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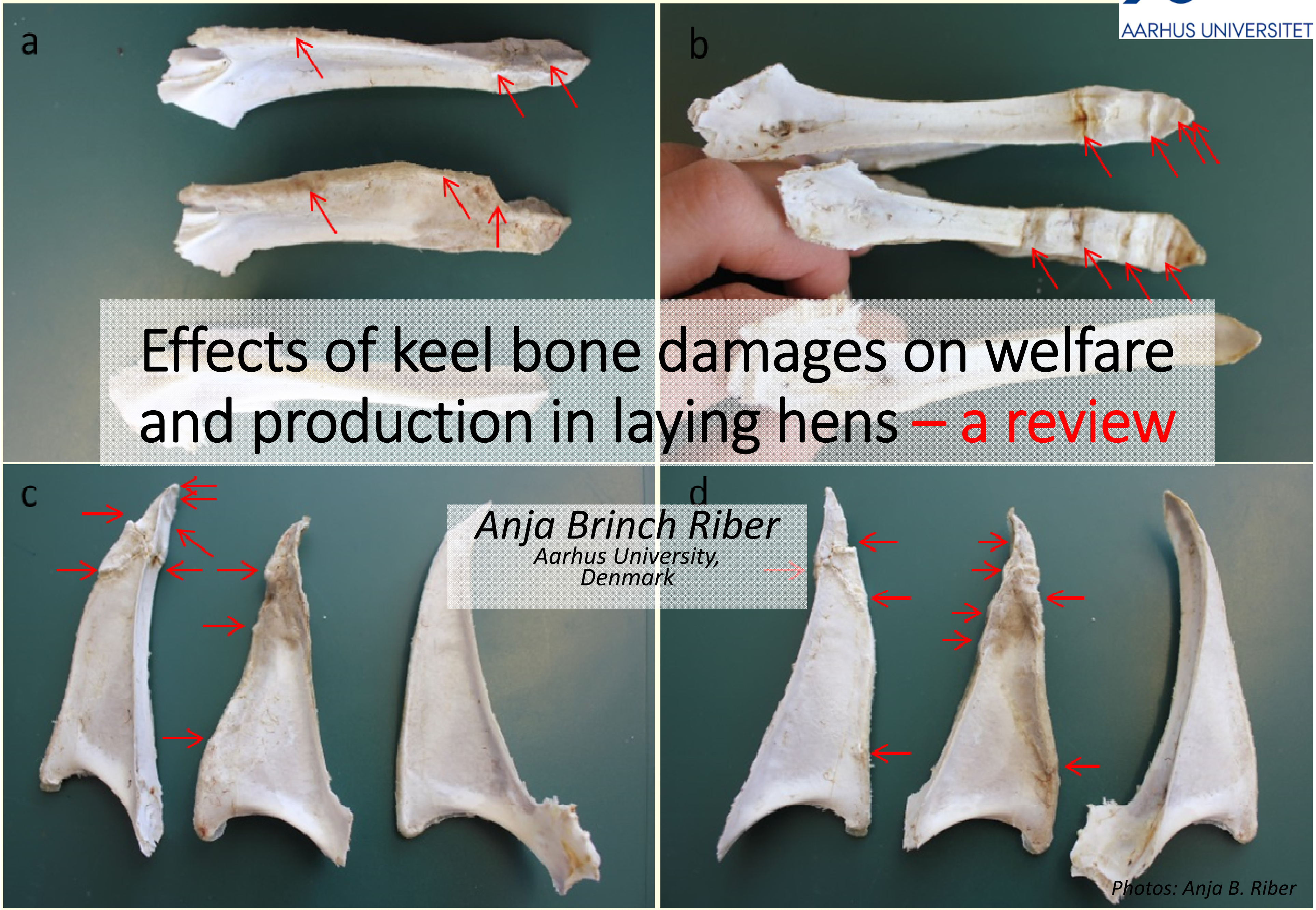
Effects of keel bone damages on welfare and production in laying hens – a review

Anja Brinch Riber
Aarhus University, Denmark



Photos: Anja B. Riber

Ministry of Environment
and Food of Denmark

DCA – Nationalt Center for Jordbrug og Fødevarer
30. maj 2016

The influence of keel bone damages ~~and foot disorders~~ on welfare of laying hens – a review

including productivity

Anja B. Riber[a], Mette S. Herskin[a], Teresa Casey-Trott[b]

[a]*Animal Science, Aarhus University, Blichers Allé 20, DK-8830 Tjele, Denmark*

[b]*Animal and Poultry Science, University of Guelph, 50 Stone Road East, Guelph. Ontario, N1G 2W1, Canada*

