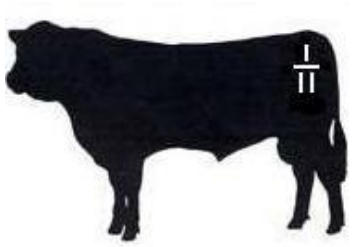
Genetics of Heart Score and Relationships with Performance

S. E. Speidel, R. Mark Enns, M. G. Thomas, I.M. Kukor and T. N. Holt
Department of Animal Sciences
Department of Clinical Sciences
Colorado State University

CGEL
CENTER FOR GENETIC EVALUATION OF LIVESTOCK
Colorado State University



Many contributors to pulmonary hypertension research

Faculty:
R. Mark Enns
Scott Speidel
Milt Thomas

Grad Students:
Natalie Crawford
Kaysie Jennings
Miguel Sanchez
Heather Foxworthy
Emma Briggs
Courtney Pierce
Kathryn Heffernan
Taylor Zimprich
Lane Giess
Isabella Kukor

Health (DVM/MD/PhD):
Tim Holt ******
Frank Garry
Greta Krafsur (pathology & DVM-PhD)
Kurt Stenmark
Dale Brown

Post-doc:
Hamad Saad

Collaborators:
ABS Global
Cactus Feeders
Hy-Plains Feedyard, LLC
Veterinary Research and Consulting Services, LLC
USDA MARC – Drs. Kuehn, McDaneld, Jones, Keele

Cattle's Biological Disadvantages

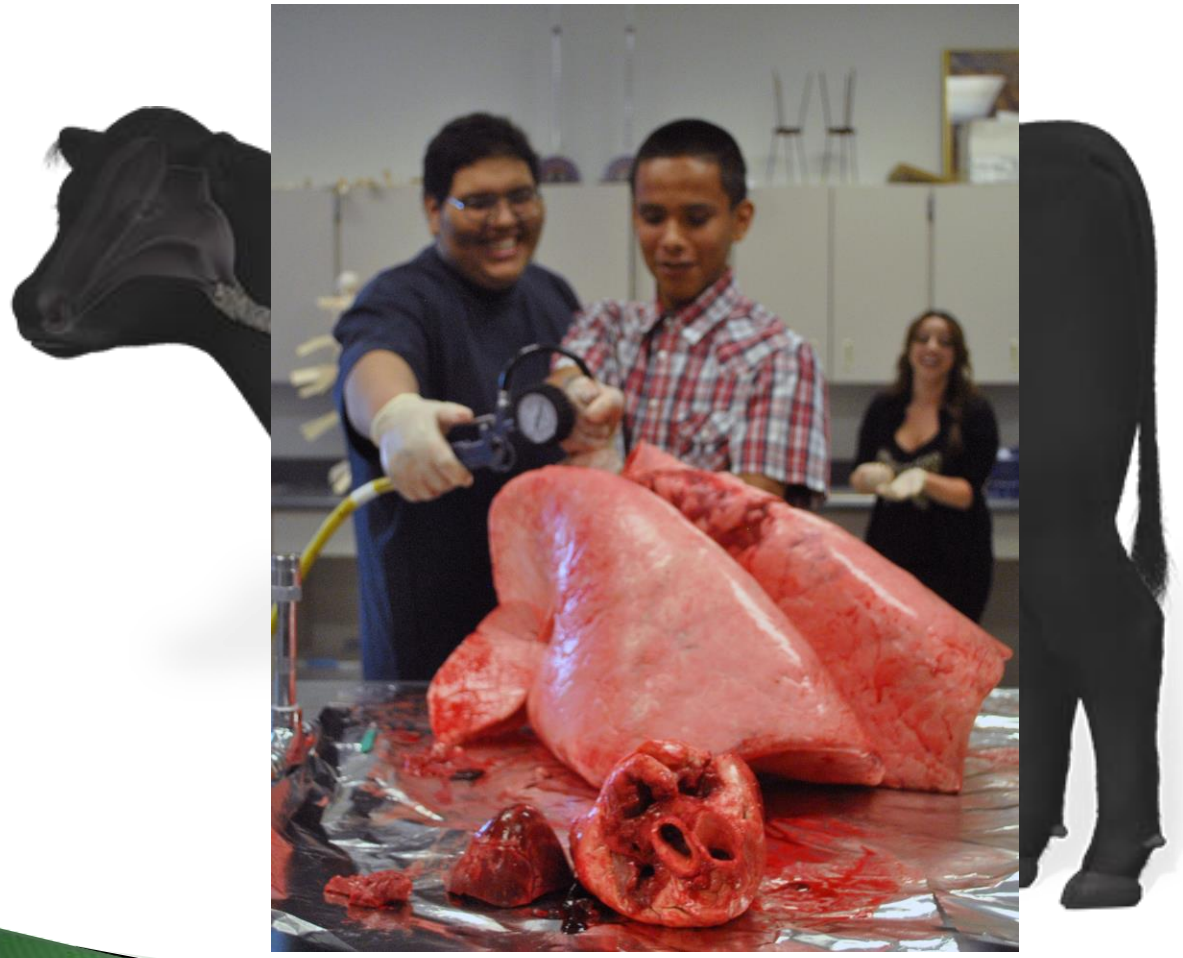


Photo provided by Frost Racing Limited. Equine lung inflated fully.

Kukor, 2022

Progression of Pulmonary Hypertension

Critical Piece:

Is the cause

Genetic?
Environmental?

Alveolar Hypoxia

↓

Pulmonary Vasoconstriction

↓

Pulmonary Remodeling

↓

Pulmonary Hypertension

↓

Right Ventricular Hypertrophy

↓

Right Ventricular Dilation

↓

Right Heart Congestive Failure

Dr. Tim Holt

High Altitude Disease

- Condition affecting cattle at altitudes of >5,000 ft.
- Pulmonary artery begins to constrict and thicken in response to low oxygen being transported.
- Selecting bulls with lower PAP has been successful in producing progeny with lower PAP scores.

Feedlot Heart Disease

- Condition affecting feedlot cattle at low to moderate altitudes.
- Direct cause is currently unknown, but these individuals experience heart remodeling which is similar to animals experiencing brisket disease.

