Agriculture et Agroalimentaire Canada | Agriculture and Agri-Food Canada

Quantitative Lameness Assessment:
. Utilising Kinematics
. Employing a Force-Plate Scale

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Canada

Plan of presentation

1. Kinematics
   - A. The aim
   - B. Design and Method
   - C. Validation
   - D. Relation with lameness
   - E. Pros and Cons
2. Force plate
3. Comparison of methods
4. General discussion and perspectives

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Kinematics

Aim: To quantify gait

Welfare quality® :

0 Normal gait, or the animal has difficulties walking but is still using all its legs, the stride may be shortened and/or there may be swagger of the caudal part of the body when walking

1 The animal is severely lame; it resists bearing weight on the affected limb

2 There is no weight bearing on the affected limb or the animal is unable to walk

Main et al. (2000)

0 Even strides. Caudal body sways slightly while walking. Pig is able to accelerate and change direction rapidly.

1 Abnormal stride length (not easily identified).Movements are no longer fluent- pig appears stiff. Pig still able to accelerate and change direction.

2 Shortened strides. Minimum weight-bearing on affected limb. Swagger of caudal, body while walking. Will still trot and gallop.

3 The sow does not place affected limb on the floor.

4 Does not move.

FeetFirst® :

0 Sow moves easily with little inducement. She is comfortable on all her feet.

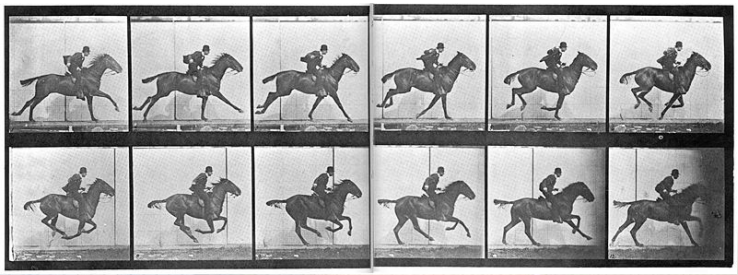
1 She moves relatively easy, but visible signs of lameness are apparent in at least one leg. She is reluctant to bear weight on that leg but still moves easily from site to site in the barn.

2 Lameness is involved in one or more limbs. The sow exhibits compensatory behaviors such as dipping her head or arching her back.

3 There is a real reluctance to walk and bear weight on one or more legs. It is difficult to move her from place to place on the farm.

Kinematics

"the study of the motion of bodies without reference to mass or force"



Eadweard Muybridge (1830-1904)

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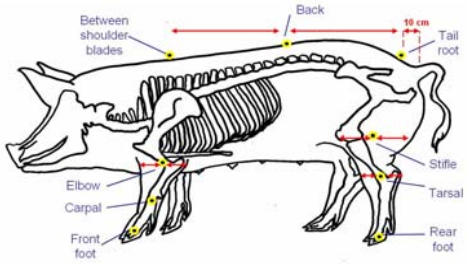
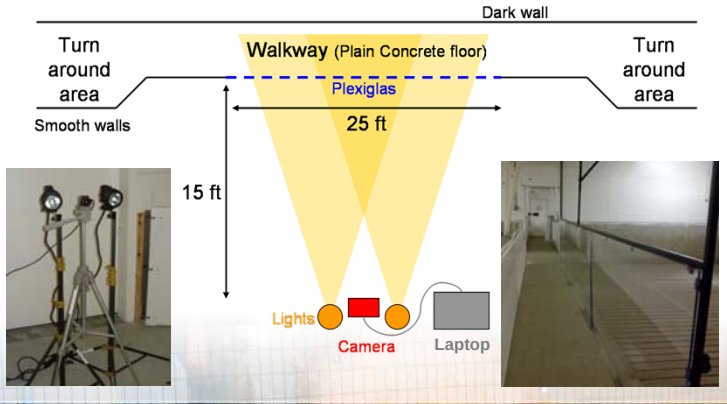
Kinematics — Placement of reflective markers