Views on animal welfare

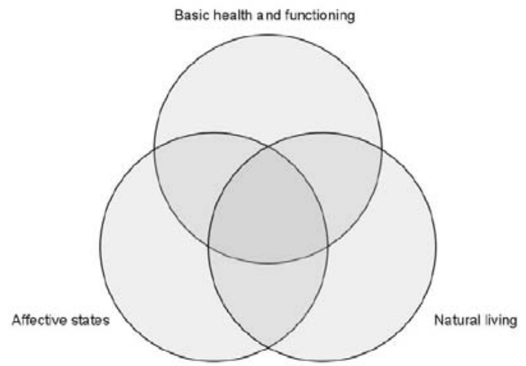


Fig 4. Overview of the three major types of concern for animal welfare (from Fraser, 2008*).*

1. **Biological functioning**
   - Emphasizing basic animal health and functioning

2. **Affective states**
   - Centred on the animals' affective states (a collective term covering emotions, feelings and moods characterised by a certain level of arousal and a valence different from neutral (Mendl et al., 2010))

3. **Naturalness**
   - Centred on the ability of animals to lead reasonable natural lives

(*Fraser, 2003, Anim. Welf. 12*: 433-443)

Welfare indicators used

- **Behavioural measures**
- **Physiological measures**
- **Clinical measures**
- **Indicators of affective states**
- **Production parameters***

Photo: Anja B. Riber

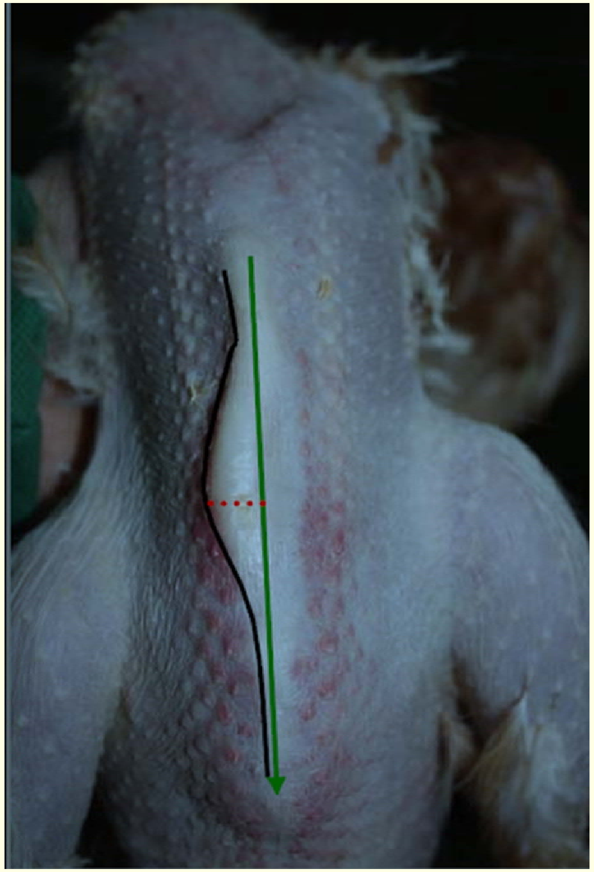
Photo: Anja B. Riber

*It is important to stress that when measures of animal productivity are included as welfare indicators they cannot stand alone, especially when no effects on production are found (Broom, 1986, Mendl, 2001).

Fractures (KF)

VS

Deviations (KD)



Keel bone damages (KBD) = common term for fractures and deviations

Photos: Healthy hen protocol

Fractures: Behavioural measures

Free-range laying hens collected on-farm

- Severe, healed KF
- Minor, healed, KF
- No KF

Data collected

- Behavioural observations
- Landing/flying tests
- Walkway with two obstacles

Table 5 Mean (± SEM) of walking velocity, flying, landing, keel-bone strength and spontaneous perch access in hens with and without keel fractures (classified following keel-bone dissection).

Factor	Hens with no keel fractures	Hens with keel fractures
Number of birds	15	49
Spontaneous access perch height 50 cm	11.33 (± 2.10)	9.14 (± 1.03)
Spontaneous access perch height 100 cm	3.67 (± 0.69)	3.04 (± 0.37)
Number of birds	16	56
Reach first obstacle (s)	1.92 (± 0.71)	2.86 (± 0.34)
Reach second obstacle (s)	5.61 (± 1.67)	10.44 (± 1.37)
Reach food (s)	9.41 (± 2.15)*	16.74 (± 2.11)
Flying from ground to perch height 50 cm (s)	134.38 (± 31.97)	151.47 (± 16.45)
Flying from ground to perch height 100 cm (s)	203.98 (± 30.39)	231.04 (± 11.40)
Landing from 50 cm perch height to floor (s)	9.33 (± 2.02)*	33.63 (± 9.18)
Landing from 100 cm perch height to floor (s)	25.90 (± 6.94)**	80.10 (± 11.99)
Landing from 150 cm perch height to floor (s)	78.70 (± 24.50)	127.78 (± 12.57)
Keel strength area A (kg)	33.24 (± 1.16)**	26.08 (± 0.65)
Keel strength area B (kg)	15.49 (± 0.63)**	12.50 (± 0.34)

Means in the same row differ significantly (t-test). * $P < 0.05$; ** $P < 0.01$.
Area A: directly below the manubrial spine; Area B: mid -ateral surface.

