Characterising farrowing and piglet viability using a modified APGAR scoring system to predict piglet performance

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Abstract

Swine breeding goals have primarily focused on prolificacy, often overlooking the implications of larger litters on piglet welfare and performance. Parturition assessment via modified APGAR scoring systems to predict piglet survivability and performance remains novel in Australia. The objective is to utilise an APGAR scoring system to not only predict survivability, but to determine the effect of APGAR scores on growth performance. We hypothesize that this methodology can accurately predict piglet survivability and performance to ultimately guide management decisions. APGAR scores were collected at parturition of 105 piglets along with farrowing parameters to predict survivability and growth was monitored till the end of weaning for 83 piglets. Key findings for pre-weaning survivability were that piglets from older sows, larger litters and those with higher birthweights were significantly less likely to survive till weaning. The study also demonstrated that piglets receiving neonatal care had significantly lower APGAR scores, however interestingly the total APGAR score was not a significant predictor of piglet survivability. Another key finding was that male piglets and heavier piglets have higher ADG prior to weaning, however after weaning these factors had no effect on pig performance throughout the study. Overall, the results from this study highlight the importance of litter size and sow parity for farrowing monitoring and demonstrates piglet resilience to maintain growth throughout production regardless how stressful parturition may seem.

Introduction

Over time, selection of maternal breeds of sows have focused on high prolificacy, without much regard for individual piglet vitality and growth performance. These actions have been associated with increased pre-weaning mortality due to decreased birthweight and low litter heterogeneity[1], posing potential serious animal welfare issues. Additionally, pre-weaning mortality results in opportunity costs to the Australian pork sector as 18.5% of piglets born will die before weaning[2] and of these mortalities 80% will occur within the first 72 hours of a piglet's life[3]. Recently Austrian pig breeding organisations have revised breeding programs to include litter quality by assessment of piglet survivability, vitality and growth to address piglet mortality[4]. Viability relates to piglet survivability, whereas piglet vitality describes its strength and vigour which are essential for growth and performance. In 1966 a newborn scoring system was developed for clinics to describe vitality of newborn human babies[5]. It consisted of five parameters; Appearance, Pulse, Grimace, Activity and Respiration (APGAR).

Recently, this scoring system has been retrofitted to include parameters that can assess piglet vitality after birth[6]. It consisted of five parameters: skin colour, umbilical cord condition and latency for respiration, standing and suckling. Where skin colour of the snout as either pale or cyanotic[7] and ruptured umbilical cords can indicate hypoxaemia[6,7]. Respiration latency is time from birth till first breath, indicated via the first movement of the thorax followed by air exhalation. Latency to stand and suckle assesses neonates neuromuscular functions with prolonged periods indicating neurological deficits that can reduce vitality[7]. Each parameter is scored as either 0 (poor), 1 (moderate) or 2 (good), with a maximum obtainable score of 12. Additionally, a threshold of 6 was used to classify a neonatal piglet as viable[8]. Further parameters to be considered for piglet vitality were meconium staining associated with hypoxia[8] and interpiglet periods with prolonged intervals

increasing stillbirth incidence[9] and decreasing piglet vitality[10]. This methodology is yet to be applied to Australian pig breeding programs as these selection parameters can help curtail piglet mortalities, thereby improving neonatal welfare. Additionally, APGAR scoring correlation with factors proceeding farrowing remain yet to be evaluated within the literature with most studies terminating monitoring at the end of the nursery phase[6,11-13]. From evaluating APGAR scores along with average daily gain in this study the results can be further developed into industry certified checklists to be implemented within farming settings to improve piglet welfare standards and optimise commercial returns. Therefore, the objective of the present study is to evaluate the effect of vitality responses at parturition on growth performance throughout production till the grower phase.

Methods

The University of Sydney Ethics Committee (approval number: 2020/1481) approved the observational study, which was conducted at 'MayFarm', the University of Sydney piggery. A total of 10 Large White-Landrace (F1) sows and their litters (105 piglets) were included in the study. F1 sows and their litters were housed individually in farrowing swap pens (3m x 2.1m) in an environmentally controlled room containing eight crates with concrete and cast-iron slatted (1cm gap) flooring, a sow wet/dry feeder, one piglet nipple drinker for *ad libitium* water access and a heated creep area with wood shavings.

At parturition piglets were classified as live or still born and identified with marking paint to conduct vitality assessment using an adjusted APGAR scoring system[6]. In this study the APGAR score was modified and scored as either 0 (poor), 1 (moderate) or 2 (good). These APGAR parameters were; snout colour (Abnormal/Cyanotic, pale or pink), umbilical cord condition (ruptured before 15cm, ruptured after 15cm or connected to placenta), respiration latency (greater than 60 sec, between 15 and 60 sec or before 15 sec), standing latency (greater than 5 min, between 1 and 5min or less than 1min), suckling latency (greater than 30 min, between 15 and 30min or less than 15min) and meconium staining (body coverage greater than 25%, patchy staining less than 25% or no meconium present). Additional recorded parameters were neonatal care (rubbing piglet if no respiration after 15sec or removing mucous from the snout), sow intervention (oxytocin use or obstetrics), sow induction (luteinized) and sow neuroleptic administration (Stresnil).

