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

N. DEVILLERS & S. CONTE
Dairy and Swine Research and Development Centre
Sherbrooke, QC

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

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.

FeetFirst®:
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 is still able to accelerate and change direction.
3 The pig does not place affected limb on the floor.
4 Does not move.

Main et al. (2000)
0 Even strides: Caudal body sways slightly while walking. Pig is able to accelerate and change direction rapidly.
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4 Does not move.
Kinematics

“the study of the motion of bodies without reference to mass or force”

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Kinematics

Placement of reflective markers

Equipment and set-up
Kinematics Data processing

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Kinematics Internal validation

<table>
<thead>
<tr>
<th></th>
<th>INTRA-DAY</th>
<th>INTER-DAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limb position</td>
<td>Front</td>
<td>Rear</td>
</tr>
<tr>
<td>Walking speed</td>
<td>11.93</td>
<td>15.37</td>
</tr>
<tr>
<td>Stride length</td>
<td>4.55</td>
<td>7.01</td>
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<tr>
<td>Stance time</td>
<td>13.28</td>
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<tr>
<td>Swing time</td>
<td>10.19</td>
<td>10.46</td>
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<tr>
<td>Foot height</td>
<td>17.14</td>
<td>15.42</td>
</tr>
<tr>
<td>Carpal or Tarsal joint angle amplitude</td>
<td>7.71</td>
<td>10.46</td>
</tr>
<tr>
<td>Carpal or Tarsal joint angle average</td>
<td>1.32</td>
<td>1.19</td>
</tr>
</tbody>
</table>

Grégoire et al. 2013

Kinematics Front vs. Rear limbs

<table>
<thead>
<tr>
<th></th>
<th>Limb position</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Front</td>
</tr>
<tr>
<td>Stride length (cm)</td>
<td>97.4</td>
</tr>
<tr>
<td>Stance time (s)</td>
<td>0.75</td>
</tr>
<tr>
<td>Swing time (s)</td>
<td>0.37</td>
</tr>
<tr>
<td>Foot height (cm)</td>
<td>4.54</td>
</tr>
<tr>
<td>Carpal or Tarsal joint angle amplitude (°)</td>
<td>73.7</td>
</tr>
<tr>
<td>Carpal or Tarsal joint angle average (°)</td>
<td>169.3</td>
</tr>
</tbody>
</table>

Grégoire et al. 2013
**Kinematics**

**Front VS. Rear limbs**

<table>
<thead>
<tr>
<th></th>
<th>Front</th>
<th>Rear</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stride length (cm)</td>
<td>97.4</td>
<td>98.2</td>
<td>0.34</td>
</tr>
<tr>
<td>Stance time (s)</td>
<td>0.75</td>
<td>0.74</td>
<td>0.04</td>
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<tr>
<td>Swing time (s)</td>
<td>0.37</td>
<td>0.38</td>
<td>0.03</td>
</tr>
<tr>
<td>Foot height (cm)</td>
<td>4.54</td>
<td>5.94</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Carpal or Tarsal joint angle amplitude (°)</td>
<td>73.7</td>
<td>43.0</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Carpal or Tarsal joint angle average (°)</td>
<td>169.3</td>
<td>138.3</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
</table>

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   - E. Pros and Cons

2. **Force plate**

3. **Comparison of methods**

4. **General discussion and perspectives**

**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**

- **Non lame**
- **Mildly lame**
- **Lame**

- **Walking speed (m/s)**
- **Stride length (cm)**
- **Stance time (s)**

Grégoire et al. 2013
### STUDY 2 Non lame (n = 23) Mildly lame (n = 20) Lame (n = 17) Effects

#### FRONT LIMBS

<table>
<thead>
<tr>
<th>Joint Angle (°)</th>
<th>Swing Phase</th>
<th>Stance Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carpal joint angle</td>
<td>177, 191, 174, 186</td>
<td>173, 186</td>
</tr>
<tr>
<td>Carpal joint angle amplitude</td>
<td>61, 48, 51, 50</td>
<td>68, 47</td>
</tr>
<tr>
<td>Stride length (cm)</td>
<td>87.5, 81.9, 81.4, 76.4</td>
<td>70.4, 76.1</td>
</tr>
<tr>
<td>Foot height (cm)</td>
<td>3.7, 4.7, 3.5, 4.2, 3.5, 4.3</td>
<td>3.5, 4.3</td>
</tr>
<tr>
<td>Stance time (s)</td>
<td>0.69, 0.52, 0.57, 0.66</td>
<td>0.57, 0.66</td>
</tr>
<tr>
<td>Swing time (s)</td>
<td>0.45, 0.43, 0.41, 0.42, 0.48, 0.43</td>
<td>0.41, 0.42</td>
</tr>
</tbody>
</table>