(Nasr et al., 2012 , Anim. Welf. 21:127-135)

Fractures: Behavioural measures

KF status was confirmed by dissection at the end of study, and divided into 4 categories of severity for a more detailed analysis:

Table 6 Linear Regression of home-pen, free-perch access, walking velocity, flying, landing and keel-bone strength in hens with different keel-fracture severity (classified following keel-bone dissection).

Traits	df	*F*	*P*-value	β
Spontaneous access perch height 50 cm	1, 62	4.87	0.031	−1.808
Spontaneous access perch height 100 cm	1, 62	2.97	0.090	−0.502
Average of time taken to reach 1st obstacle	1, 70	3.11	0.082	0.509
Average of time taken to reach 2nd obstacle	1, 70	4.00	0.049	2.11
Average of time taken to reach food	1, 70	2.61	0.110	2.62
Average of time taken to fly from ground to perch 50 cm height	1, 70	1.20	0.276	14.97
Average of time taken to fly from ground to perch 100 cm height	1, 70	4.54	0.037	21.69
Average of time taken to land from perch 50 cm height to ground	1, 70	1.51	0.223	8.33
Average of time taken to land from perch 100 cm height to ground	1, 70	7.25	0.009	23.75
Average of time taken to land from perch 150 cm height to ground	1,70	4.37	0.040	21.80
Keel-bone strength area A (kg)	1, 74	22.97	0.000	−2.620
Keel-bone strength area B (kg)	1, 74	26.29	0.000	−1.389

Area A: directly below the manubrial spine; Area B: mid lateral surface. β: Regression coefficient.

Hens with keel fractures spent more time sleeping on the floor compared to hens with no keel bone fractures: 0.18 [± 0.09] vs 0.00 [± 0.00].

Mobility in birds with KF is decreased.

(Nasr et al., 2012 , Anim. Welf. 21:127-135)

Fractures: Behavioural measures

TABLE 3 | Association between fracture severity and the percentage of time resting on the floor vs. perch.

	F_0 $N = 16$ %	F_1 $N = 9$ %	F_2 $N = 23$ %	P-value
Rest on perch	20.2. ± 6.9[a]	42.5 ± 12.5[b]	48.1 ± 7.8[b]	0.0114
Rest on floor	80.0 ± 6.9[a]	56.9 ± 12.4[b]	51.5 ± 7.7[b]	0.0161

[a,b] Differences in designate statistical significant difference of $P < 0.05$.

F_0: Non-fractured
F1: Minor fracture; single "greenstick" fracture at the caudal tip
F2: Severe fracture; multiple fractures, including at least one complete fracture

Furnished cages =>

Perches at 10 cm height, i.e. no flying or jumping required to access.

"The differences in results between these two studies highlight the importance of considering how housing environment can alter the expression of pain behavior."

(Casey-Trott & Widowski, 2016, Frontiers in Vet. Sci.)

Fractures:
Behavioural measures

Free-range
Commercial farm
Scale:
0 = no damage
1 = minor damage
2 = severe damage