All latencies were measured by stop watches, where respiration did not include agonal breathing, standing latency required extension of all four limbs and suckling required the piglet to latch onto the nipple with negative pressure. The total APGAR score was derived from the addition of the points from each of the six factors, with the highest score possible being 12 and the lowest score being 0. Out of the total 117 born piglets, 12 were stillborn and 105 were born alive. Due to post-parturition deaths (overlay, savaging or starvation) 22 piglets were excluded from the analysis for average daily gain (ADG). Additionally, sow parity, birth order and interpiglet interval were recorded. Bodyweight data was measured at birth & before weaning (28 days of age) using a digital bench scale, but after weaning (56 days of age) it was measured with a walkover weight scale.

All statistical analysis was conducted with RStudio (ver 1.4.1717, RStudio PBC, Massachusetts, USA). For all analyses, a p-value of <0.05 was considered significant.

The effect of umbilical cord condition, respiration latency, suckling latency, standing latency, neonatal care, meconium staining, sow parity, sow induction, sow neuroleptic administration, sow intervention, piglet sex, interpiglet interval, total born, born alive, total APGAR score and birthweight on survivability (post farrowing death) was assessed using generalized linear mixed models with an

underlying binary distribution and random effect of sow. Unfortunately, there was insufficient variability in counts for the two variables of snout colour and litter size to be statistically analyzed.

APGAR outcomes were analyzed using linear mixed models including a random effect of sow to determine the effect of sow induction, sow neuroleptic administration, sow intervention, neonatal care, piglet sex, litter size, interpiglet interval, total born, born alive and birthweight on total APGAR score.

For the models of sucker, weaner and overall ADG the effect of snout colour, umbilical cord condition, respiration latency, standing latency, meconium staining, suckling latency, neonatal care, litter size, sow parity, sow neuroleptic administration, sow intervention, sow induction, piglet sex, interpiglet interval, total born, born alive and total APGAR score on daily growth was assessed using linear mixed models, including a random effect of sow.

Univariate analyses from survivability, APGAR scores and ADG identified fixed effects for inclusion in the multivariate models, where P-values <0.25. Stepwise backwards elimination approach was used to determine the final model for each outcome, in which all terms were significant.

Results

Survivability data

The farrowing parameters of respiration, standing and suckling latencies, umbilical cord condition, meconium staining, neonatal care, sow neuroleptic administration, induction agents, sow intervention, piglet sex, birth order, interpiglet interval, born alive and total APGAR score had no significant effect on piglet survivability post farrowing (P = 0.0593-0.4845) [Table 1, 2]. There was a significant effect of sow parity on piglet survivability, with piglets from 5th parity sows being 10.5 times (95%Cl = 3.09-44.25) more likely to die compared to piglets born to gilts (P = 0.0036)[Table 1]. Total births had a significant effect on survivability; for every additional piglet born within a litter, the odds of post farrowing death increased by 1.4 units (P=0.01)[Table 2]. Additionally, birthweight had a significant effect on survivability; for every 1kg increase the odds of post-farrowing death increases by 0.01 units (P = 0.001) [Table 2]. The final model to predict piglet survivability included meconium staining (P = 0.013), respiration latency (P = 0.045), birthweight (P<0.001) and total born (P = 0.001) where piglets with higher respiration latencies, lower meconium staining, higher birthweights and larger litters were associated with greater post-farrowing deaths and poorer survivability.

Table 1. Univariate analysis of associations between post-farrowing survival status in 105 piglets and their farrowing parameters with sow included as a random effect. Variables with two categories the p-value is provided, whereas for variables with greater than two categories the overall p-value is provided. * indicates significance when P<0.05.

	Alive *n* (%)	Dead *n* (%)	OR	CI	p-value	Overall p-value
Respiration latency						0.2234
> 60 s	1 (1)	1 (1)	Ref			
15-60s	3 (2.9)	3 (2.9)	1.24	0.02-71.71	0.9935	
<15 s	79 (75.2)	18(17.1)	0.25	0.004-10.20	0.7248	
Standing latency						0.0872
> 5 min	10(9.5)	7 (6.7)	Ref			
1-5 min	47 (44.8)	10(9.5)	0.2	0.04-0.83	0.0831	
< 1 min	26 (24.8)	5 (4.8)	0.2	0.03-1.03	0.1499	
Suckling latency						0.3274