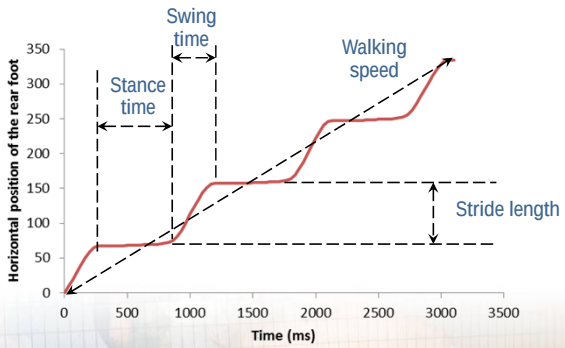
Kinematics — Equipment and set-up



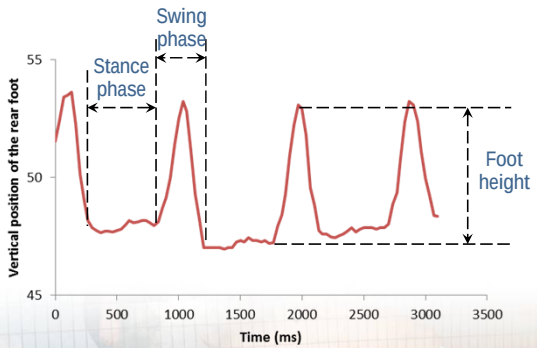
Kinematics — Video example

Kinematics — Data processing

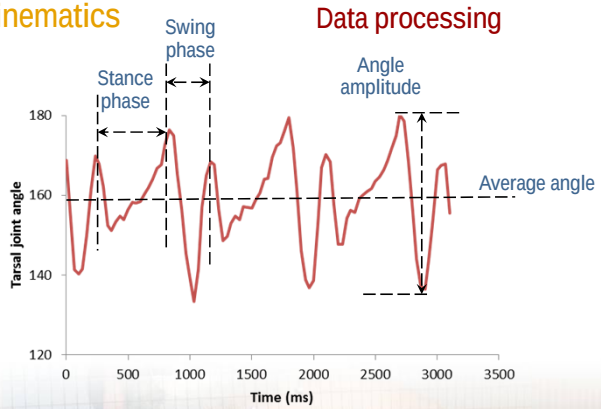
Kinematics — Data processing



Kinematics — Data processing



Kinematics — Data processing



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Kinematics — Internal validation

	INTRA-DAY sow variability (%CV)		INTER-DAY sow variability (%CV)	
Limb position	**Front**	**Rear**	**Front**	**Rear**
Walking speed	11,93		15,37	
Stride length	4,55		7,01	
Stance time	13,28		17,72	
Swing time	10,19	8,68	12,17	12,99
Foot height	17,14	15,42	15,63	20,01
Carpal or Tarsal joint angle amplitude	7,71	10,46	8,61	13,92
Carpal or Tarsal joint angle average	1,32	1,19	3,71	2,80

Grégoire et al. 2013

Kinematics — Front *vs.* Rear limbs

	Limb position		
	Front	**Rear**	***P*-value**
Stride length (cm)	97,4	98,2	0,34
Stance time (s)	0,75	0,74	0,64
Swing time (s)	0,37	0,38	0,03
Foot height (cm)	4,54	5,94	< 0,001
Carpal or Tarsal joint angle amplitude (°)	73,7	43,0	< 0,001
Carpal or Tarsal joint angle average (°)	169,3	138,3	< 0,001

Grégoire et al. 2013

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Grégoire et al. 2013

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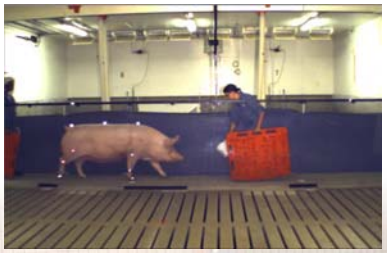
Kinematics — Effect of lameness visual score

- 1st study: 50 sows of various parity at AAFC
- 2nd study: 60 sows of various parity at AAFC and PSC
- 3rd study: 465 sows of various parity at PSC, UoM and UoG
- Effect of lameness visual score:

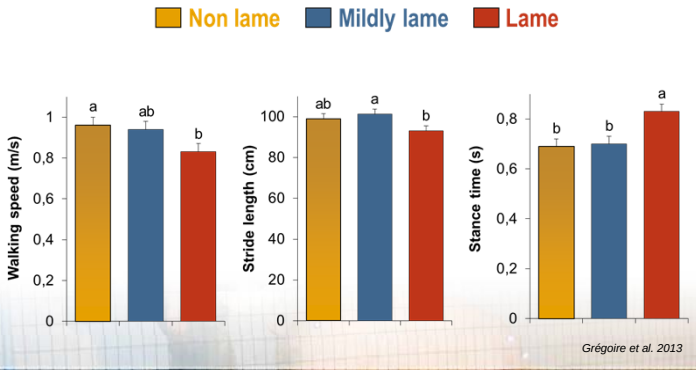
Non lame:
normal gait, even strides

Mildly lame:
abnormal gait, stiffness but no easy identification of lameness

Lame:
lameness detected, shortened strides, put less weight on one leg



Kinematics — Effect of lameness visual score – Study 1



Grégoire et al. 2013

STUDY 2	Non lame (n = 23)		Mildly lame (n = 20)		Lame (n = 17)		Effects		
FRONT LIMBS	AAFC	PSC	AAFC	PSC	AAFC	PSC	L	S	LxS
Carpal joint angle (°) – Swing phase	177	191	174	186	173	186	ns	***	ns
Carpal joint angle amplitude (°) – Swing phase	61	48	56	50	68	47	ns	***	ns
Carpal joint angle (°) – Stance phase	212	212	208	208	211	210	ns	ns	ns
Carpal joint angle amplitude (°) – Stance phase	22	11	22	12	20	13	ns	***	ns
Stride length (cm)	87,5	81,9	81,4	79,4	92,4	78,1	ns	***	†
Foot height (cm)	3,7	4,7	3,5	4,2	3,5	4,3	ns	**	ns
Stance time (s)	0,69	0,52	0,82	0,57	0,66	0,66	†	***	†
Swing time (s)	0,45	0,43	0,41	0,42	0,46	0,43	ns	ns	ns

STUDY 2	Non lame (n = 23)		Mildly lame (n = 20)		Lame (n = 17)		Effects		
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Carpal joint angle amplitude (°) – Swing phase	61	48	56	50	68	47	ns	***	ns
Carpal joint angle (°) – Stance phase	212	212	208	208	211	210	ns	ns	ns
Carpal joint angle amplitude (°) – Stance phase	22	11	22	12	20	13	ns	***	ns
Stride length (cm)	87,5	81,9	81,4	79,4	92,4	78,1	ns	***	†
Foot height (cm)	3,7	4,7	3,5	4,2	3,5	4,3	ns	**	ns
Stance time (s)	0,69	0,52	0,82	0,57	0,66	0,66	†	***	†
Swing time (s)	0,45	0,43	0,41	0,42	0,46	0,43	ns	ns	ns

STUDY 2	Non lame (n = 23)		Mildly lame (n = 20)		Lame (n = 17)		Effects		
REAR LIMBS	AAFC	PSC	AAFC	PSC	AAFC	PSC	L	S	LxS
Tarsal joint angle (°) – Swing phase	154	155	150	148	157	155	**	ns	ns
Tarsal joint angle amplitude (°) – Swing phase	26	32	30	34	27	26	*	*	ns
Tarsal joint angle (°) – Stance phase	152	150	148	142	152	149	**	*	ns
Tarsal joint angle amplitude (°) – Stance phase	13	12	15	12	13	10	†	**	ns
Stride length (cm)	87,2	80,7	80,9	78,4	89,1	76,5	ns	**	ns
Foot height (cm)	2,7	4,0	3,5	4,0	3,0	3,6	ns	*	ns
Stance time (s)	0,66	0,53	0,79	0,57	0,63	0,67	*	***	**
Swing time (s)	0,46	0,42	0,44	0,42	0,48	0,42	ns	***	ns

STUDY 2	Non lame (n = 23)		Mildly lame (n = 20)		Lame (n = 17)		Effects		
REAR LIMBS	AAFC	PSC	AAFC	PSC	AAFC	PSC	L	S	LxS
Tarsal joint angle (°) – Swing phase	154	155	150	148	157	155	**	ns	ns
Tarsal joint angle amplitude (°) – Swing phase	26	32	30	34	27	26	*	*	ns
Tarsal joint angle (°) – Stance phase	152	150	148	142	152	149	**	*	ns
Tarsal joint angle amplitude (°) – Stance phase	13	12	15	12	13	10	†	**	ns
Stride length (cm)	87,2	80,7	80,9	78,4	89,1	76,5	ns	**	ns
Foot height (cm)	2,7	4,0	3,5	4,0	3,0	3,6	ns	*	ns
Stance time (s)	0,66	0,53	0,79	0,57	0,63	0,67	*	***	**
Swing time (s)	0,46	0,42	0,44	0,42	0,48	0,42	ns	***	ns

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Tarsal joint angle amplitude (°) – Swing phase	26	32	30	34	27	26	*	*	ns
Tarsal joint angle (°) – Stance phase	152	150	148	142	152	149	**	*	ns
Tarsal joint angle amplitude (°) – Stance phase	13	12	15	12	13	10	†	**	ns
Stride length (cm)	87,2	80,7	80,9	78,4	89,1	76,5	ns	**	ns
Foot height (cm)	2,7	4,0	3,5	4,0	3,0	3,6	ns	*	ns
Stance time (s)	0,66	0,53	0,79	0,57	0,63	0,67	*	***	**
Swing time (s)	0,46	0,42	0,44	0,42	0,48	0,42	ns	***	ns