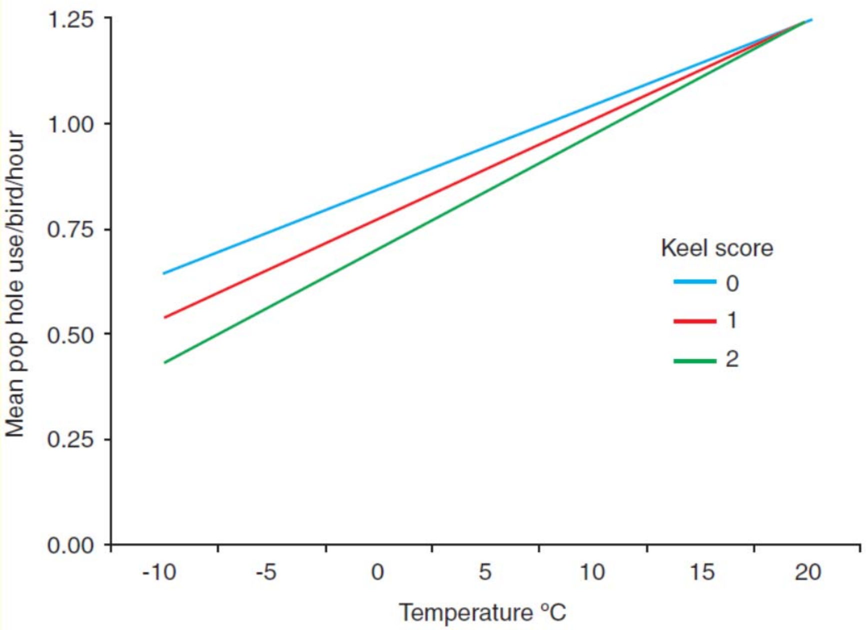


FIG 1: The interaction effect of temperature and keel score on predicted mean pop hole use/bird/hour

(Richards et al., 2012, Vet. Record 170:494)

TABLE 2: Percentage of birds with each keel score determined by palpation* at each visit week throughout the laying period (percentage based on assessments of newly tagged birds and birds re-caught at each visit week)

		Visit week					
Batch	Keel score	25	35	45	55	65	68 to 70
Batch 1 (%)	0	94	76.2	43.0	35.1	28.1	19.0
	1	6	18.7	42.7	42.9	46.0	49.0
	2	0	5.1	14.3	22.0	25.9	32.0
N		100	235	281	333	374	415
Batch 2 (%)	0	95	72.9	57.8	41.0	36.0	24.0
	1	4	19.9	29.1	38.0	38.0	43.0
	2	1	7.2	13.1	21.0	26.0	33.0
N		200	251	344	405	339	351

* Wilkins and others (2004)

TABLE 3: Percentage of birds with each keel score (determined by palpation* at each visit week throughout the laying period of batches 1 and 2 combined) that had used the pop holes or remained in the house (percentages based on only those birds that had been re-caught at each visit week)

		Visit week			
	Keel score	35	45†	55	65
Used pop hole (%)	0	70.7	53.9	40.0	29.5
	1	22.0	35.3	42.0	50.5
	2	7.3	10.8	18.0	20.0
N		164	371	462	539
Remained inside (%)	0	61.3	36.4	32.8	22.6
	1	25.8	36.3	39.3	50.0
	2	12.9	27.3	27.9	27.4
N		31	55	61	62

* Wilkins and others (2004)
† Chi-squared exact estimate P=0.002

Decreased mobility in birds with KF, affected by ambient temperature.

Fractures: Behavioural measures

- Experimental study
- Small groups
- 43 palpations from weeks 19-64
- RFID system (hens and nestboxes)

<u>Data collected</u>

Duration of nesting during 10-day periods before and after fracturing the keels

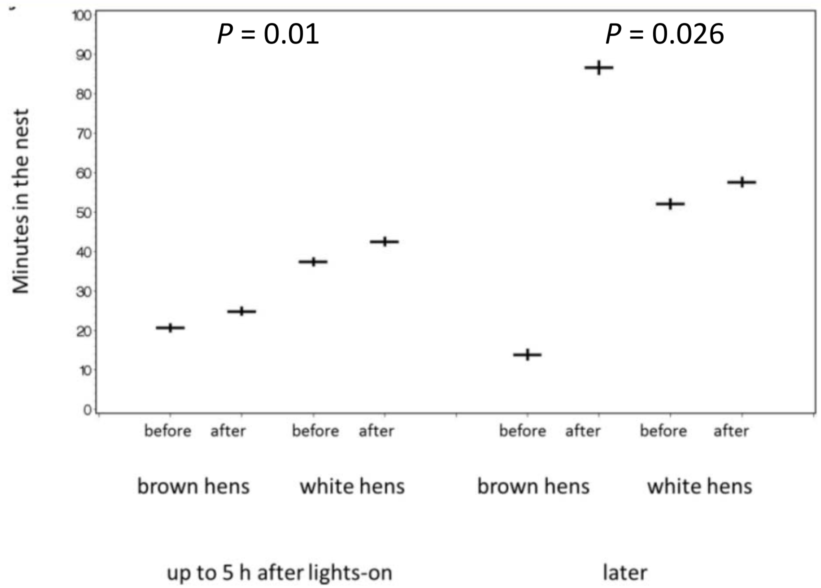


Figure 6. Hens were longer in the nest during the 10 days after the fracture of the keel bone than during the 10 days before the fracture (back transformed least square means). Means (horizontal bars) and standard errors (vertical bars) are given.

"This behavioural change may be due to laying of the egg is difficult or even painful after the keel bone fracture."