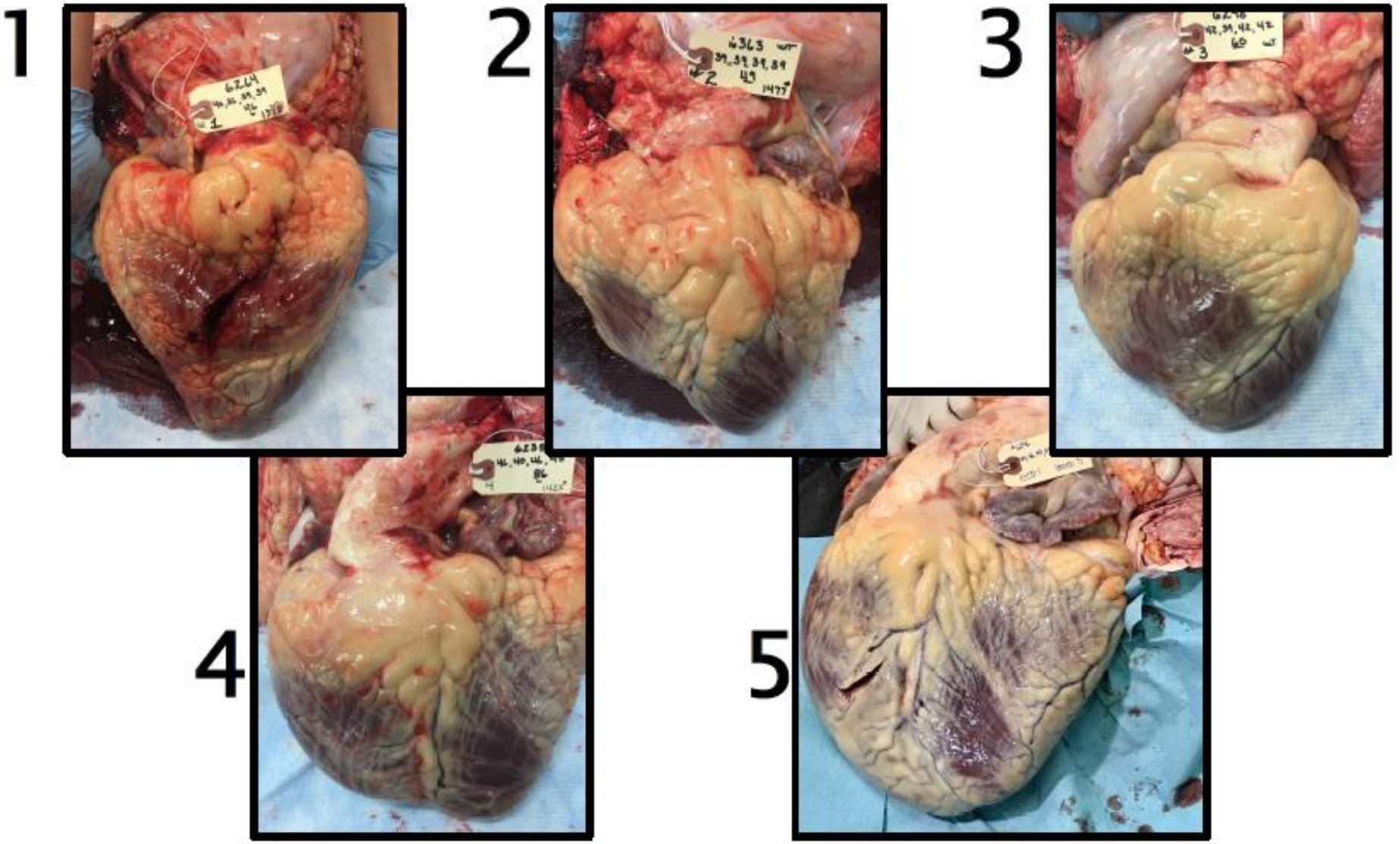
PAP is currently used as a decision factor for culling animals in the herd, who display high PAP at early ages.

Kukor et al., 2021

Performance and Carcass Traits Relationship to Cardiovascular Health

- Carcass traits tend to have a weak to moderate correlation with yearling PAP. Larger cattle tend to have higher PAP scores.
- Heavily muscled cattle may be more prone to higher risk of PH.
- High PAP cattle are less efficient in terms of feed efficiency and average dry matter intake.
- Stress in cattle can influence meat quality, possible to see this if cortisol levels increase (as shown in humans with pulmonary hypertension) quality of meat could be affected.

Heart Scoring System



Holt et al., as presented in Heffernan et al., 2020

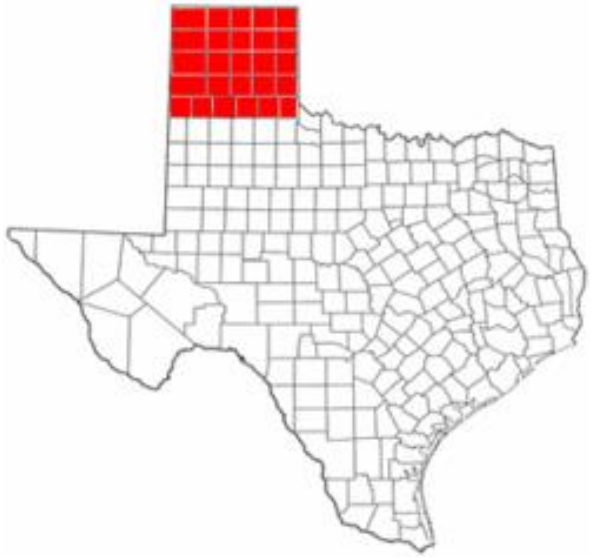
Development of metrics to identify cattle predisposed to feedlot heart failure.

- Foundation for Food and Agricultural Research's (FFAR)
- International Consortium for Antimicrobial Stewardship in Agriculture (ICASA)
- FFAR-ICASA-0000000018
- Collaborators:
  - Colorado State University
  - RTI LLC. Brookings, SD
  - ABS Global
  - Cactus Research, Hy-Plains Feedyard LLC.
  - Veterinary Research and Consulting Services, LLC

- Objectives:
  1. Quantify the relationship between pulmonary arterial pressure measured in fattened cattle and heart scores collected at slaughter.
  2. Examining potential factors indicated in feedlot heart disease including the role of genetics in disease incidence.
  3. Determine the effect of heart remodeling during the feeding period on feedlot and carcass performance.
  4. Development of selection tools in the form of EPD for Feedlot Heart Disease Resistance.

Phenotypic Differences in Normal Cattle Heart Structures and Remodeled Cattle Heart Structures in Response to Pulmonary Hypertension

Data -



- 1,422 head of cattle, Angus influenced breeds, panhandle of Texas
  - 760 steers and 662 heifers.
  - Average age: 483 d
- Elevation to be 1,080m
- Cattle harvested at Tyson Foods in Amarillo, TX.
- Carcass traits collected by West Texas University Meat Science students.

- Data were analyzed utilizing R-Studio software and the Animal Breeders Toolkit.