Kinematics — Effect of lameness visual score – Study 3

FRONT LIMBS	Arkell (UoG) (n = 152)		Sask. (PSC) (n = 173)		Glenlea (UoM) (n = 140)		Effects		
Lameness	Sound	Lame	Sound	Lame	Sound	Lame	L	S	LxS
Carpal joint angle (°) – Swing phase	184	185	178	182	165	167	*	***	ns
Carpal joint angle amplitude (°) – Swing phase	45	42	59	53	75	69	***	***	ns
Carpal joint angle (°) – Stance phase	203	201	208	208	204	204	ns	***	ns
Carpal joint angle amplitude (°) – Stance phase	16	14	16	15	14	17	ns	***	ns
Stride length (cm)	94,7	92,0	78,8	75,8	92,0	89,2	**	***	ns
Foot height (cm)	4.44	4.35	4.02	4.01	4.00	3.79	ns	***	ns

Kinematics — Effect of lameness visual score – Study 3

FRONT LIMBS	Arkell (UoG) (n = 152)		Sask. (PSC) (n = 173)		Glenlea (UoM) (n = 140)		Effects		
Lameness	Sound	Lame	Sound	Lame	Sound	Lame	L	S	LxS
Carpal joint angle (°) – Swing phase	184 <	185	178 <	182	165 <	167	*	***	ns
Carpal joint angle amplitude (°) – Swing phase	45 >	42	59 >	53	75 >	69	***	***	ns
Carpal joint angle (°) – Stance phase	203	201	208	208	204	204	ns	***	ns
Carpal joint angle amplitude (°) – Stance phase	16	14	16	15	14	17	ns	***	ns
Stride length (cm)	94,7 >	92,0	78,8 >	75,8	92,0 >	89,2	**	***	ns
Foot height (cm)	4.44	4.35	4.02	4.01	4.00	3.79	ns	***	ns

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Lameness	Sound	Lame	Sound	Lame	Sound	Lame	L	S	LxS
Tarsal joint angle (°) – Swing phase	156	153	156	153	158	158	*	***	ns
Tarsal joint angle amplitude (°) – Swing phase	36	36	30	32	28	28	ns	***	ns
Tarsal joint angle (°) – Stance phase	157	155	151	149	155	154	**	***	ns
Tarsal joint angle amplitude (°) – Stance phase	18	17	12	12	14	14	ns	***	ns
Stride length (cm)	94.2	91.7	77.9	74.6	90.4	87.6	**	***	ns
Foot height (cm)	4.85	5.68	4.41	4.69	4.19	4.07	*	***	*

Kinematics — Effect of lameness visual score – Study 3

REAR LIMBS	Arkell (UoG) (n = 152)		Sask. (PSC) (n = 173)		Glenlea (UoM) (n = 140)		Effects		
Lameness	Sound	Lame	Sound	Lame	Sound	Lame	L	S	LxS
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Tarsal joint angle (°) – Stance phase	157 >	155	151 >	149	155 >	154	**	***	ns
Tarsal joint angle amplitude (°) – Stance phase	18	17	12	12	14	14	ns	***	ns
Stride length (cm)	94.2 >	91.7	77.9 >	74.6	90.4 >	87.6	**	***	ns
Foot height (cm)	4.85 <	5.68	4.41 <	4.69	4.19	4.07	*	***	*

Kinematics — Effect of lameness visual score

Lame sows can be characterised by:

- Slower walking speed
- Shorter stride length
- Longer stance time
- Reduced amplitude of the radio-carpal joint during the swing phase
- Higher average angle of the tibio-tarsal joint
- Higher rear feet height

