's weight was ranked as easy (35 of 60 scores).

The sked was the most durable with an 8.9 cm crease on the 9th drag and a rip (2.5cm long x 1.3 cm wide) 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 to 11.0 cm in length, rips 2.5 to 35.6 cm in length, and holes 2.5 to 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 cadaver or employee.

Discussion

Field expertise associated with moving non-ambulatory pigs has resulted in several guidance documents. The American Meat Institute recommends using slide boards, sleds, and cripple carts to move non-ambulatory pigs within meat processing plants.[9] Similarly, the Transport Quality Assurance program recommends stretchers, sleds, hand carts, and specialized skid loaders for moving non-ambulatory pigs.[3] When non-ambulatory pigs occur on farms, the Pork Quality Assurance Plus program recommends using plastic sleds or drag mats.[2] From the scientific perspective, only one publication has explored the use of modified mats to move non-ambulatory pigs but were not recommended for pig movement.[10]

Cadaver movement duration 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 through the alley, farm 1 took twice as long to move cadavers using all handling tools, and the difference could be explained by the smaller alley width in farm 1, 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 the home to hospital pen. It is suggested when conducting future research on handling tools for the grow-finish pig, an important measure to collect is the amount of manure on the pen and alley floor as this could factor into movement ease.

Future research should also evaluate whether the peak force changed based on where the handle was positioned, for example, if the handle was held more at shoulder height (75° angle) vs being pulled at waist height (45° angle). The combination of employee height and handle lengths could also affect overall force.

Furthermore, baseline physiological measures (ie, heartrate, respiratory rate) were obtained to evaluate the difference in these traits prior to and after use of tools to move cadavers. Rather than using the raw physiological measure from the employees, the difference between these values prior to using a cadaver moving tool and the values measured after moving a cadaver was used as the dependent variable in the statistical analysis. The actual time to move a cadaver on any one tool might differ based on the

Table 3: Time to move grow-finish pig cadavers from the home pen to the hospital pen using three handling tools by four employees on three commercial grow-finish sites

	TOD		TTS		TTA		MUA		TD	
	LS Means* (SE), s	Range, s	LS Means* (SE), s	Range, s	LS Means* (SE), s	Range, s	LS Means* (SE), s	Range, s	LS Means* (SE), s	Range, s
Handling tools										
Sked	5.8 (0.4)	1-13	19.0 (1.7)[a]	9-47	12.5 (0.8)	5-28	29.9 (2.5)[a]	13-71	67.1 (3.0)[a]	32-98
Sled	6.2 (0.4)	2-14	57.9 (1.7)[b]	27-100	11.5 (0.8)	4-43	31.9 (2.5)[a]	14-80	107.5 (3.0)[b]	56-201
MDS	5.2 (0.4)	1-13	NA[†]	NA[†]	14.1 (0.8)	6-36	43.6 (2.5)[b]	16-190	63.0 (3.0)[a]	28-210
Employee										
1	5.7 (0.4)	1-13	41.2 (2.4)	9-97	14.0 (1.1)	5-43	36.4 (3.2)	18-151	83.3 (3.4)	28-201
2	6.6 (0.4)	1-13	33.3 (2.4)	9-100	11.8 (1.1)	4-34	33.0 (3.2)	12-190	73.7 (3.4)	30-210
3	5.6 (0.4)	2-14	41.6 (2.4)	11-97	14.2 (1.1)	7-29	34.9 (3.2)	16-125	82.6 (3.4)	33-154
4	5.1 (0.4)	2-12	37.5 (2.4)	13-87	10.8 (1.1)	5-36	36.1 (3.2)	19-127	77.2 (3.4)	28-170
Farm										
1	5.7 (0.4)	1-13	39.5 (2.6)	9-88	14.2 (1.1)[a]	5-36	55.0 (3.3)[a]	20-190	101.2 (3.7)[a]	44-210
2	6.0 (0.3)	2-14	39.9 (1.9)	11-100	14.4 (0.8)[a]	6-43	30.1 (2.5)[b]	13-127	77.02 (2.7)[b]	28-170
3	5.5 (0.3)	1-12	35.9 (1.9)	11-97	9.5 (0.9)[b]	4-28	20.4 (2.5)[c]	15-63	59.3 (2.7)[c]	28-127

* The LS means (SE) and range was derived from 15 cadavers (range: 59-134 kg) across three commercial farm sites.
† No results are available for restraining a cadaver onto the MDS, as the handling tool did not include restraints.
[a-c] LS Means within a column and each main effect with different superscripts differ ($P < .05$).
TOD = Duration to move cadaver from home pen floor onto the handling tool; TTS = Duration to secure cadaver on the handling tool; TTA = Duration to move handling tool and cadaver from home pen into the alleyway; MUA = Duration to move handling tool and cadaver along the alleyway and into the hospital pen; TD = Total duration to move cadaver from home to hospital pen (TOD+TTS+TTA+MUA); MDS = modified deer sled; NA = not applicable.