> 30 min	35 (33.3)	14 (13.3)	Ref			
15-30 min	30 (28.6)	6 (5.7)	0.53	0.15-1.74	0.56	
< 15 min	18 (17.1)	2 (1.9)	0.3	0.04-1.52	0.3724	
Meconium stain						0.13
> 25 %	11 (10.5)	4 (3.8)	Ref			
< 25 %	45 (42.9)	7 (6.7)	0.64	0.12-3.92	0.8646	
None	27 (25.7)	11 (10.5)	2.39	0.45-16.76	0.5985	
Cord condition						0.3279
Ruptured before 15cm	2 (1.9)	3 (2.9)	Ref			
Ruptured after 15cm	10 (9.5)	5 (4.8)	0.44	0.04-4.41	0.702	
Connected	71 (67.6)	14 (13.3)	0.23	0.02-2.02	0.3742	
Neonatal care						
No	78 (74.3)	17 (16.2)	Ref			
Yes	5 (4.8)	5 (4.8)	4.46	0.93-22.93	0.0593	
Sow Parity						0.0017*
0	36 (34.2)	4 (3.8)	Ref			
1	9 (8.6)	1 (0.1)	0.99	0.04-7.86	1	
2	8 (7.6)	1 (0.1)	1.12	0.05-8.99	1	
3	19 (18.1)	3 (2.9)	1.42	0.25-7.09	0.9928	
5	11 (10.5)	13 (12.4)	10.64	3.09-44.25	0.0036*	
Stresnil						
No	54 (51.4)	20 (19)	Ref			
Yes	29 (27.6)	2 (1.9)	0.18	0.01-1.20	0.0757	
Luteinized						
No	70 (66.7)	13 (12.4)	Ref			
Yes	13 (12.4)	9 (8.6)	3.8	0.57-28.03	0.1061	
Sow intervention						
No	81 (77.1)	20 (19)	Ref			
Yes	2 (1.9)	2 (1.9)	1.67	0.14-18.78	0.6665	
Sex						
Female	38 (36.2)	11 (10.5)	Ref			
Male	45 (42.9)	11 (10.5)	0.83	0.28-2.36	0.7263	

Table 2. Univariate analysis of associations between post-farrowing survival status in 105 piglets and their farrowing parameters with sow included as a random effect. * indicates significance when P<0.05.

Parameters	Intercept	SE	Estimate	SE	P-value
Birth order	0.254101	0.157416	0.94753	0.073055	0.4845
Interpiglet interval	0.329696	0.165676	0.968479	0.017491	0.0762
Total born	0.003207	0.005645	1.415519	0.191944	0.0104*
Born alive	0.010518	0.021711	1.298741	0.22689	0.1346
Total APGAR	1.702544	2.242761	0.775056	0.116336	0.0988
Birthweight	50.37252	67.80141	0.011777	0.012931	<0.001*

Factors affecting APGAR scores

The farrowing parameters of sow neuroleptic administration, induction agents, sow intervention, piglet sex, litter size, parity, born alive, total born, interpiglet interval, birth order and birthweight

have no significant effect on total APGAR scores (P= 0.060-0.840) [Table 3, 4]. Piglets receiving neonatal care shortly after birth averaged significantly lower mean total APGAR scores, compared to piglets that did not receive neonatal care (P<0.001) [Table 3]. The final model to predict total APGAR scores included birth order (P=0.049), neonatal care (P<0.001) and birthweight (P=0.031) where piglets born later in the farrowing, receiving supportive care at parturition and having higher birthweights were associated with lower total APGAR scores.

Table 3. Univariate analysis of associations between APGAR score in 105 piglets and their farrowing parameters with sow included as a random effect. * indicates significance when P<0.05.

	Mean APGAR	SE	CL	P-value
Stresnil				
No	9.05	0.435	8.05-10.05	0.2959
Yes	8.17	0.65	6.65-9.69	
Luteinized				
No	8.81	0.43	7.82-9.81	0.8401
Yes	8.61	0.884	6.6-10.62	
Sow intervention				
No	8.79	0.36	7.98-9.61	0.612
Yes	8.22	1.16	5.91-10.52	
Neonatal care				
No	9.07	0.291	8.41-9.73	<0.0001*
Yes	5.29	0.643	4.01-6.57	
Sex				
Female	8.88	0.409	8-9.75	0.6042
Male	8.69	0.394	7.84-9.55	
Litter size				
<9	8.06	0.871	6.03-10.1	0.5684
9-13	9.05	0.457	7.97-10.1	
>13	8.25	1.166	5.40-11.1	
Sow parity				
0	8.7	0.689	6.92-10.5	0.8279
1	9.22	1.37	5.65-12.8	
2	9.88	1.381	6.31-13.4	
3	8.89	0.97	6.36-11.4	
5	7.95	1.009	5.44-10.5	

Table 4. Univariate analysis of associations between APGAR score in 105 piglets and their farrowing parameters with sow included as a random effect. * indicates significance when P<0.05.