(Gebhardt-Henrich and Fröhlich, 2015, Animals 5:1192-1206)

Fractures: Physiological measures

Laying hens collected on-farm

- Severe, healed KF
- Minor, healed, KF
- No KF

Thermal images on days 1, 4, 10 and 19.

KF status confirmed by dissection at the end of study.

Table 3 Mean (± SEM) of keel-area temperature, [redacted] in hens with and without keel fractures (classified following keel-bone dissection).

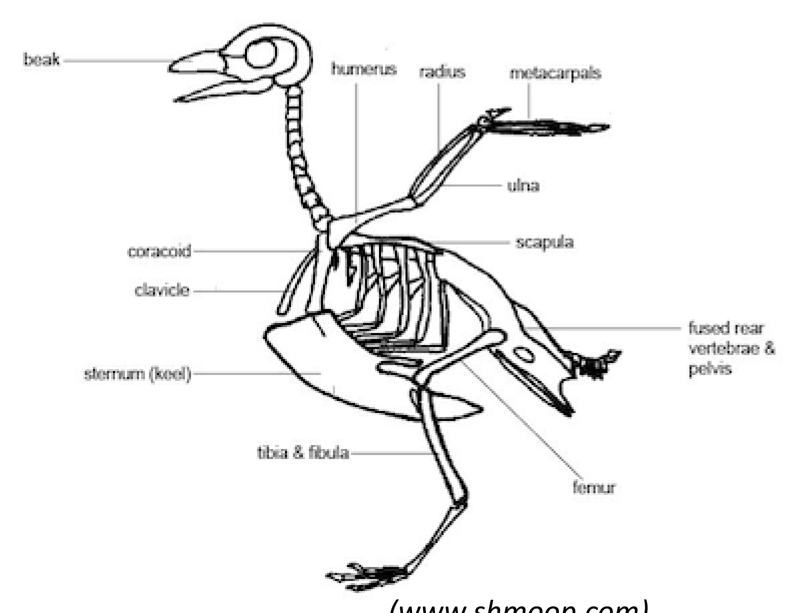
Factor	Hens with no keel fractures	Hens with keel fractures
Number of birds	16	60
Temperature of keel area	37.90 (± 0.17)**	37.29 (± 0.12)

Means in the same row differ significantly (*t*-test).
* $P < 0.05$, ** $P < 0.01$. [redacted]

"Perhaps due to the atrophy and disuse of the breast muscle tenders (Pectoralis minor) or the breast muscle fillets (Pectoralis major)."

(Nasr et al., 2012 , Anim. Welf. 21:127-135)

Fractures: Physiological measures



(www.shmoop.com)

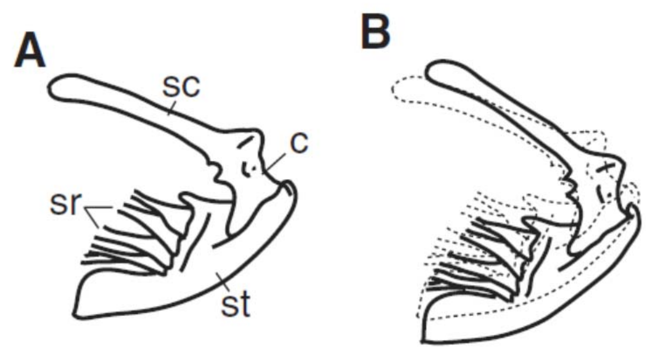


Fig. 5. Rotation of the pectoral girdle with respect to the sternum at the coracosternal joint, modeled based on film sequence 2. During expiration, the angle between the coracoid and the sternum is sharpest (**A**). During inspiration, the sternum is displaced ventrally, and the angle between the coracoid and sternum becomes more obtuse. Pectoral girdle in expiratory position shown in dashed outline (**B**).

sr = sternal ribs, sc = scapula, st = sternum, c = coracoid

(Claessens et al., 2009, J. Exp. Zool. 311A:586-599)

Hypothesis: If the keel bone is severely damaged, the involvement of the keel in respiration may be reduced due to pain or physical restriction of motion, potentially influencing the metabolic or thermoregulatory capacity of the birds.

Fractures: Clinical measures

The presence of KF is in itself a clinical measure, which is an indicator of reduced welfare (*FAWC, 2010*).

KF and mortality

- Neither an on-farm study nor an experimental study have found associations between KF and mortality (Heerkens et al., 2016; Gebhardt-Henrich and Fröhlich, 2015).

Mortality seems not to be affected by KF.

Fractures:
Clinical measures

Table 3 **Mean (± SEM) of [redacted] bodyweight [redacted] in hens with and without keel fractures (classified following keel-bone dissection).**

Factor	Hens with no keel fractures	Hens with keel fractures
Bodyweight (kg)	1.83 (± 0.03)	1.81 (± 0.02)

Means in the same row differ significantly (*t*-test).
* $P < 0.05$, ** $P < 0.01$. Area A: directly below the manubrial spine; Area B: mid-lateral surface.