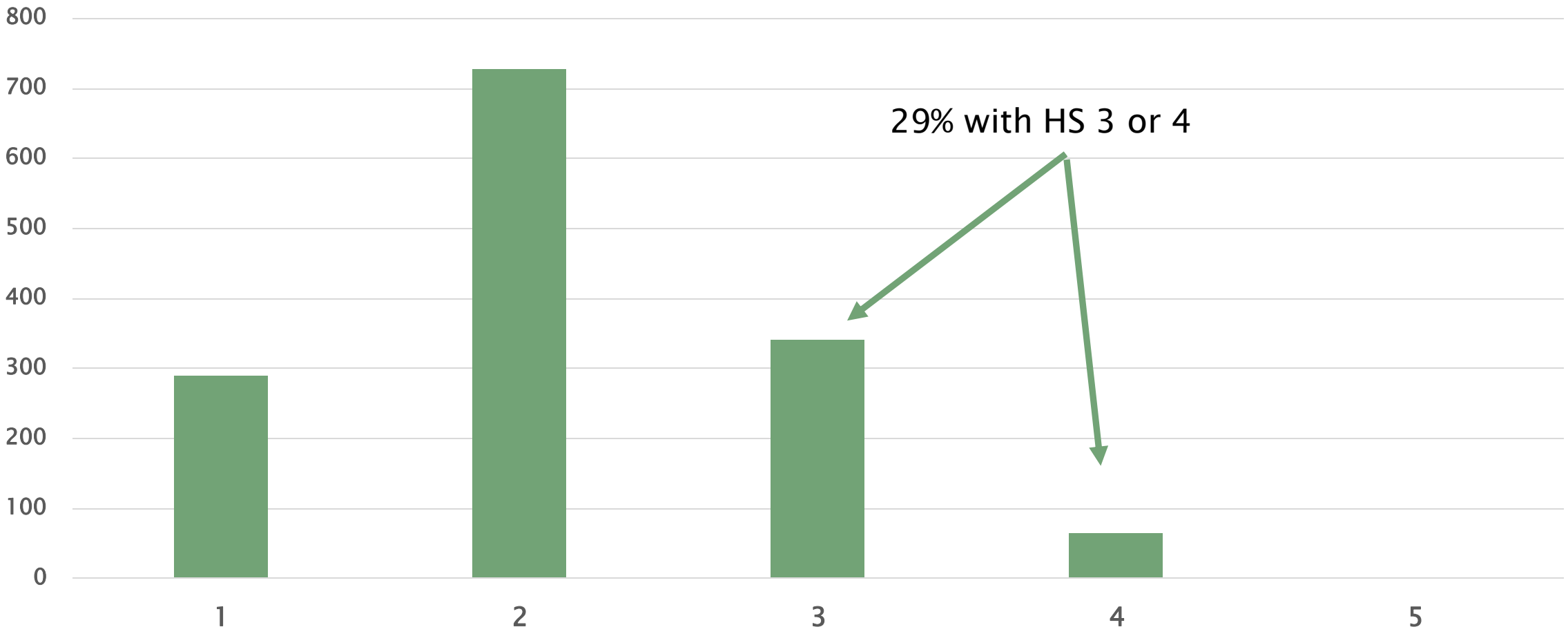
Summary Statistics:

Total of 1,422 head

- Majority of data are traits collected at the plant.
- Intake data
  - ~45 days in program
  - ~200 days on feed

Trait	n	Mean	Std. Dev.	Min	Max
Heart Score	1,422	2.13	0.78	1	4
PAP (9 months)	178	39.8	2.83	34.0	48.0
PAP (14 months)	352	49.4	12.84	32.0	151.0
Backfat (mm)	1,401	17.8	5.33	4.64	41.7
Marbling Score	1,401	502.2	97.23	281.0	952.0
Ribeye Area (mm^2)	1,401	9,116.1	922.58	5,374.2	12619.3
Hot Carcass Weight (kg)	1,414	404.8	50.31	214.1	561.8
Average Daily Gain (kg)	557	2.1	0.51	-1.4	3.4
Dry Matter Intake (kg)	323	10.3	1.38	4.7	15.2
Feed Conversion Ratio	206	2.4	1.10	-7.4	6.3
Weaning Weight (kg)	868	208.2	42.09	87.3	349.1

Histogram of Heart Scores



Results

Healthy heart scores (1 and 2) in comparison with unhealthy scores.

Welch t test comparisons of means used to determine the differences between group means.

$$t = \frac{\mu_A - \mu_B}{\sqrt{\frac{\sigma^2}{n_A} + \frac{\sigma^2}{n_B}}}$$

Trait	Healthy Hearts (Scores 1 & 2)			Unhealthy Hearts (Scores 3+)			P-value
	n	mean	sd	n	mean	sd	
PAP(9m)	140	39.7	2.62	38	40.3	3.5	0.352
PAP (14m)	246	46.9	8.11	106	55.2	18.7	<0.01***
Backfat(mm)	1,007	17.8	5.33	399	17.8	5.1	0.998
Marbling	1,007	507.0	101.12	399	483.8	100.9	<0.01***
Ribeye Area (mm^2)	1,007	9,148.4	961.21	399	9,129.0	954.8	0.752
HCW (kg)	1,014	403.4	49.24	400	408.5	52.8	0.10*
ADG (kg)	388	2.0	0.47	169	2.1	0.60	0.359
DMI (kg)	231	10.2	1.29	92	10.3	1.6	0.674
FCR	162	2.52[A]	0.59	44	1.96[A]	2.1	0.08*
Yield Grade	1,018	3.97	0.87	404	4.02	0.90	0.318

Phenotype= Lot + Heart Score

Sex Hdate Scorer

PAP14:

HS: $\beta = 6.04$, $P < 0.05$

Lot : $P < 0.05$

Marbling:

HS: $\beta = -8.52$, $P < 0.05$

Lots: $P < 0.05$

HCW:

HS: $\beta = 10.94$, $P < 0.05$

Lot: $P < 0.05$

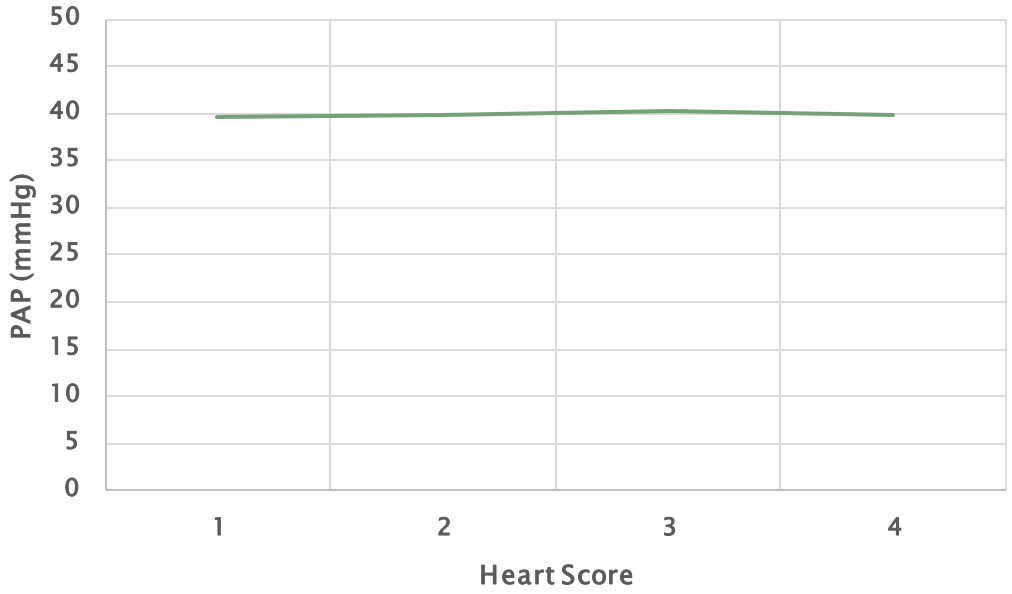
Trait	Heart Scores			
	1	2	3	4
	mean	mean	mean	mean
PAP(9m)	39.61 ± 2.48	39.82 ± 2.78	40.36 ± 3.47	39.80 ± 3.77
PAP (14m)	45.00 ± 5.71	47.77 ± 8.95	51.79 ± 11.82	66.83 ± 30.27
Backfat (mm)	17.78 ± 5.84	17.78 ± 5.80	17.78 ± 4.82	17.27 ± 5.33
Marbling Score	520.06 ± 107.09	502.51 ± 96.49	484.87 ± 102.43	478.17 ± 92.73
Ribeye Area (mm^2)	9,290.30 ± 941.93	9,206.43 ± 903.22	9,174.18 ± 941.93	8896.76 ± 987.09
Hot Carcass Weight	390.71 ± 51.49	407.23 ± 47.37	410.19 ± 51.51	393.74± 57.28
Average Daily Gain	1.91 ± 0.44	2.09 ± 0.48	2.12 ± 0.49	1.95 ± 0.87
Dry Matter Intake	10.07 ± 1.28	10.32 ± 1.29	10.31 ± 1.53	10.31 ± 1.88
Yield Grade	2.95 ± 0.90	3.00 ± 0.83	3.06 ± 0.81	3.02 ± 0.96

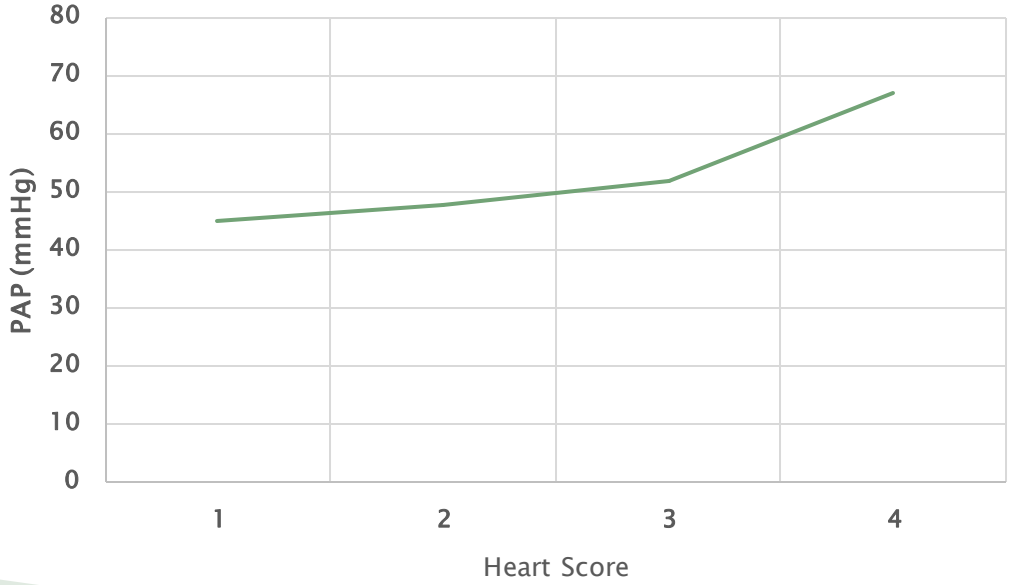
Kukor, 2022

Pulmonary Arterial Pressure by Heart Score

Heart Score	9-month PAP	Standard Deviation
1	39.61	2.48
2	39.82	2.78
3	40.36	3.47
4	39.8	3.77

Heart Score	14-month PAP	Standard Deviation
1	45	5.71
2	47.77	8.95
3	51.79	11.82
4	66.83	30.27