Parameter	Intercept	SE	Estimate	SE	P-value
Born alive	9.15152	1.56066	-0.03575	0.14314	0.8093
Total born	10.2186	1.5067	-0.1285	0.1303	0.3523
Interpiglet interval	8.864587	0.398678	-0.00361	0.007064	0.6162
Birth order	9.32132	0.46493	-0.09229	0.04807	0.0607
Birthweight	7.0972	1.0381	1.1931	0.6818	0.0893

Factors affecting ADG

Nursery ADG

The farrowing parameters of snout colour, respiration, standing and suckling latencies, umbilical cord condition, meconium staining, sow neuroleptic administration, induction agents, sow intervention, neonatal care, litter size, sow parity, birth order, interpiglet interval, born alive, total born and total APGAR score had no significant effect on the ADG of piglets during the nursery phase of production (P = 0.081 – 0.821) [Table 5, 6]. Sex had a significant effect on nursery ADG as males (253g ± 19.5) had a significantly higher ADG compared to female piglets (221g ± 19.9) (P=0.0135)[Table 5]. Additionally, birthweight had a significant effect on ADG; for every 1kg increase in birthweight the mean average daily gain increased by 77g (P = 0.004)[Table 6]. The final model to predict nursery ADG included birthweight (P=0.003) and total born (P=0.042), where piglets from larger litters and with lower birthweights had significantly decreased ADG.

Table 5. Univariate analysis of associations between average daily gain (g) of 83 **nursery piglets** and their farrowing parameters with sow included as a random effect. * indicates significance when P<0.05.

	Estimated mean ADG (g)	**SE**	**CL**	**P-value**
Snout colour				0.0811
Cyanotic	207	60.7	86.4-328	
Pale	194	28.4	136.1-252	
Pink	244	20.2	198.5-290	
Cord condition				0.9549
Ruptured before 15cm	246	47.2	152-340	
Ruptured after 15cm	243	27.4	187-299	
Connected	238	20.2	192-238	
Respiration latency				0.3847
> 60 s	291	63.8	165-418	
15-60s	201	41	119-283	
<15 s	240	19.2	196-283	
Standing latency				0.3401
> 5 min	234	28.3	176-292	
1-5 min	232	20.9	186-278	
< 1 min	253	22.6	205-302	
Meconium stain				0.6639
> 25 %	237	26.1	183-291	
< 25 %	233	20.8	188-279	
None	248	22.5	200-296	
Suckling latency				0.648
> 30 min	236	21.2	190-282	
15-30 min	234	21.5	188-281	
< 15 min	251	23.7	201-301	
Stresnil				0.8211
No	236	25.4	177-294	
Yes	246	38.4	157-335	
Luteinized				0.6962
No	235	23.4	181-289	
Yes	256	47.4	148-364	
Sow intervention				0.8107
No	238	20	193-248	

Yes	249	46.4	156-341	
Neonatal care				0.6649
No	240	20.2	194-285	
Yes	227	33.1	161-294	
Sex				0.0135*
Female	221	19.9	177-264	
Male	253	19.5	210-296	
Litter size				0.426
<9	295	45.3	189-402	
9-13	225	24	168.1-282	
>13	225	62.3	75.5-375	
Sow parity				0.06907
0	267	35.1	176.5-358	
1	206	70	24.4-387	
2	263	70.4	81.7-444	
3	243	49.6	114.5-371	
5	180	50.7	52.7-308	

Table 6. Univariate analysis of associations between average daily gain of 83 **nursery piglets** and their farrowing parameters with sow included as a random effect. * indicates significance when P<0.05.

Parameter	Intercept (g)	SE	Estimate (g)	SE	P-value
Born alive	365.439	71.646	-12.025	6.584	0.1055
Total born	386.537	68.154	-13.194	5.896	0.0549
Interpiglet interval	232.3418	20.2401	2.625	0.2723	0.3425
Birth order	248.323	22.455	-1.625	1.879	0.3921
Birthweight	130.15	40.57	77.38	25.69	0.0039*
Total APGAR	185.997	42.617	6.023	4.28	0.1687

Grower ADG

None of the recorded parameters had a significant effect on the ADG of pigs through the grower phase of production (P=0.0774-0.9742)[Table 7, 8].

Table 7. Univariate analysis of associations between average daily gain (g) of **83 weaners** and their farrowing parameters with sow included as a random effect. * indicates significance when P<0.05.