Table 4: Peak force to move grow-finish pig cadavers at the start and end of the alley using three handling tools by four employees on three commercial grow-finish sites

	SOA		EOA	
	LS Means (SE), N	Range, N	LS Means (SE), N	Range, N
Handling tools				
Sked	256.3 (7.1)[a]	90-443	228.3 (5.8)[a]	118-407
Sled	202.2 (7.1)[b]	99-384	181.1 (5.8)[b]	88-352
MDS	205.3 (7.1)[b]	84-423	191.5 (5.8)[c]	105-458
Employee				
1	237.7 (10.9)	122.8-428.9	184.4 (8.4)	117.9-291.5
2	222.5 (10.9)	90-384	207.5 (8.4)	114-340
3	232.2 (10.9)	132-443	207.5 (8.4)	88-458
4	192.7 (10.9)	84-325	201.9 (8.5)	112-381
Farm				
1	212.8 (10.4)[a]	108-442	185.3 (8.2)[a]	88-339
2	273.2 (9.1)[b]	90-428	236.9 (6.9)[b]	117-458
3	177.9 (9.1)[c]	84-326	178.6 (6.9)[a]	131-273

* The LS means (SE) and range was derived from 15 cadavers (range: 59-134 kg) across three commercial farm sites.
[a-c] Means within a column within each main effect with different superscripts differ ($P < .05$).
SOA = start of alley where peak force was measured immediately outside of the home pen; EOA = end of alley where peak force was measured inside the hospital pen; MDS = modified deer sled.

physical fitness for each employee. However, that was not the goal of the present study. The goal was to evaluate the duration difference required to perform the same task between varying cadaver weights using 3 handling tools. The employees enrolled in the study would represent similar range in fitness of barn workers that might eventually use the handling tools to move pig cadavers. In effect, the employees represent a nuisance variable that should be accounted for in the statistical model that evaluated the dependent variable of interest in this study.

Although there were no significant differences in oxygen saturation between employees, the health status of employees was unknown at the time of enrollment. It should be noted that if these tools are considered for use on farm, then caretaker health status should be discussed to make sure that the recommended tool is safe for the animals and employee health.

Throughout the handling tool survey, the MDS was ranked similarly to the sked and sled. However, when employees were asked about the MDS ease of movement and if they would recommend this handling tool, all employees said no because the MDS did not have restraint straps. After conclusion of the study, restraints similar to the sked's were affixed to the MDS and taken on-farm to be tested on a pig cadaver. 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 MDS would not be a suitable handling tool to move a non-ambulatory pig.

Future research should test whether different cadaver positioning on handling tools could affect movement ease. For example, positioning the cadaver with the tail closest to the handle vs head closest to the handle and cadaver in lateral recumbence vs 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. Furthermore, testing should occur when a pig becomes non-ambulatory inside the alley or the chute.

Table 5: Frequency of employee responses to the handling tool survey*

	Score frequency (%)				
Question†	**1**	**2**	**3**	**4**	**5**
Sked					
1. Rate the HT for:					
a) Rolling cadaver from home pen floor onto HT	0 (0)	1 (1.7)	7 (11.7)	32 (53.3)	20 (33.3)
b) Securing cadaver onto HT	0 (0)	0 (0)	6 (10.0)	23 (38.3)	31 (51.7)
2. Positioning ease of cadaver onto HT:					
a) Home pen	0 (0)	0 (0)	5 (8.3)	33 (55.0)	22 (36.7)
b) Alley	0 (0)	0 (0)	15 (25.0)	30 (50.0)	15 (25.0)
3. Rate the HT on:					
a) Moving HT in home pen towards pen gate	0 (0)	0 (0)	4 (6.7)	39 (65.0)	17 (28.3)
b) Moving HT out of home pen and into alley	0 (0)	0 (0)	12 (20.0)	32 (53.3)	16 (26.7)
c) Moving HT down the alley to hospital pen	0 (0)	3 (5.0)	8 (13.3)	34 (56.7)	15 (25.0)
4. Rate the HT on:					
a) HT size to move cadaver	0 (0)	0 (0)	27 (45.0)	26 (43.3)	7 (11.7)
b) HT weight to move cadaver	0 (0)	0 (0)	14 (23.3)	40 (66.7)	6 (10.0)
Sled					
1. Rate the HT for:					
a) Rolling cadaver from home pen floor onto HT	0 (0)	0 (0)	3 (5.0)	33 (55.0)	24 (40.0)
b) Securing cadaver onto HT	0 (0)	16 (26.7)	19 (31.7)	20 (33.3)	5 (8.3)
2. Positioning ease of cadaver onto HT:					
a) Home pen	0 (0)	1 (1.7)	5 (8.3)	33 (55.0)	21 (35.0)
b) Alley		0 (0)	4 (6.7)	11 (18.3)	27 (45.0)
3. Rate the HT on:					
a) Moving HT in home pen towards pen gate	0 (0)	0 (0)	2 (3.3)	26 (43.3)	32 (53.3)
b) Moving HT out of home pen and into alley	0 (0)	2 (3.3)	6 (10.0)	22 (36.7)	30 (50.0)
c) Moving HT down the alley to hospital pen	0 (0)	1 (1.7)	1 (1.7)	26 (43.3)	32 (53.3)
4. Rate the HT on:					
a) HT size to move cadaver	0 (0)	0 (0)	8 (13.3)	30 (50.0)	22 (36.7)
b) HT weight to move cadaver	0 (0)	0 (0)	0 (0)	35 (58.3)	25 (41.7)