(Nasr et al., 2012 , Anim. Welf. 21:127-135)

Table 2. *Feed intake, water intake, [redacted] body weight [redacted] in hens with and without keel fractures*

	Hens with no fracture ($n = 60$)		Hens with fractures ($n = 105$)		
Parameter	Mean	SE	Mean	SE	P^3
Body weight (kg)	1.80	0.02	1.78	0.02	0.37
Feed intake (g)	139.0	4.65	151.1	3.66	0.04
Water intake (ml)	212.2	8.04	237.4	7.24	0.03

[3] P = Probability (2-tailed).

(Nasr et al., 2013, Br. Poult. Sci. 54:165-170)

KF seems to reduce feed conversion ratio as well as increase water intake, influencing the economics of egg production negatively.

Fractures: Indicators of affective states

Laying hens collected on-farm:

- KF or no-KF by palpation

Landing test: Latency to fly down from a 50, 100 or 150 cm high perch.

Each bird:

- 2 x butorphanol and 2 x saline

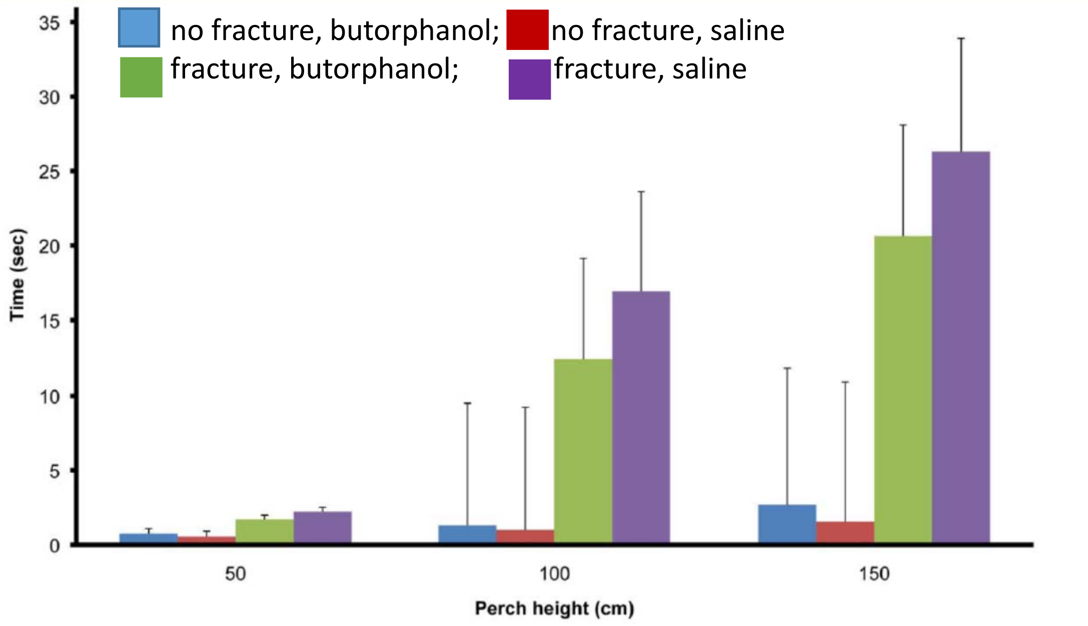


Figure 1. Latency to land from different perch heights after saline and butorphanol treatment. Mean (SEM) latency to land (seconds) from three different perch heights (50, 100, 150 cm) in birds with (n = 35) and without (n = 23) keel bone fractures following treatment saline or butophanol, 2 mg/kg injected subcutaneously in the dorsal neck. Birds without keel fractures are indicated in red (following saline treatment) or blue (following butorphanol treatment). Birds with keel fractures are indicated in purple (following saline treatment) or green (following butorphanol treatment).
doi:10.1371/journal.pone.0042420.g001

Administration of analgesic butorphanol reduced latency to fly down only in the fractured hens, providing evidence for pain involvement in KF.

(Nasr et al., 2012 , Plos One 7: e42420)

Fractures: Indicators of affective states

Conditioned place preference

- Training: Injected with either saline or butorphanol -> placed in a specific coloured (blue or orange) environment (a T-maze with one arm blocked).
- Test: T-maze choices (blue or orange arm).