	Estimated mean ADG (g)	SE	CL	P-value
Snout colour				0.9742
Cyanotic	406	105.7	196-617	
Pale	424	42.9	338-510	
Pink	417	24	363-471	
Cord condition				0.8117
Ruptured before 15cm	440	77.3	286-593	
Ruptured after 15cm	398	40.3	317-479	
Connected	419	24.5	364-474	
Respiration latency				0.5028
> 60 s	502	107.5	288-716	
15-60s	366	66.4	234-499	

< 15 s	419	23.3	366-471	
Standing latency				0.4832
> 5 min	436	41.7	352-520	
1-5 min	406	25.6	350-462	
< 1 min	432	29.5	370-494	
Meconium stain				0.0774
> 25 %	474	37.2	398-549	
< 25 %	397	26.1	340-454	
None	424	29.6	362-486	
Suckling latency				0.4285
> 30 min	434	28.6	373-496	
15-30 min	400	29.3	337-462	
< 15 min	411	33.7	341-480	
Stresnil				0.9525
No	418	29.9	349-487	
Yes	415	44.8	310-519	
Luteinized				0.5628
No	410	27	347-473	
Yes	447	55.8	321-574	
Sow intervention				0.3100
No	415	23.3	363-468	
Yes	491	75.7	340-642	
Neonatal care				0.5787
No	419	23.4	367-472	
Yes	392	51.1	290-494	
Sex				0.9511
Female	417	26.6	359-474	
Male	418	25.7	362-474	
Litter size				0.7553
< 9	399	58.2	264-535	
9 - 13	414	30.6	341-486	
> 13	471	78	281-662	
Sow parity				0.5203
0	429	37.1	332-526	
1	322	73.6	129-515	
2	450	74.5	257-642	
3	468	52.2	332-605	
5	369	55.3	233-505	

Table 8. Univariate analysis of associations between average daily gain (g) of 83 **weaners** and their farrowing parameters with sow included as a random effect. * indicates significance when P<0.05.

Parameter	Intercept (g)	SE	Estimate (g)	SE	P-value
Born alive	330.731	95.189	8.182	8.721	0.3764
Total born	397.057	102.269	1.788	8.844	0.8448
Interpiglet interval	433.5393	25.5159	-0.67	0.4593	0.1554
Birth order	434.086	30.509	-2.846	3.223	0.3841
Birthweight	346.2	67.92	50.64	45.37	0.2778
Total APGAR	451.499	68.368	-3.909	7.289	0.6016

Overall ADG

The farrowing parameters of snout colour, respiration, standing and suckling latencies, umbilical cord condition, meconium staining, sow neuroleptic administration, induction agents, sow intervention, neonatal care, litter size, sow parity, sex, birth order, interpiglet interval, born alive, total born and total APGAR score had no significant effect on ADG of pigs through the entire duration of the study from parturition till entering the grower phase of production (P=0.1225-0.9882)[Table 9, 10]. Birthweight was the only factor to have a significant effect on overall ADG; for every 1kg increase in birthweight the mean overall ADG will increase by 66g (P=0.0496) [Table 10].

Table 9. Univariate analysis of associations between average daily gain (g) of 83 piglets **over the studies entire period** and their farrowing parameters with sow included as a random effect. * indicates significance when P<0.05.

	Estimated mean ADG (g)	SE	CL	P-value
Snout colour				0.8281
Cyanotic	319	72.6	175-464	
Pale	324	30.1	264-385	
Pink	340	17.6	300-380	
Cord condition				0.8699
Ruptured before 15cm	357	53.5	250-464	
Ruptured after 15cm	329	28.4	272-387	
Connected	339	18.1	298-379	
Respiration latency				0.3014
> 60 s	417	73.7	270-563	
15-60s	293	45.8	202-384	
< 15 s	339	16.8	301-377	
Standing latency				0.329
> 5 min	348	29.3	289-407	
1-5 min	328	18.8	287-370	
< 1 min	353	21.3	308-397	
Meconium stain				0.1225
> 25 %	369	36.4	316-423	
< 25 %	324	19	283-365	
None	347	21.3	302-391	
Suckling latency				0.4756
> 30 min	347	20.2	304-391	
15-30 min	325	20.7	281-369	
< 15 min	340	23.7	291-389	
Stresnil				0.9451
No	337	22.5	285-389	
Yes	340	33.8	261-419	
Luteinized				0.5458
No	332	20.3	286-379	
Yes	362	41.6	267-456	
Sow intervention				0.377
No	337	17.5	297-377	
Yes	382	52.4	278-486	

Neonatal care				0.5962
No	340	17.7	300-379	
Yes	321	35.8	250-393	
Sex				0.3119
Female	329	19.2	288-371	
Male	345	18.6	305-386	
Litter size				0.8402
< 9	354	44.4	251-458	
9 - 13	330	23.4	275-386	
> 13	358	60.1	212-504	
Sow parity				0.4172
0	357	26.4	289-426	
1	273	52.3	136-410	
2	366	52.9	229-502	
3	367	37	270-464	
5	285	39.1	189-381	

Table 10. Univariate analysis of associations between average daily gain (g) of 83 piglets **over the studies entire period** and their farrowing parameters with sow included as a random effect. * indicates significance when P<0.05.