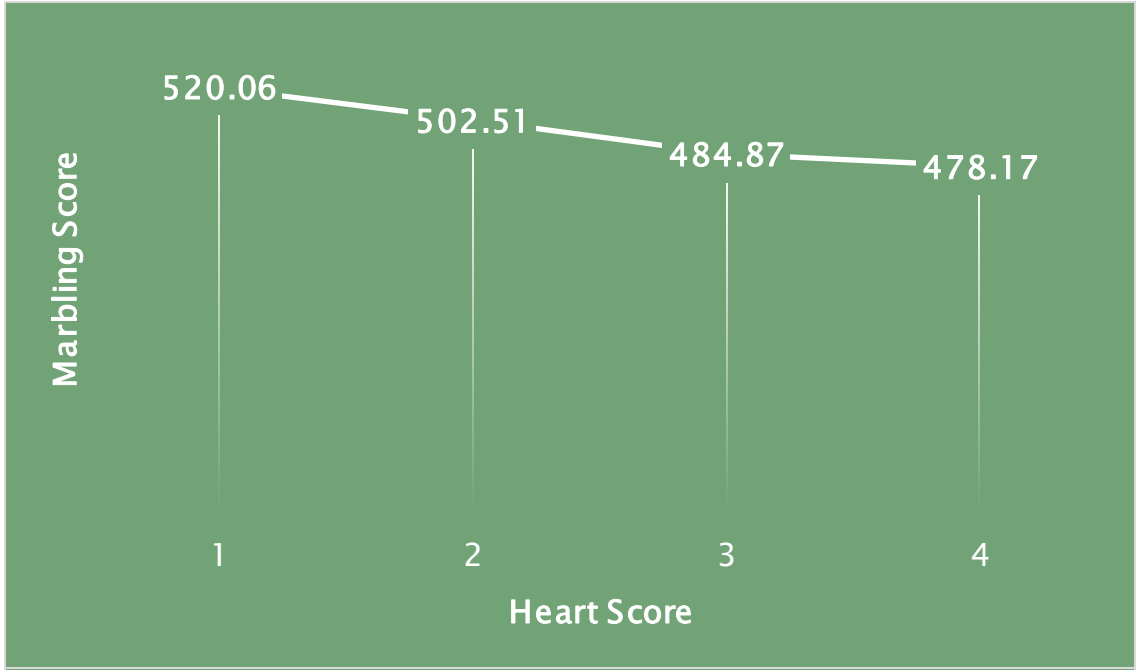


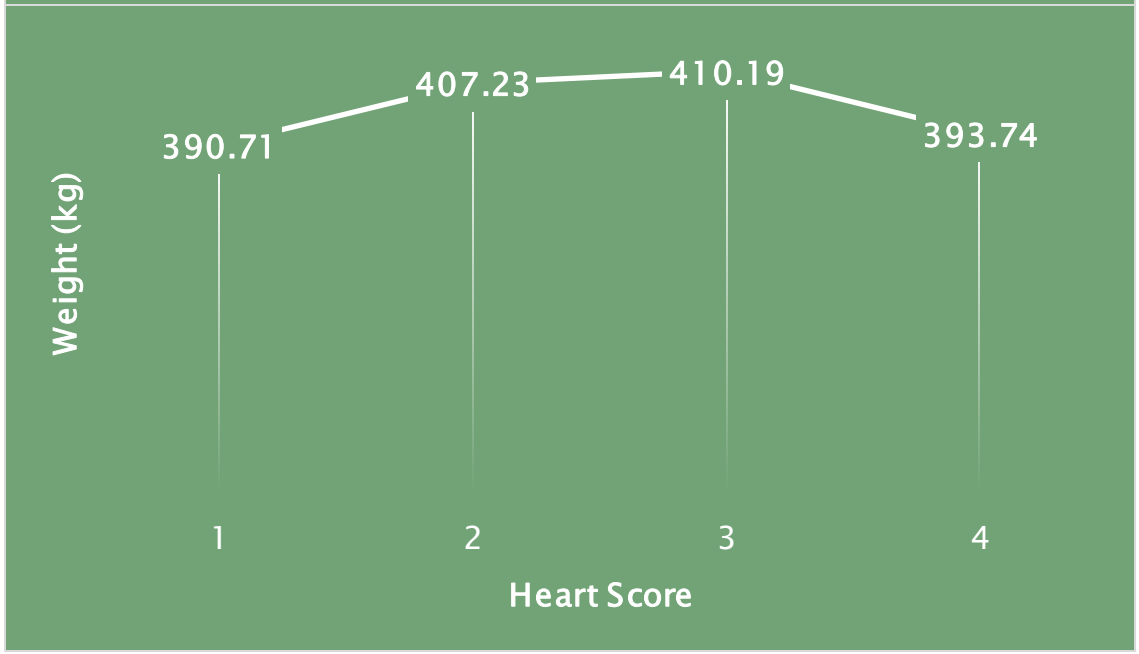


Carcass Traits by Heart Score

Heart Score	Marbling Score	Standard Deviation
1	520.06	107.09
2	502.51	96.49
3	484.87	102.43
4	478.17	92.73

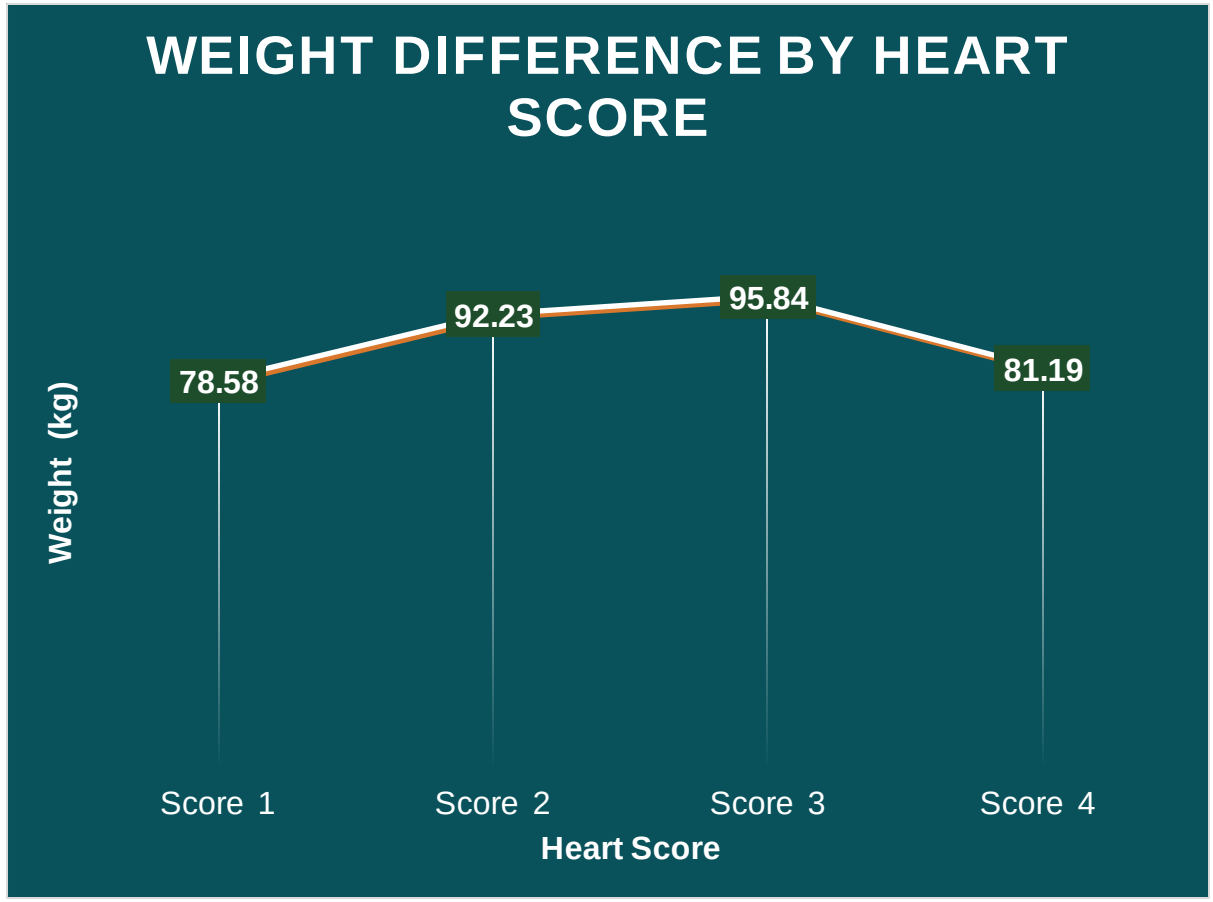
Heart Score	Carcass Weight	Standard Deviation
1	390.71	51.49
2	407.23	47.37
3	410.19	51.51
4	393.74	57.28