However: Strong site effect

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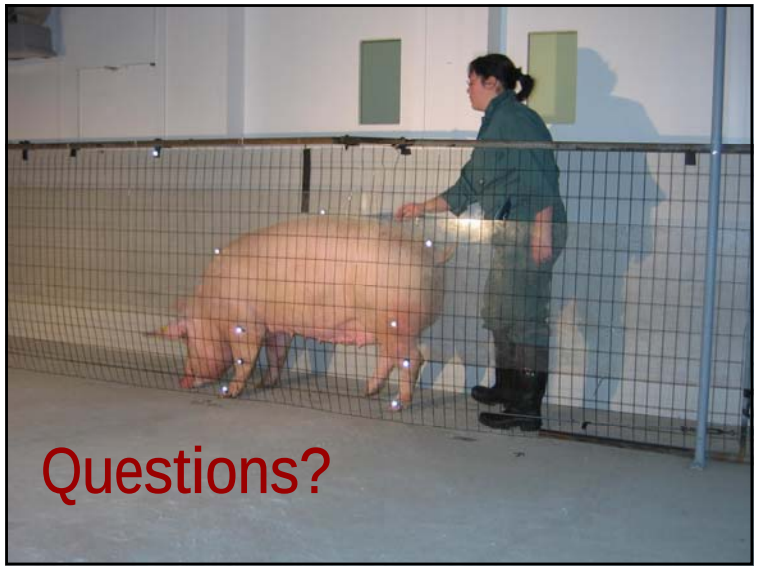
Kinematics — Pros and Cons

+	-
+ More objective than visual	- Only assess ambulatory animals
+ Can be standardised	- Cumbersome set-up
+ Very precise	- Quite expensive system
	- Some variations due to markers placement and measurement conditions
	- Difficult to applied on field

Rather a research tool than a diagnostic method



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Force Plate

Aim: To quantify weight bearing and weight distribution

Welfare quality® :

1. The animal is severely lame; it resists bearing weight on the affected limb
2. There is no weight bearing on the affected limb or the animal is unable to walk

Main et al. (2000)

1. Abnormal stride length (not easily identified).Movements are no longer fluent- pig appears stiff. Pig still able to accelerate and change direction.
2. Shortened strides. Minimum weight-bearing on affected limb. Swagger of caudal, body while walking. Will still trot and gallop.
3. The sow does not place affected limb on the floor.

FeetFirst® :

She moves relatively easy, but visible signs of lameness are apparent in at least one leg.

1. She is reluctant to bear weight on that leg but still moves easily from site to site in the barn.
2. Lameness is involved in one or more limbs. The sow exhibits compensatory behaviors such as dipping her head or arching her back.
3. There is a real reluctance to walk and bear weight on one or more legs. It is difficult to move her from place to place on the farm.

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Force Plate

Design and method

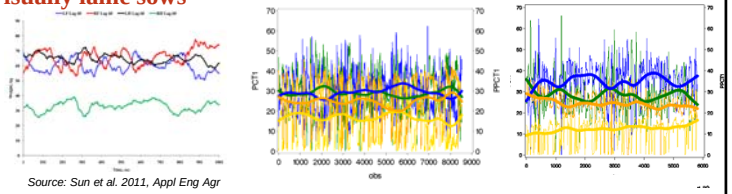
- 4 load cells / quadrant
- each quadrant: 250 ± 0,1 kg
- recording rate: 14 data/sec
- recording period: 15 min

Force Plate

Raw data

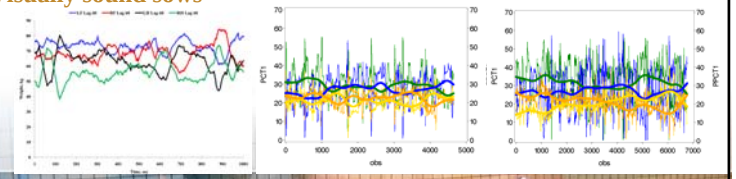
Front left Back left Front right Back right