#### REAR LIMBS

<table>
<thead>
<tr>
<th>Joint Angle (°)</th>
<th>Swing Phase</th>
<th>Stance Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tarsal joint angle</td>
<td>154, 155, 150, 148, 157, 155</td>
<td>** ns ns</td>
</tr>
<tr>
<td>Tarsal joint angle amplitude</td>
<td>26, 32, 30, 34</td>
<td>27, 28</td>
</tr>
<tr>
<td>Stride length (cm)</td>
<td>87.2, 80.7, 80.9, 76.4, 89.1, 76.5</td>
<td>89.1, 76.5</td>
</tr>
<tr>
<td>Foot height (cm)</td>
<td>4.0, 4.0, 3.5, 4.0, 3.0, 3.8</td>
<td>3.8, 3.8, 3.8</td>
</tr>
<tr>
<td>Stance time (s)</td>
<td>0.66, 0.53, 0.79, 0.57, 0.63, 0.67</td>
<td>0.57, 0.63</td>
</tr>
<tr>
<td>Swing time (s)</td>
<td>0.49, 0.42, 0.44, 0.42, 0.48, 0.42</td>
<td>0.48, 0.42</td>
</tr>
<tr>
<td>Kinematics</td>
<td>Effect of lameness visual score – Study 3</td>
<td></td>
</tr>
<tr>
<td>------------</td>
<td>------------------------------------------</td>
<td></td>
</tr>
<tr>
<td><strong>FRONT LIMBS</strong></td>
<td>Arkell (UoG) (n = 152)</td>
<td>Sask. (PSC) (n = 173)</td>
</tr>
<tr>
<td>Lameness</td>
<td>Sound</td>
<td>Lame</td>
</tr>
<tr>
<td>Carpal joint angle (°) – Swing phase</td>
<td>184</td>
<td>185</td>
</tr>
<tr>
<td>Carpal joint angle amplitude (°)</td>
<td>46</td>
<td>42</td>
</tr>
<tr>
<td>Carpal joint angle (°) – Stance phase</td>
<td>203</td>
<td>201</td>
</tr>
<tr>
<td>Carpal joint angle amplitude (°)</td>
<td>16</td>
<td>14</td>
</tr>
<tr>
<td>Stride length (cm)</td>
<td>94.7 92.0 78.8 75.8 92.0 89.2</td>
<td></td>
</tr>
<tr>
<td>Foot height (cm)</td>
<td>4.44 4.38 4.32 4.27 4.24 4.19</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Kinematics</th>
<th>Effect of lameness visual score – Study 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>REAR LIMBS</strong></td>
<td>Arkell (UoG) (n = 152)</td>
</tr>
<tr>
<td>Lameness</td>
<td>Sound</td>
</tr>
<tr>
<td>Tarsal joint angle (°) – Swing phase</td>
<td>156 153 156 153</td>
</tr>
<tr>
<td>Tarsal joint angle amplitude (°)</td>
<td>28 29 28 24</td>
</tr>
<tr>
<td>Tarsal joint angle (°) – Stance phase</td>
<td>157 155 151 149</td>
</tr>
<tr>
<td>Tarsal joint angle amplitude (°)</td>
<td>14 14 12 12</td>
</tr>
<tr>
<td>Stride length (cm)</td>
<td>94.2 91.7 77.9 74.6 90.4 87.6</td>
</tr>
<tr>
<td>Foot height (cm)</td>
<td>4.86 4.86 4.86 4.86 4.86 4.86</td>
</tr>
</tbody>
</table>
### Kinematics

#### Effect of lameness visual score – Study 3

<table>
<thead>
<tr>
<th>REAR LIMBS</th>
<th>Arkell (UoG) (n = 152)</th>
<th>Sask. (PSC) (n = 173)</th>
<th>Glenlea (UoM) (n = 140)</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lameness</td>
<td>Sound Lame Sound Lame</td>
<td>L S</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>Tarsal joint angle (°) – Swing phase</td>
<td>156 ≥ 153 156 ≥ 153 158 ≥ 158</td>
<td>* ≥ *** ns</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tarsal joint angle amplitude (°) – Swing phase</td>
<td>46 ≤ 36 30 ≤ 26 28 ≤ 28</td>
<td>* ns</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tarsal joint angle (°) – Stance phase</td>
<td>157 ≥ 155 151 ≥ 149 156 ≥ 154</td>
<td>* ≥ *** ns</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tarsal joint angle amplitude (°) – Stance phase</td>
<td>32 ≤ 12 12 ≤ 14 14 ≤ 14</td>
<td>* ns</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stride length (cm)</td>
<td>94.2 ≥ 91.7 77.9 ≥ 74.6 90.4 ≥ 87.6</td>
<td>* ≥ *** ns</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Foot height (cm)</td>
<td>4.85 ≥ 4.85 4.92 ≤ 4.92 4.78 ≤ 4.78 4.39 ≤ 4.39</td>
<td>* ≥ *** ns</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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
Questions?