Weight gain by Heart Score

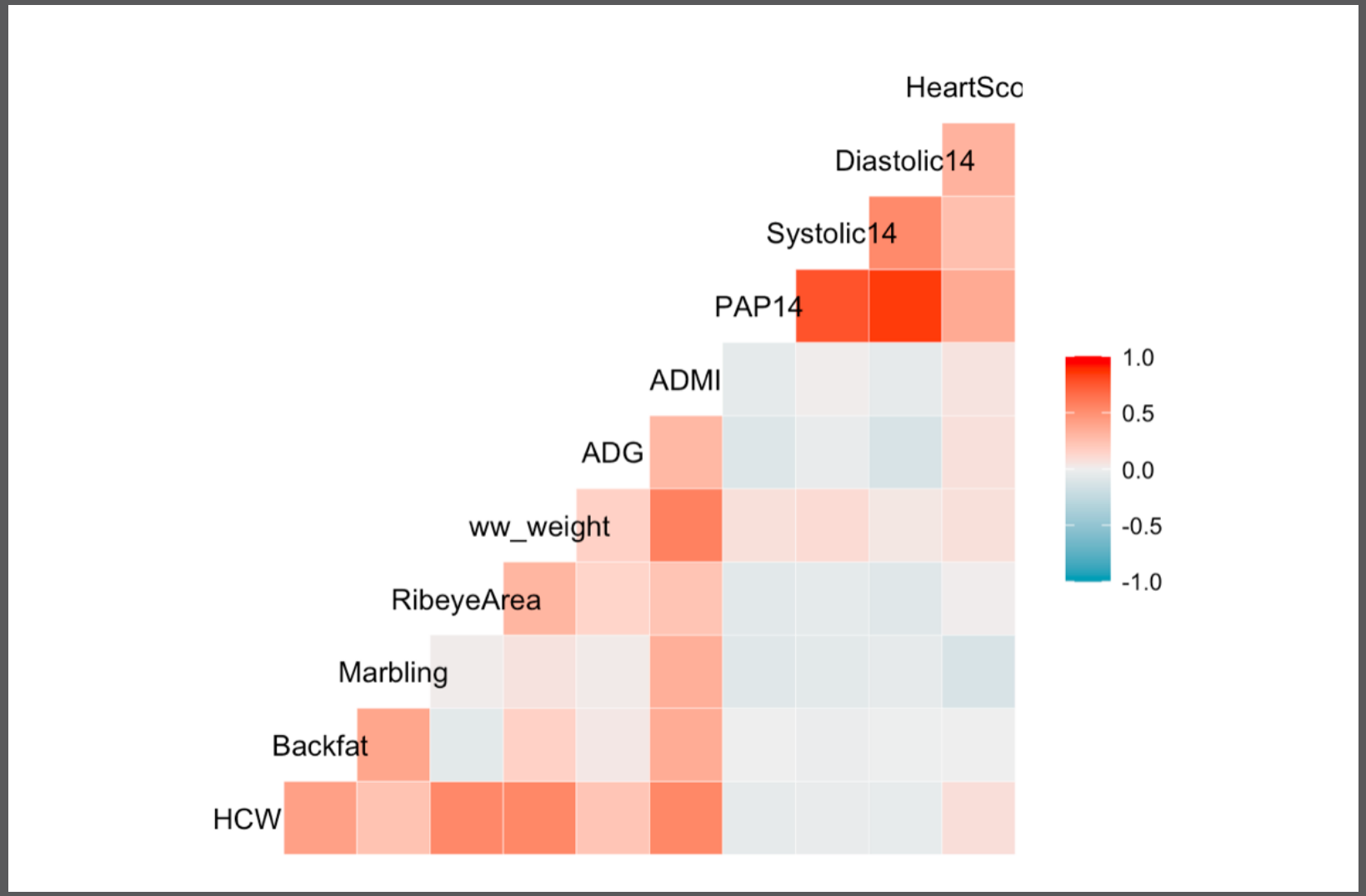
Weight gain in fattening feedlot cattle by individual heart score		
Heart Score	**Mean of weight gain (kg)**	**Standard Deviation (kg)**
1	78.58	20.63
2	92.23	21.77
3	95.84	23.14
4	81.19	45.92



Kukor, 2022

Phenotypic Correlation Heat Map

- Heat Map correlations indicating directional relationships between traits.
- Cardiovascular traits have a strong correlation with each other
- Carcass traits are all positively correlated with each other (excluding REA x BF)



Kukor, 2022

Phenotypic Correlations (Pearson above, Spearman below diagonal

	Heart Score	HCW	BF	Marb	REA	WWT	ADG	ADMI	PAP14	Sys14	Dia14
Heart Score		0.08***	0.00	-0.12***	0.01	0.08***	0.07*	0.06	0.36***	0.25***	0.32***
HCW	0.11***		0.42***	0.25***	0.54***	0.54***	0.22***	0.54***	-0.05	-0.03	-0.04
BF	0.03	0.40***		0.39***	-0.06**	0.16***	0.04	0.36***	0.00	-0.02	-0.01
Marb	-0.14***	0.21***	0.39***		0.03	0.06 .	0.03	0.32***	-0.08	-0.07	-0.06
REA	0.02	0.51***	-0.06**	0.01		0.31 ***	0.14***	0.23***	-0.07	-0.05	-0.08
WWT	0.07**	0.52***	0.17***	0.08**	0.27***		0.16***	0.57***	0.08	0.10	0.04
ADG	0.12***	0.22***	0.01	0.01	0.13***	0.23***		0.29	-0.09	-0.03	-0.12**
ADMI	0.08	0.47***	0.32***	0.35***	0.21***	0.54***	0.31***		-0.05	0.01	-0.04
PAP14	0.30***	0.00	-0.02	-0.10 .	-0.10 .	0.13 .	0.01	-0.01		0.77***	0.85***
Sys14	0.18***	-0.04	-0.06	-0.08	-0.08	0.07	0.03	0.02	0.57***		0.53***
Dia14	0.20***	0.02	-0.01	-0.03	0.02	0.05	-0.08	0.01	0.70***	0.20***	