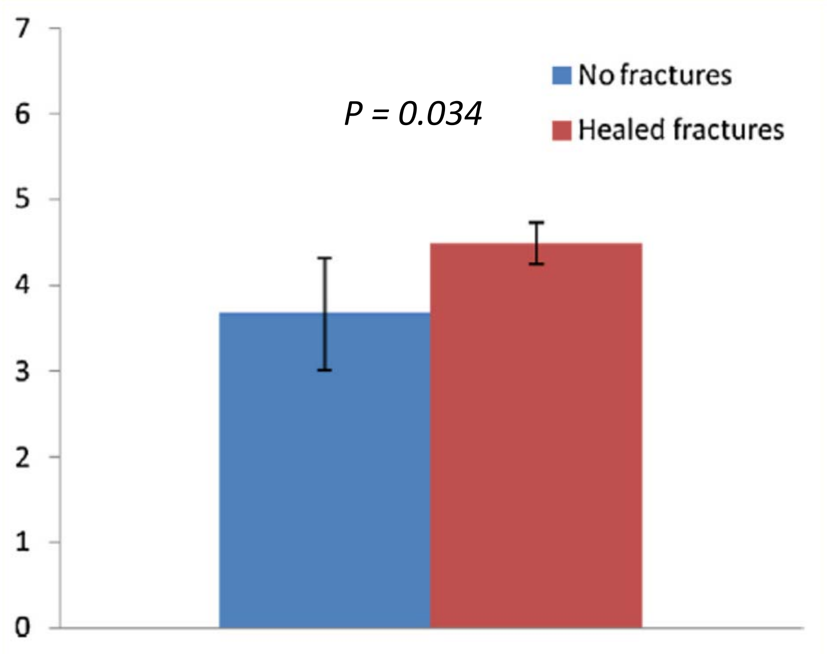


Fig. 1. Number of T-maze choices (out of a maximum of 7) made for a test environment paired with butorphanol for hens with no fractures ($n = 12$) and hens with healed keel bone fractures ($n = 35$). Bars indicate s.e.m.

Probability of choosing the colour where the butorphanol had been experienced

- 0.524 for birds with no KF (chance level)
- 0.679 for birds with KF (≠ chance level)

That the conditioned place preference was shown only by the fractured birds suggests that the analgesic properties of butorphanol was found rewarding
=> healed keel fractures are a source of chronic pain.

(Nasr et al., 2013 , Appl. Anim. Behav. Sci. 147:127-131)

Fractures: Production parameters

Table 3 Mean (± SEM) of [redacted] egg quality [redacted] in hens with and without keel fractures (classified following keel-bone dissection).

Factor	Hens with no keel fractures	Hens with keel fractures
Number of birds	26	76
Number of eggs	172	473
Egg weight (g)	63.25 (± 1.10)	61.26 (± 0.52)
Egg-shape index (%)	76.95 (± 0.45)	77.74 (± 0.22)
Egg-surface area (cm^2)	74.16 (± 0.91)	72.51 (± 0.43)
Shell thickness (mm)	0.41 (± 0.006)	0.41 (± 0.005)
Shell weight (g)	5.81 (± 0.09)*	5.57 (± 0.06)
Shell percentage (%)	9.21 (± 0.10)	9.10 (± 0.08)
Shell density (mg cm^{-2})	78.34 (± 0.77)	76.76 (± 0.70)
Bodyweight (kg)	1.83 (± 0.03)	1.81 (± 0.02)
Egg production (%)	94.51 (± 1.39)**	89.10 (± 1.58)

Means in the same row differ significantly (*t*-test).
* $P < 0.05$, ** $P < 0.01$. Area A: directly below the manubrial spine; Area B: mid-lateral surface.

Table 4 Linear Regression of [redacted] egg-quality parameters [redacted] in hens with different keel-fracture severity (classified following keel-bone dissection).

Traits	df	*F*	*P*-value	β
Average egg weight (g)	1, 100	5.469	0.021	–0.985
Average egg-shape index (%)	1, 100	1.902	0.171	0.248
Average egg-surface area (cm^2)	1, 100	6.646	0.011	–0.812
Average eggshell thickness (mm)	1, 100	0.028	0.867	0.001
Average eggshell weight (g)	1, 100	0.681	0.411	–0.040
Average eggshell percentage (%)	1, 100	1.731	0.191	0.079
Average eggshell density (mg cm^{-2})	1, 100	0.558	0.457	0.320
Average egg production percentage during 7 days	1, 100	0.218	0.642	–0.524

Area A: directly below the manubrial spine; Area B: mid-lateral surface. β: Regression coefficient.

In this experimental study, different parameters of egg production have been found to be negatively impacted by KF.