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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

**Middle line bar**

**Transversal bar**

**One quadrant**

**Feeder**

---

**Force Plate Data processing**

![Graph showing data processing](image)

- Mean = 32.7%
- Standard Deviation = 7.94%
- Time (sec)
- Percentage of weight applied to the anterior hind leg

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**Visually sound sows**

Source: Sun et al. 2011, Appl Eng Agr

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**Visually lame sows**

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**Force Plate Raw data**

- Front left
- Back left
- Front right
- Back right
Force Plate Data processing: asymmetry

Ratio = average ratio of the weight applied between contralateral legs (lightest/heaviest) = 0.597 for anterior legs

Mean = 32.7%

Standard Deviation = 7.94%

Force Plate Data processing: weight shifting

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Intra-sow Repeatability

- Measures 2 measures X 2 different days X 10 sows.

Inter-sow Variability

- Measures on 10 sows.

### Force Plate Validation

<table>
<thead>
<tr>
<th>Limb position</th>
<th>Front</th>
<th>Rear</th>
<th>Front</th>
<th>Rear</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right</td>
<td>19.9</td>
<td>10</td>
<td>17.6</td>
<td>14.2</td>
</tr>
<tr>
<td>Left</td>
<td>20.4</td>
<td>20.1</td>
<td>32.9</td>
<td>29.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Percentage of weight</th>
<th>9.9</th>
<th>10</th>
<th>17.6</th>
<th>14.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard deviation of weight</td>
<td>20.4</td>
<td>20.1</td>
<td>32.9</td>
<td>29.0</td>
</tr>
<tr>
<td>Ratio of %BW between contralateral limbs</td>
<td>7.4</td>
<td>14.9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Frequency of weight shifting</th>
<th>23.9</th>
<th>25.3</th>
<th>24.7</th>
<th>25.8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of time of weight shifting</td>
<td>9.9</td>
<td>9.8</td>
<td>22.7</td>
<td>20.3</td>
</tr>
<tr>
<td>Amplitude of weight removing</td>
<td>19.4</td>
<td>13.4</td>
<td>26.1</td>
<td>19.5</td>
</tr>
<tr>
<td>Amplitude of weight bearing</td>
<td>17.1</td>
<td>21.6</td>
<td>24.5</td>
<td>33.5</td>
</tr>
</tbody>
</table>

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   - The aim
   - Design and Method
   - Validation
   - Relation with lameness
   - Pros and Cons

2. **Force plate**
   - A. The aim
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   - 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)

<table>
<thead>
<tr>
<th>Lameness score (LS)</th>
<th>Non lame (n=24)</th>
<th>Mildly lame (n=19)</th>
<th>Lame (n=17)</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pair of limbs (PL)</td>
<td>Front Rear Front Rear Front Rear LS PL PLxPL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage of weight (%BW)</td>
<td>28.7 21.3 28.8 21.2 29.1 20.9 ns *** ns</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Standard deviation of weight (%BW)</td>
<td>7.48 4.83 7.24 4.96 7.64 5.87 ns *** ns</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ratio of %BW between contralateral limbs</td>
<td>0.678 0.725 0.674 0.713 0.660 0.624 ** ns †</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency of weight shifting (/min)</td>
<td>22.5 20.4 24.1 21.9 30.3 30.7 ns *** ns</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Percentage of time of weight shifting (%)</td>
<td>69.8 49.5 72.2 47.8 73.1 56.4 † *** ns</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amplitude of weight removing (%BW)</td>
<td>-5.2 -3.9 -5.0 -4.1 -5.2 -4.6 ns *** ns</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amplitude of weight bearing (%BW)</td>
<td>9.1 7.2 8.9 7.3 9.2 7.7 ns *** ns</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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Force Plate

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

Pros and Cons

- Only assess static animals
- Expensive system

Need to determine thresholds and diagnostic criteria

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)

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

Perspectives

Acknowledgment

• Collaborators
  - Renee Bergeron, University of Guelph, ON
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  - Jennifer Brown, Prairie Swine Centre, SK
  - Laurie Conner, University of Manitoba, MB
  - Fiona Lang, Prairie Swine Centre, SK
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