Kukor, 2022

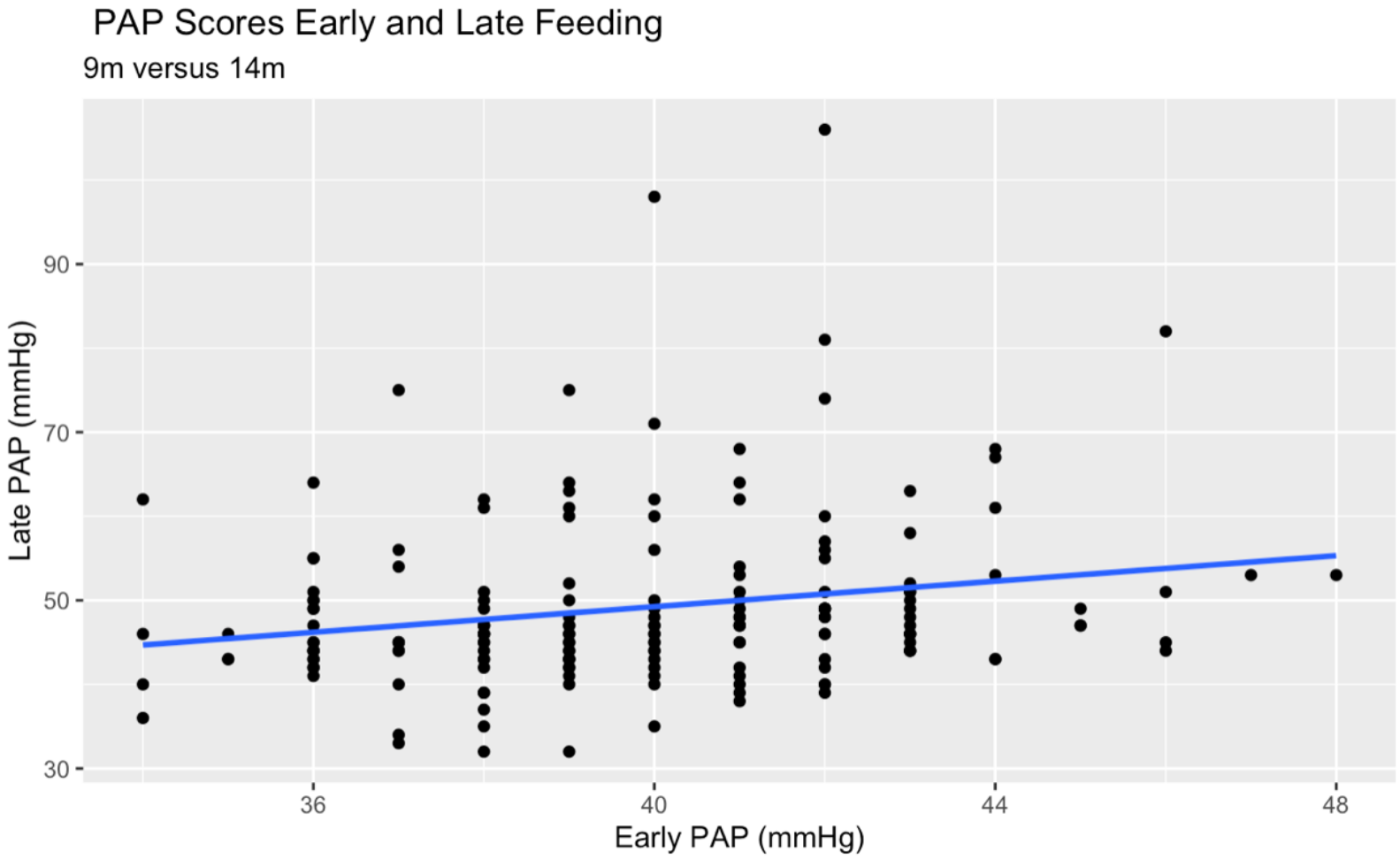
Sequential Pulmonary Arterial Pressure Measures

Linear Relationship between early feeding and late feeding period PAP

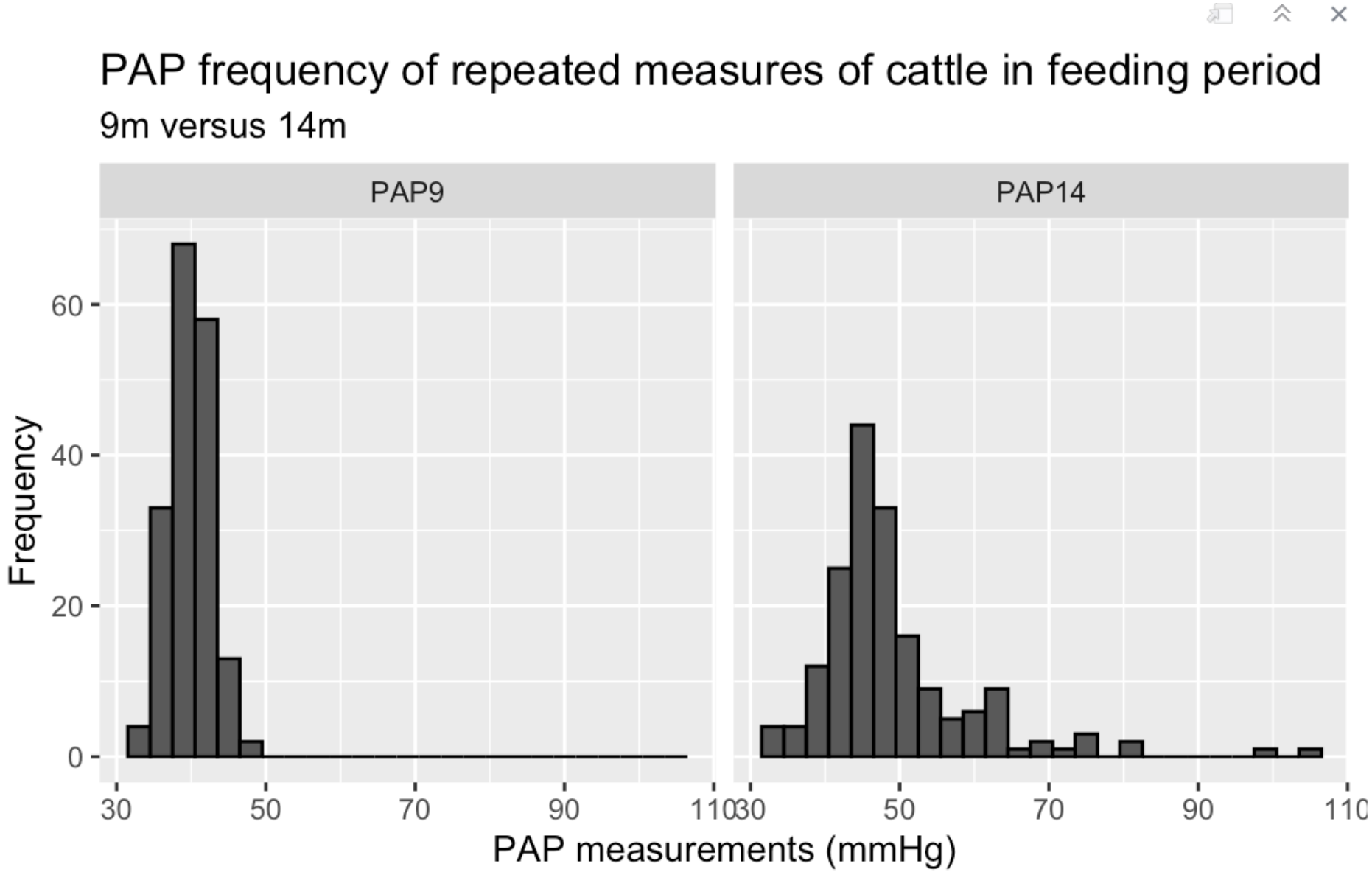
Only cattle with both a 9 month PAP and a 14 month PAP in study.

Utilizing a linear regression. PAP14 and PAP9 were compared. PAP9 had a slope of 0.76.