Table 5: Continued

Question[†]	Score frequency (%)				
	1	2	3	4	5
MDS					
1. Rate the HT for:					
a) Rolling cadaver from home pen floor onto HT	0 (0)	0 (0)	4 (6.7)	24 (40.0)	32 (53.3)
b) Securing cadaver onto HT[‡]	NA	NA	NA	NA	NA
2. Positioning ease of cadaver onto HT:					
a) Home pen	0 (0)	2 (3.3)	6 (10.0)	24 (40.0)	28 (46.7)
b) Alley	1 (1.7)	6 (10.0)	16 (26.7)	14 (23.3)	23 (38.3)
3. Rate the HT on:					
a) Moving HT in home pen towards pen gate	0 (0)	1 (1.67)	4 (6.7)	20 (33.3)	35 (58.3)
b) Moving HT out of home pen and into alley	0 (0)	4 (6.7)	10 (16.7)	21 (35.0)	25 (41.7)
c) Moving HT down the alley to hospital pen	0 (0)	6 (10.0)	9 (15.0)	15 (25.0)	30 (50.0)
4. Rate the HT on:					
a) HT size to move cadaver	0 (0)	0 (0)	1 (1.7)	15 (25.0)	44 (73.3)
b) HT weight to move cadaver	0 (0)	0 (0)	0 (0)	15 (25.0)	45 (75.0)

* Four employees completed a combined total of 180 surveys.
[†] Questions 1 through 4 were scored using a 5-point scale: 5 = very easy, 4 = easy, 3 = neutral, 2 = difficult, and 1 = very difficult.
[‡] No results are available for securing cadavers onto MDS, as the handling tool did not include restraints.
HT = handling tool; MDS = modified deer sled; NA = not applicable.

Table 6: Mean employee responses to the handling tool survey*

Question[†]	Sked	Sled	MDS
	Mean (SD)[‡]	Mean (SD)[‡]	Mean (SD)[‡]
1. Rate the HT for:			
a) Rolling cadaver from home pen floor onto HT	4.2 (0.7)	4.4 (0.6)	3.2 (0.9)
b) Securing cadaver onto HT	4.4 (0.7)	4.5 (0.6)	NA[§]
2. Positioning ease of cadaver onto HT:			
a) Home pen	4.3 (0.6)	4.3 (0.8)	3.9 (0.9)
b) Alley	4.2 (0.7)	4.0 (0.7)	3.9 (1.1)
3. Rate the HT for:			
a) Moving HT in home pen towards pen gate	4.2 (0.6)	4.5 (0.6)	4.5 (0.7)
b) Moving HT out of home pen and into alley	4.1 (0.7)	4.3 (0.8)	4.1 (0.9)
c) Moving HT down the alley to hospital pen	4.0 (0.8)	4.5 (0.6)	4.2 (1.0)
4. Rate the HT for:			
a) HT size to move cadaver	4.0 (0.7)	4.2 (0.7)	4.7 (0.5)
b) HT weight to move cadaver	4.0 (0.6)	4.4 (0.5)	4.8 (0.4)

* Four employees completed a combined total of 180 surveys.
[†] Questions 1 through 4 were scored using a 5-point scale: 5 = very easy, 4 = easy, 3 = neutral, 2 = difficult, and 1 = very difficult.
[‡] The mean (SD) was compiled from 15 cadavers (range: 59-134 kg) across three commercial farm sites.
[§] No results for securing cadavers onto MDS, as the handling tool did not have restraints.
HT = handling tool; MDS = modified deer sled; NA = not applicable.

It is important to test potential on-farm handling tools for ease of use, employee safety,[11] and pig welfare.[12,13] 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.[14] The purpose of this study was to determine if the sked, sled, and MDS could be suitable handling tools for live non-ambulatory pigs on-farm. The 3 handling tools were selected due to durability, ability to move across a variety of terrain, large enough to withstand heavy weights, and can be rapidly deployed by one employee. These handling tools were chosen because they ranged in price, which would allow producers to have options when implementing these handling tools on farm. If producers have multiple farm sites, they may not be able to afford the sked ($327), but could afford the sled ($30) across multiple sites. These handling tools can be bought online and are relatively economical to modify.

This research would not support the MDS in its current form as a handling tool due to no restraints. No restraints caused pig cadavers to slide off the end and cadaver head and legs to get caught in the alleyway gates. This research does support the use of the sked and sled as practical handling tools to move grow-finish pig cadavers and show promise as useful handling tools to move non-ambulatory pigs on-farm.

Implications

Under the conditions of this study:

- The sked and sled were suitable for moving non-ambulatory grow-finish pigs.
- The MDS was not a suitable tool for moving non-ambulatory grow-finish pigs.
- More research on the sked and sled is needed for commercial farm application.

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Conflict of interest

None reported.

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