Parameter	Intercept (g)	SE	Estimate (g)	SE	P-value
Born alive	349.943	75.466	-1.127	6.927	0.8749
Total born	396	74.342	-5.203	6.43	0.4415
Interpiglet interval	343.3864	19.4433	-0.2192	0.319	0.4999
Birth order	352.266	21.839	-2.397	2.21	0.2852
Birthweight	248.87	46.51	63.59	30.75	0.0457*
Total APGAR	337.4	47.65	0.07622	5.044	0.9882

Discussion

To our knowledge this is the first Australian study that reports on the effects of parturition on piglet survivability and growth using a modified APGAR scoring system. The findings from this study emphasises the detrimental effects of hypoxia on survivability during parturition previously reported in the literature, however these effects were short-lived with no significant effect on the overall subsequent growth rate of piglets monitored throughout the study.

Overall, post-farrowing survivability was found to negatively influenced sow parity, litter size and piglet birthweight. The study highlighted that sow parity significantly affected post-farrowing survival with piglets from 5th parity sows were approximately 10.5 times more likely to die after birth compared to piglets from gilts. Under Australian production system settings litter size has been found to be positively correlated with sow age until the sow reaches two years of age as their maximum physiological size has been achieved[14]. Therefore, higher parity sows which are older than gilts will have larger litters and subsequently their piglets will have lower birthweights, which has been found to compromise piglet survivability[15-17]. Increasing litter sizes with older sows is likely due to higher ovulation rates along with embryo survival that induces uterine crowding[18], thereby reducing uterine blood flow per foetus to compromise nutrient supply and result in reduced bodyweight in piglets from larger litters[17]. Findings from this study determined that older parity sows and larger litters had decreased survivability, aligning the with previous literature mentioned

above. However, due to the restricted sow numbers within this study the interpretation of their parameters should be taken into consideration and subsequently further research with additional sows is required to ascertain a more conclusive result.

Furthermore, this study found that increased birthweight resulted in lower piglet survivability which contradicts with phenomena explained above and the current literature which consistently found that increased birthweight increases piglet survivability[16]. This studies discrepancy likely stems from larger piglets at higher risk of experiencing dystocia during farrowing[19] and subsequently resulting in hypoxemic piglets with physically exhausted sows, where both outcomes could greatly increase the incidence of overlay in the farrowing pen contributing to preweaning mortalities. In relation to the final model for post-farrowing survivability, both meconium staining and respiration were significant along with birthweight and total born when predicting pre-weaning mortality. This study concluded that piglets with no meconium staining were 2.4 times more likely die post-farrowing than piglets with a meconium staining covering more than 25% of their body. The literature states that meconium staining is positively correlated with hypoxaemia[6,20]. This discrepancy between results could be due to the following reasons. Firstly, meconium staining was subjectively measured which is prone to potential observer bias or desensitisation overtime and in futures studies a meconium staining chart can be developed and utilised to standardise staining measurement. Alternatively, piglets could have been subject to meconium aspiration syndrome (MAS) where piglets aspirate meconium during their first few breathes and develop a multifocal granulomatous inflammation involving all the lung lobes[20]. Meconium staining is not correlated with MAS[20], which could be responsible for the conflicting post-farrowing mortality results. Future studies should include histological analysis from pre-weaning piglet mortalities to rule out the presence of multifocal respiratory infections potentially induced by MAS. Respiration latency teetered into significance within the final survivability model, where piglets initiating respiration within the first 15 seconds of life were 4 times less likely to die post-farrowing compared to piglets initiating respiration after 60 seconds of life. In humans respiration is induced by sensory stimulation (cutaneous cooling or sciatic nerve stimulation) during birth, however any delay in gas exchange induces a rise in arterial partial pressure of carbon dioxide (pCO_2), increases lactate levels and lowers pH inducing respiratory acidosis[21]. This ideology holds true in neonatal anaesthetised piglets with increased arterial pCO_2 inducing a decrease in renal blood flow, thereby inciting reduced renal tissue perfusion and polyuria with increased electrolyte excretion[22], which is likely to be the underlying mechanism for the increased likelihood of post-farrowing mortality with delayed respiration at parturition[22]. To minimise pre-weaning mortality, producers must employ adequate farrowing monitoring systems that target older parity sows likely to have larger litters and identify hypoxaemic piglets due to dystocia. Unfortunately, the modified APGAR scoring system is unfeasible to be applied on-farm and also does not provide an accurate measurement of piglet viability in Australian pork production. Therefore, future research should be focused on the integration of video software that can estimated piglet size upon parturition and monitor farrowing intervals in real-time to flag sows undergoing dystocia and accurately direct staff to provide support to hypoxemic piglets.

Applicability of the modified APGAR scoring system on-farm provides logistical issues based around labour and yields little cost benefit. Therefore, industry can implement a targeted monitoring approach based on birthweight and litter order to best utilise staff to help combat and prevent post-farrow mortality. This observation study has highlighted that neonatal care was the only external farrowing factor to significantly influence an individual piglets APGAR score. As piglets receiving any neonatal care in the form of rubbing to help initiate respiration, snout mucous removal or amniotic sac detachment averaged a total APGAR score of five. This finding is in alignment with the literature as piglets receiving neonatal care had poorer viability[2], therefore highlighting the critical importance

of neonatal care to help support these piglets through the nursery phase and into weaning. Within the final model, piglets receiving neonatal care along with both lower birthweights and later birth orders led to lower total APGAR scores. Biologically this corresponds with a recent study that found that heavier piglets and piglets born within the first 75% of the litter had increased survival till weaning[16]. Overall, these results highlight that focussing resources to piglets born later in the birth order and with lower birthweights is critical to reduce pre-weaning mortality, therefore further highlighting the future potential for real-time monitoring on farm to help identify piglets at high risk of pre-weaning mortality.