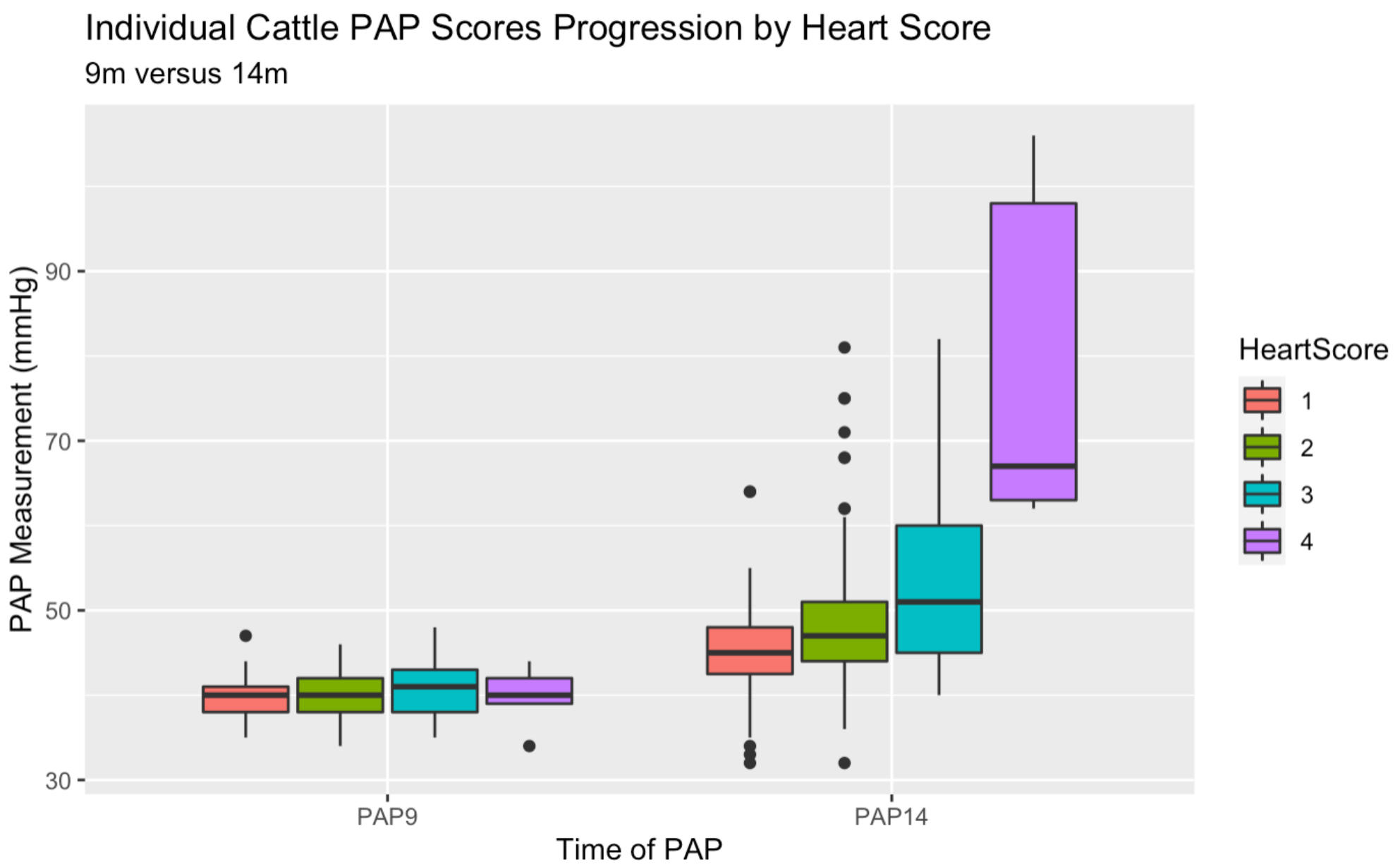
The correlation between the two measurements was found to be 0.20.



Distribution of PAP scores by Time



Kukor, 2022


Individual Cattle PAP Scores Progression by Heart Score
9m versus 14m
PAP Measurement (mmHg)
90
70
50
30
PAP9
PAP14
Time of PAP
HeartScore
1
2
3
4

Relationship between PAP and Heart Score

Analysis of Variance by Heart Score		
Scores	Early PAP (mmHg)	Late PAP (mmHg)
Intercept	39.24	45.54
Score 2	0.27	3.73*
Score 3	0.49	7.46***
Score 4	0.35	33.81***

General Form: $y_{ij} = B_0 + B_1 x_{ij} + B_2 x_{ij} + e_{ij}$

Predictors: Heart Score and Lot

Kukor, 2022

Heritability and Genetic Correlations between Heart Score, PAP and Production Traits

Materials & Methods

- 1,507 head of Angus influenced cattle
- Elevation is 1,080m
- heifers(n = 712) and steers (n = 793)
- 88 unique sires ~ 17.1 progeny / sire
- Fixed Effects: Harvest age, sex, and harvest date

Kukor, 2022

Heritabilities and Genetic Correlations

Trait	HS	PAP	HCW	BF	REA	Marb
HS	0.28 ± 0.10	0.94 ± 0.17	0.63 ± 0.20	0.15 ± 0.24	0.27 ± 0.22	0.07 ± 0.24
PAP		0.29 ± 0.16	0.66 ± 0.25	0.28 ± 0.29	0.15 ± 0.30	0.05 ± 0.30
HCW			0.61 ± 0.14	0.41 ± 0.16	0.51 ± 0.13	0.29 ± 0.18
BF				0.43 ± 0.13	-0.24 ± 0.19	0.35 ± 0.19
REA					0.60 ± 0.14	-0.17 ± 0.19
Marbling						0.45 ± 0.13

Kukor, 2022

Summary – Trends

- Relatively high incidence of hearts where remodeling has started to occur
  - 29% Overall
- We are not seeing animals with a heart score of 5 in the plants.
  - We do see them in necropsies in the feedlot.
- 14-month PAP is showing a relationship with Heart Score
  - Higher PAP indicating higher heart scores
  - PAP is costly and invasive. Heart scores are cheap to collect and abundant.
  - Still unclear as to the relationship between earlier PAP and Heart Score
- Phenotypically
  - Trends of increases in heart score indicate decreases in efficiency
  - Indications of increases in heart score with decreases in carcass characteristics.
    - Carcass Weight and Marbling Score

Summary – Trends

- PAP is increasing across the feeding period
  - Increasing in both magnitude and variability
- Heart Score is heritable ($h^2 = 0.29$)
- Antagonistic correlations with Carcass Traits
  - Strong genetic correlation between HS and HCW: 0.63
  - Moderate genetic correlation between HS and REA: 0.27
  - Weak genetic correlation between HS and both BF and MARB: 0.15, and 0.07, respectively

Questions?