Visually lame sows



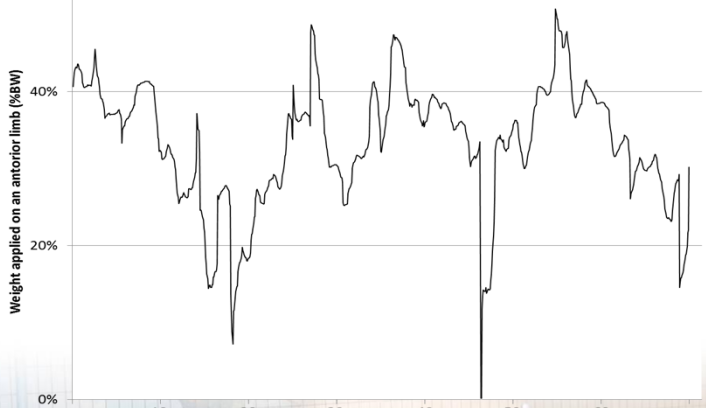
Source: Sun et al. 2011, Appl Eng Agr

Visually sound sows



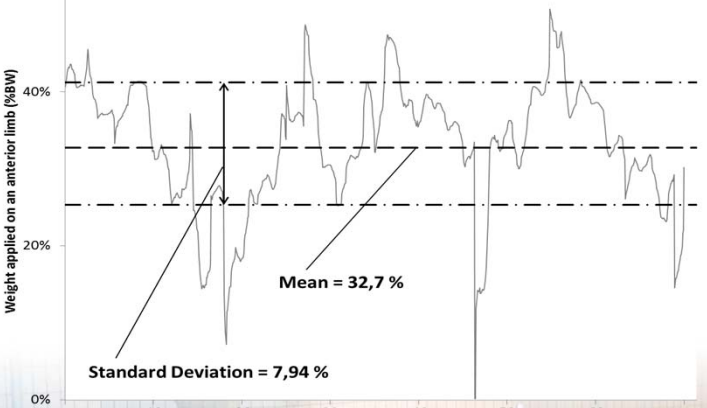
Force Plate

Data processing

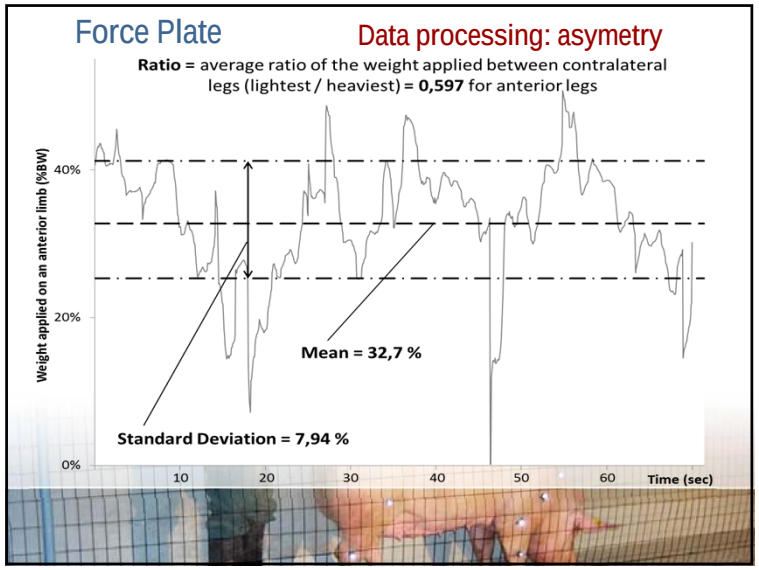


Force Plate

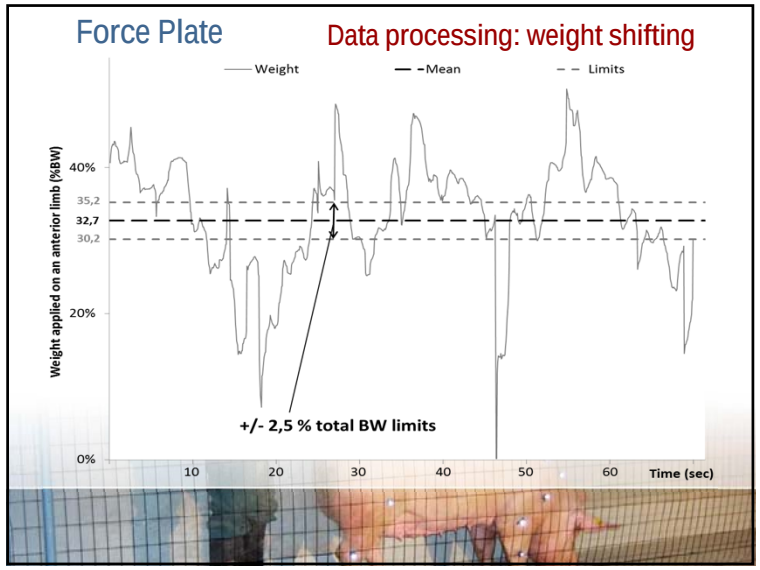
Data processing



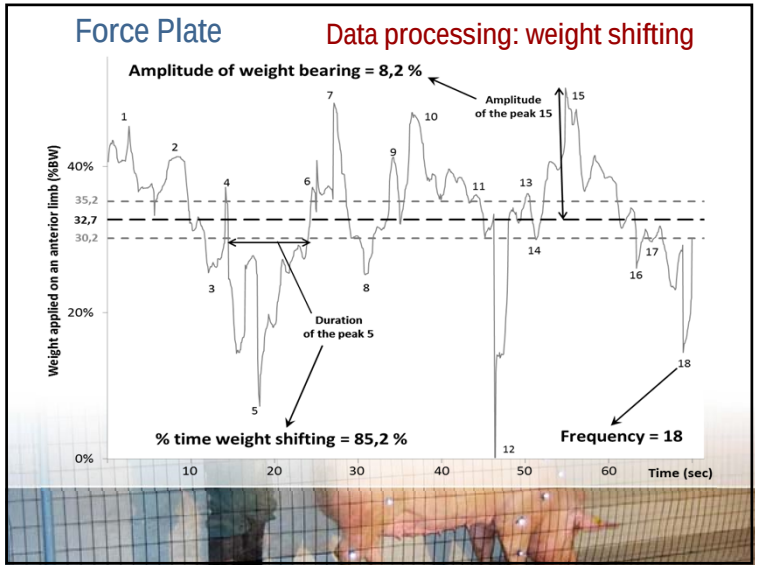
Force Plate — Data processing: asymetry



Force Plate — Data processing: weight shifting



Force Plate — Data processing: weight shifting



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Force Plate Validation

- Intra-sow Repeatability 2 measures X 2 different days X 10 sows
- Inter-sow Variability Measures on 10 sows

Force Plate Validation

Limb position	INTER-sow variability (%CV) Front Right	Front Left	Rear Right	Rear Left	INTRA-sow variability (%CV) Front Right	Front Left	Rear Right	Rear Left
Percentage of weight	9.9	10	17.6	14.2	6.2	6.0	5.3	4.2
Standard deviation of weight	20.4	20.1	32.9	29.0	10.4	11.0	10.9	14.0
Ratio of %BW between contralateral limbs	7.4		14.9		3.5		5.4	
Frequency of weight shifting	23.9	25.3	24.7	25.8	13.2	12.2	12.6	13.8
Percentage of time of weight shifting	8.9	9.8	22.7	20.3	5.3	5.6	9.1	10.4
Amplitude of weight removing	19.4	13.4	26.1	19.5	12.5	10.2	11.3	13.5
Amplitude of weight bearing	17.1	21.6	24.5	33.5	12.6	14.2	12.3	13.1

Force Plate Validation

Limb position	INTER-sow variability (%CV) Front Right	Front Left	Rear Right	Rear Left		INTRA-sow variability (%CV) Front Right	Front Left	Rear Right	Rear Left
Percentage of weight	9.9	10	17.6	14.2	>	6.2	6.0	5.3	4.2
Standard deviation of weight	20.4	20.1	32.9	29.0	>	10.4	11.0	10.9	14.0