Interestingly, in this study, sexual dimorphism had significantly influenced piglet ADG during the nursery phase (28 days of life) with the estimated mean ADG of males being 33g ± 19.5g higher than females (P = 0.013). This finding conflicts with the current literature as previous studies found that sex has no significance on ADG[23] or male only litters had poorer growth in comparison to female only litters[24]. However, in both these studies litters were cross fostered based on bodyweight[23] or sex[24], which could explain the discrepancies between all published findings and this studies results. Birthweight was found to be positively correlated with ADG within the nursery period specifically and the overall time period as heavier piglets had higher growth. This finding is consistent with the literature stating that piglets with lower birthweights have compromised ADG and these smaller piglets tended to originate from larger litters[25]. Again, this knowledge aligns with the trend found within this study, as larger litter sizes negatively influenced ADG because larger piglets have a better capacity to compete for the teat, therefore having overall higher levels of colostrum intake[25]. One interesting trend found during the nursery phase of production was that piglets with cyanotic and pale pink snouts had lower ADG compared to piglets with pink non-hypoxemic snouts. Findings from numerous studies have demonstrated mixed results with the one study quantifying hypoxaemia via umbilical blood lactate and determined that piglets with asphyxia had slower growth rates over the first 10 weeks of life[26]. Whereas another prior study utilising visual assessment of hypoxaemia determined that cyanotic skin colour was only an indicator of pre-weaning mortality and not growth performance[27]. This discrepancy within the literature is that visual assessment of hypoxemia via a qualitative trait like skin colour could be failing to identify subtle forms of hypoxia due to variable nursery lighting intensity or observer bias from desensitisation over time and therefore, failing to identify the downstream effects of asphyxia on growth performance. Future research should focus on the development and verification of snout colour charts or video software programmes that could help standardise the visual assessment of hypoxia and potentially ascertain if the presence of visual hypoxia does actually impact upon piglet performance throughout production. Additionally, further research could focus on gastrointestinal changes in piglets previously challenged with asphyxia to determine if this decline in ADG from the previous literature[27] was simply due to compromised colostrum intake or long-term physiological or histological changes of the gastrointestinal tract.

In conclusion this paper demonstrated that out of all the measured farrowing characteristics, the only significant effect on piglet ADG was the cumulative effect of birthweight on piglet ADG prior to weaning. Additionally, bodyweight or any of the other farrowing characteristics had no prolonged effect as piglets matured progressing into grower production. These findings indicated that heavier piglets will be able to obtain the higher ADG and that producers should focus on monitoring farrowings of older sows with larger litters to minimise neonatal mortality, as the effects of parturition were found to have no significant effect on subsequent growth during the production process till the grow out phase. Future research should include the grower and finisher stages of production along with carcase characteristics to determine whether farrowing characteristics can influence growth on later production stages or potentially alter meat quality.