(Nasr et al., 2012 , Anim. Welf. 21:127-135)

Fractures: Production parameters

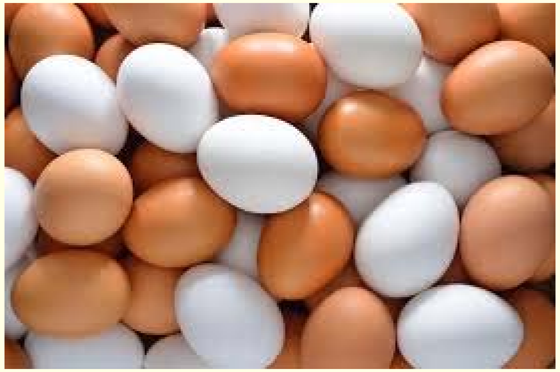
Gebhardt-Henrich and Fröhlich (2015)

- no associations between total number of eggs produced and KF.
- no differences in the rate of egg production between a 28 days pre- and post-fracture periods.

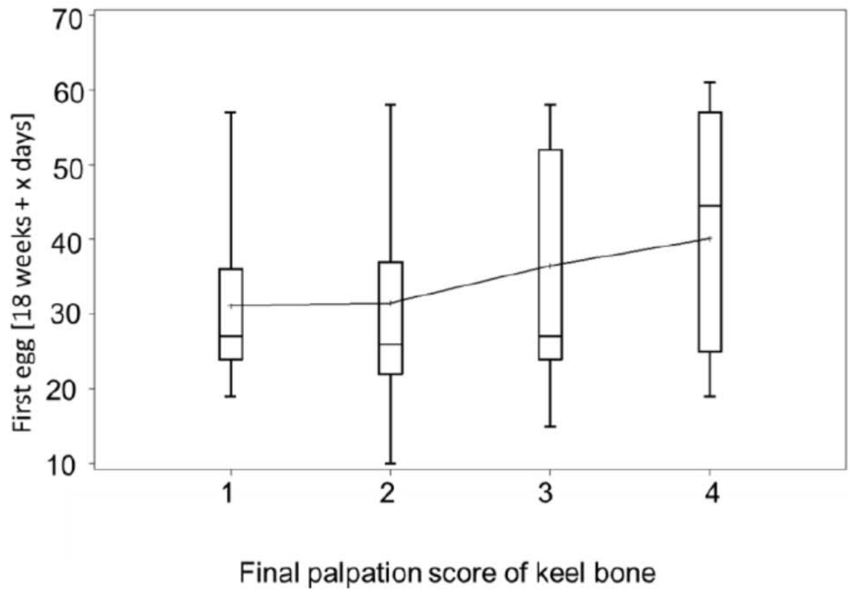
Heerkens et al. (2016)

- no associations between egg production and KF in an on-farm study of 47 flocks of laying hens housed in aviaries.

In these studies, the rate of egg production has not been found to be impacted by KF.



Fractures: Production parameters



1 = severe fracture,
2 = moderate fracture,
3 = slight deviation,
4 = normal keel bone

Figure 5. Boxplot of the age when the first egg was laid for hens with different palpation scores at the end of the laying period. Means are connected for better visibility. Hens with better (=higher) score of the keel bone had laid their first egg at a later age than hens with lower scores.

(Gebhardt-Henrich and Fröhlich, 2015, Animals 5:1192-1206)

Early point-of-lay increases the risk of KBD.

Deviations

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World's Poultry Science Journal, Vol. 71, September 2015

Causes of keel bone damage and their solutions in laying hens

A. HARLANDER-MATAUSCHEK[1], T.B. RODENBURG[2], V. SANDILANDS[3], B.W. TOBALSKE[4] and M.J. TOSCANO[5]*

Recommendation 3 - Investigate the relationship between KD and KF

Hypotheses

"1) A keel with deviations may lead to unequal bone loading during wing-flapping and concentration of strain energy in ways that increase the risk of fracture.

2) Deviated keels may lead to KF indirectly by complicating balance maneuvers."

Is there a link between KF and KD? - No scientific data available yet

Conclusion

Keel bone fractures have been shown to affect most of the welfare indicators examined, i.e. KFs

- prevent the birds from performance of motivated behaviour
- are painful
- have negative effects on egg production

The welfare consequences of **keel bone deviations** remain largely unclear, but it has been suggested that they have negative effects on welfare in terms of causing increased risk of fractures and impaired movement and rest.

Some thoughts…

In many studies limited information is provided on the severity of the KF involved

- At least in Denmark, the far majority of the fractures are at the caudal tip of the keel bone ("greenstick") – do they have the same impact on welfare as complete fractures elsewhere on the keel bone?

Keel bone deviations are to a large extent overlooked

- More attention should be directed towards deviations. Not only may they have direct negative consequences on welfare, but also indirectly, if they increase the risk of birds having their keel bones fractured.

More longitudinal studies…

Thank you for your attention!

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