Ratio of %BW between contralateral limbs	7.4		14.9		>	3.5		5.4	
Frequency of weight shifting	23.9	25.3	24.7	25.8	>	13.2	12.2	12.6	13.8
Percentage of time of weight shifting	8.9	9.8	22.7	20.3	>	5.3	5.6	9.1	10.4
Amplitude of weight removing	19.4	13.4	26.1	19.5	>	12.5	10.2	11.3	13.5
Amplitude of weight bearing	17.1	21.6	24.5	33.5	>	12.6	14.2	12.3	13.1

Plan of presentation

1. Kinematics
2. Force plate
   - A. The aim
   - B. Design and Method
   - C. Validation
   - D. Relation with lameness
   - E. Pros and Cons
3. Comparison of methods
4. General discussion and perspectives

Force Plate — Relation with lameness

- Measures on 60 sows of various parity at AAFC and PSC
- Effect of lameness visual score:

Non lame:
normal gait, even strides (n=23)

Mildly lame:
abnormal gait, stiffness but no easy identification of lameness (n=19)

Lame:
lameness detected, shortened strides, put less weight on one leg (n=17)

Force Plate — Relation with lameness

Lameness score (LS)	Non lame (n = 24)		Mildly lame (n = 19)		Lame (n = 17)		Effects		
Pair of limbs (PL)	Front	Rear	Front	Rear	Front	Rear	LS	PL	LSxPL
Percentage of weight (%BW)	28.7	21.3	28.8	21.2	29.1	20.9	ns	***	ns
Standard deviation of weight (%BW)	7.48	4.83	7.24	4.96	7.64	5.87	ns	***	ns
Ratio of %BW between contralateral limbs	0.678	0.725	0.674	0.713	0.660	0.624	**	ns	†
Frequency of weight shifting (/min)	22.5	20.4	24.8	21.9	33.3	31.3	***	ns	ns
Percentage of time of weight shifting (%)	69.8	49.5	72.2	47.8	73.1	56.4	†	***	ns
Amplitude of weight removing (%BW)	-5.2	-3.9	-5.0	-4.1	-5.2	-4.6	ns	***	ns
Amplitude of weight bearing (%BW)	9.1	7.2	8.9	7.3	9.2	7.7	ns	***	ns