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References

1. Vanderhaeghe C, Dewulf J, de Kruif A, Maes D. Non-infectious factors associated with stillbirth in pigs: a review. Animal reproduction science. 2013 Jun 1;139(1-4):76-88.
2. Australian Pork Limited, 2012. Australian Herd Breeding Statistics. Australian Pig Annual 2011 - 2012,p. 14.
3. Mitchell P. Guidelines for Fostering [Internet]. Australian Pork Limited; 2018 p. 4. Available from: https://australianpork.com.au/best-practice-fostering
4. Schodl K, Revermann R, Winckler C, Fuerst-Waltl B, Leeb C, Willam A, Knapp P, Pfeiffer C. Assessment of Piglet Vitality by Farmers—Validation of A Scoring Scheme and Estimation of Associated Genetic Parameters. Animals. 2019 Jun;9(6):317.
5. Apgar V. The newborn (Apgar) scoring system: reflections and advice. Pediatric Clinics of North America. 1966 Aug 1;13(3):645-50.
6. Revermann R, Winckler C, Fuerst-Waltl B, Leeb C, Pfeiffer C. Assessment of viability of new born piglets using an adjusted APGAR score. Journal of Central European Agriculture. 2018 Dec 18;19(4):829-33.
7. Mota-Rojas D, López A, Martínez-Burnes J, Muns R, Villanueva-García D, Mora-Medina P, González-Lozano M, Olmos-Hernández A, Ramírez-Necoechea R. Is vitality assessment important in neonatal animals?. CAB Reviews. 2018;13(036):1-3.
8. Mota-Rojas D, Martinez-Burnes J, Villanueva-Garcia D, Roldan-Santiago P, Trujillo-Ortega ME, Orozco-Gregorio H, Bonilla-Jaime H, Lopez-Mayagoitia A. Animal welfare in the newborn piglet: a review. Veterinarni Medicina. 2012 Jul 1;57(7).
9. Spicer EM, Driesen SJ, Fahy VA, Horton BJ, Sims LD, Jones RT, Cutler RS, Prime RW. Causes of preweaning mortality on a large intensive piggery. Australian Veterinary Journal. 1986 Mar;63(3):71-5.
10. Islas-Fabila P, Mota-Rojas D, Martínez-Burnes J, Mora-Medina P, González-Lozano M, Roldan-Santiago P, Greenwell-Beare V, Gonzalez-Hernandez M, Vega-Manriquez X, Orozco-Gregorio H. Physiological and metabolic responses in newborn piglets associated with the birth order. Animal reproduction science. 2018 Oct 1;197:247-56.
11. Rootwelt V, Reksen O, Farstad W, Framstad T. Postpartum deaths: piglet, placental, and umbilical characteristics. Journal of Animal Science. 2013 Jun 1;91(6):2647-56.
12. Schodl K, Revermann R, Winckler C, Fuerst-Waltl B, Leeb C, Willam A, Knapp P, Pfeiffer C. Assessment of Piglet Vitality by Farmers—Validation of A Scoring Scheme and Estimation of Associated Genetic Parameters. Animals. 2019 Jun;9(6):317.
13. Santiago PR, Martínez-Burnes J, Mayagoitia AL, Ramírez-Necoechea R, Mota-Rojas D. Relationship of vitality and weight with the temperature of newborn piglets born to sows of different parity. Livestock Science. 2019 Feb 1;220:26-31.

14. French LR, Rutledge JJ, First NL. Effect of age and parity on litter size in pigs. Reproduction. 1979 Sep 1;57(1):59-60.
15. Akdag F, Arslan S, Demir H. The effect of parity and litter size on birth weight and the effect of birth weight variations on weaning weight and pre-weaning survival in piglet. Journal of Animal and Veterinary Advances. 2009;8(11):2133-8.
16. Gourley KM, Calderon HI, Woodworth JC, DeRouchey JM, Tokach MD, Dritz SS, Goodband RD. Sow and piglet traits associated with piglet survival at birth and to weaning. Journal of Animal Science. 2020 Jun;98(6):skaa187.
17. Kitkha S, Boonsoongnern A, Ratanavanichrojn N, Jirawattanapong P, Pinyopummin A. Effects of the higher parity and litter size on piglet birth weight and survival rate of later born piglets. The Thai Journal of Veterinary Medicine. 2017 Mar 1;47(1):79.
18. Milligan BN, Fraser D, Kramer DL. Within-litter birth weight variation in the domestic pig and its relation to pre-weaning survival, weight gain, and variation in weaning weights. Livestock Production Science. 2002 Aug 1;76(1-2):181-91.
19. Nam NH, Sukon P. Risk factors associated with dystocia in swine. Veterinary World. 2021 Jul 1;14(7).
20. Castro-Nájera JA, Martínez-Burnes J, Mota-Rojas D, Cuevas-Reyes H, Lopez A, Ramírez-Necoechea R, Gallegos-Sagredo R, Alonso-Spilsbury M. Morphological changes in the lungs of meconium-stained piglets. Journal of veterinary diagnostic investigation. 2006 Nov;18(6):622-7.
21. Adamson SL. Regulation of breathing at birth. J Dev Physiol. 1991 Jan 1;15(1):45-52.
22. Alward CT, Hook JB, Helmrath TA, Bailie MD. Effects of asphyxia on renal function in the newborn piglet. Pediatric research. 1978 Mar;12(3):225-8.
23. Škorjanc D, Brus M, Čandek Potokar M. Effect of birth weight and sex on pre-weaning growth rate of piglets. Archives Animal Breeding. 2007 Oct 10;50(5):476-86.
24. Dunshea FR. Sexual dimorphism in growth of sucking and growing pigs. Asian-Australasian Journal of Animal Sciences. 2001;14(11):1610-5.
25. Nuntapaitoon M, Muns R, Tummaruk P. Newborn traits associated with pre-weaning growth and survival in piglets. Asian-Australasian journal of animal sciences. 2018 Feb;31(2):237.
26. Langendijk P, Fleuren M, Van Hees H, Van Kempen T. The course of parturition affects piglet condition at birth and survival and growth through the nursery phase. Animals. 2018 May;8(5):60.
27. Panzardi A, Bernardi ML, Mellagi AP, Bierhals T, Bortolozzo FP, Wentz I. Newborn piglet traits associated with survival and growth performance until weaning. Preventive Veterinary Medicine. 2013 Jun 1;110(2):206-13.