Force Plate — Relation with lameness

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Force Plate — Pros and Cons

+ More objective than visual
+ No need to train persons and of inter-observer assessment
+ Could be integrated into ESF system
+ Could be automated

- Only assess static animals
- Expensive system

Need to determine thresholds and diagnostic criteria

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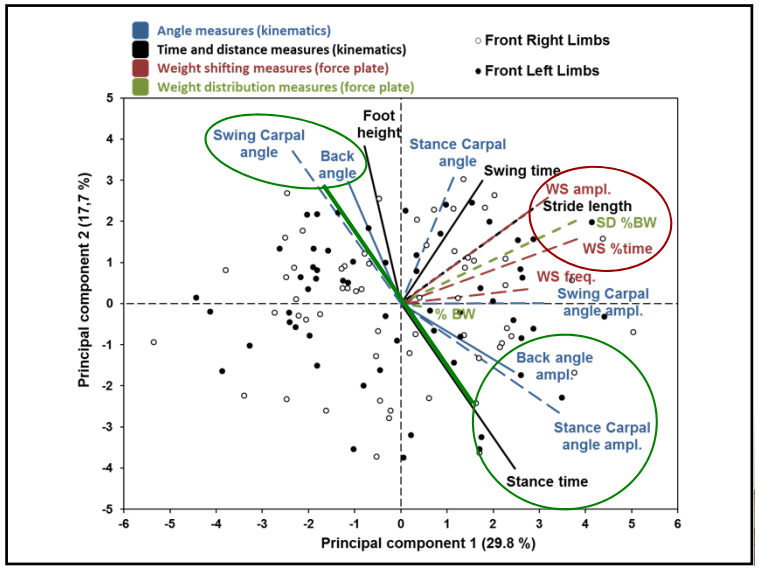
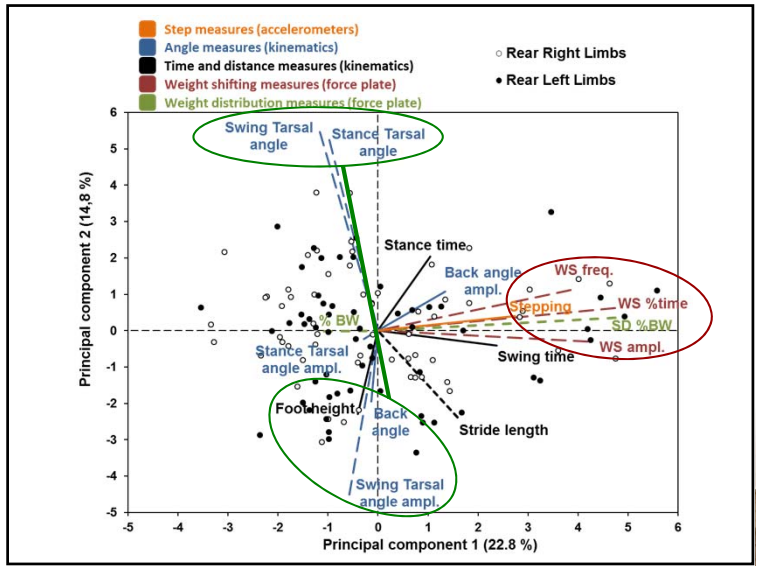
Force Plate *Vs.* Kinematics

- Measures on 59 sows of various parity
- Comparison with gait or postural behaviour quantitative methods at the foot-level:
  - Kinematics
  - Force plates
  - Accelerometers

on a hind leg: measures of acceleration on the x-axis at 10 Hz rate, converted into steps





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Findings

- Kinematics
  - Enable to precisely and reliably measure gait in sows

  Relationship with lameness visual score to be confirmed, but some differences between lame and non lame sows:
  - walking speed
  - stride length
  - stance time
  - joint angles
- Force Plate
  - Enable to precisely and reliably measure weight distribution and weight shifting in sows

  Sows visually lame and non lame differ for several measures:
  - ratio between contralateral legs
  - weight shifting frequency
  - % time weight shifting

Findings

- Comparison between methods

  Different complementary dimensions of gait and weight distribution:

  - Weight shifting – weight variation
  - Gait fluidity (joint angle)
  - Gait dynamic (time and distance)

Perspectives

Further research is needed to

1. Make the link between lameness types or indicators and
   - Number of limbs affected
   - Pain intensity
   - Underlying pathology

2. Determine indicators and thresholds for different types of lameness

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