Development of novel approaches to assess and improve skeletal integrity in laying hens

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Introduction

Over the past 20 years consumer perception of how eggs should be produced has changed significantly, for instance the ban on use of conventional cages in the EU. This has caused the industry to adapt to the needs of its consumers (Fröhlich *et al*., 2012). Challenges in the industry have since arisen, such as how to maintain skeletal integrity throughout varying systems and to retain high welfare whilst still achieving similar outputs. It is commonly acknowledged that the type of housing system affects the availability to perform exercise which has a great influence on skeletal health.

The general aim of this study was to investigate the effects of age and housing system on skeletal integrity throughout the laying period, to begin to predict skeletal health in future flocks

Methods

Six birds were collected from 14 farms every 6 weeks from 18-72 weeks of age, covering five different housing systems (3 farms per system except barn = 2). Commercial diets were fed to the hens throughout the laying period, specific to farm requirements. Birds were culled upon collection at the farms and transported back to the labs where they were weighed. Once weighed, the keel, humeri and tibiae were removed and measured for length, width, weight, breaking strength and bone ash content. To begin predicting skeletal data, a Gaussian Linear Mixed Model (LMM) was used to model bone strength over the period of lay for bone type and housing system – model formulation to the right:

$$Strength_{ij} \sim Gaussian(\mu_{ijk}, \sigma^2)$$

$$E(Strength_{ijk}) = \mu_{ijk} \quad \text{and} \quad var(Strength_{ijk}) = \sigma^2$$

$$\mu_{ijk} = Intercept + Weight_{ijk} + Age_{ijk} \times Housing_{ijk} + Age_{ijk} \times Bone_{ijk} + Bird_j + Farm_k$$

$$Bird_j \sim Gaussian(0, \sigma^2_{Bird})$$

$$Farm_k \sim Gaussian(0, \sigma^2_{Farm})$$

Results

A Gaussian Linear Mixed Model was fitted to the bone data to predict bone breaking strength over the laying period of hens from UK farms in multiple housing systems. Individual farm and bird were fitted as random terms and bone weight as a covariate. Conditional R2 was 0.703 and marginal R2 was 0.492. Model parameter estimates are shown in Table 1 and Fig. 1.

Table 1 shows the intercept (Caged tibia strength) differs significantly from 0 ($p < 0.001$). Bone weight is a significant predictor of bone strength ($p < 0.001$), with a parameter estimate of 23.60, indicating that as bone weight increases, bone strength increases at this rate. As a main effect, age was not significantly different from 0 ($p = 0.072$; estimate = -5.75), though as a trend as age increased, caged tibia strength decreased. Free-range flat deck bone strength was significantly greater than caged tibia strength ($p = 0.020$; estimate = 27.37). Free-range multi-tier bone strength was significantly stronger than caged tibia strength ($p < 0.001$; estimate = 38.30). Organic bone strength was also significantly stronger than caged tibia strength ($p < 0.001$; estimate = 56.78). The keel bone was significantly weaker than caged tibia ($p < 0.001$; estimate = -127.17). Barn bone strength and free-range flat deck bone strength both declined significantly faster than caged bone strength ($p = 0.024$; estimate = -10.64 and $p = 0.025$; estimate = -10.92 respectively). Humerus bone strength declined significantly faster than tibia bone strength ($p < 0.001$; estimate = -12.04). Keel bone strength also declined significantly faster than tibia bone strength ($p < 0.001$; estimate = -8.74).

Table 1 Summary of Gaussian LMM to model bone strength over laying period of UK laying hens with farm fitted as a random term. The estimated value for σ^2 is 1969.71, $N_{farms} = 14$, $N_{birds} = 781$, $N_{obs} = 3869$. The caged housing system was set as the baseline coefficient.

	Gaussian Model		
Coefficient	Estimates	CI (95%)	p
(Intercept)	214.44	197.88 – 231.01	**< 0.001**
Bone weight	23.60	19.05 – 28.15	**< 0.001**
Age	-5.75	-12.01 – 0.51	0.072
House [B]	16.31	-9.17 – 41.78	0.210
House [FR FD]	27.37	4.30 – 50.43	**0.020**
House [FR MT]	38.30	15.47 – 61.14	**0.001**
House [O]	56.78	33.96 – 79.59	**< 0.001**
Bone [Humerus]	-4.49	-13.93 – 4.95	0.351
Bone [Keel]	-127.17	-131.31 – -123.02	**< 0.001**
Age * House [B]	-10.64	-19.91 – -1.37	**0.024**
Age * House [FR FD]	-10.92	-20.43 – -1.40	**0.025**
Age * House [FR MT]	-2.35	-10.71 – 6.01	0.581
Age * House [O]	-0.61	-9.00 – 7.78	0.886
Age * Bone [Humerus]	-12.04	-15.19 – -8.89	**< 0.001**
Age * Bone [Keel]	-8.72	-12.65 – -4.78	**< 0.001**
	Random Effects		
σ^2	1969.71		
$\tau_{00\ Bird}$	1218.19		
$\tau_{00\ Farm}$	175.11		
ICC	0.41		
N_{Bird}	781		
N_{Farm}	14		
Observations	3869		
Marginal R^2 / Conditional R^2	0.492 / 0.703		

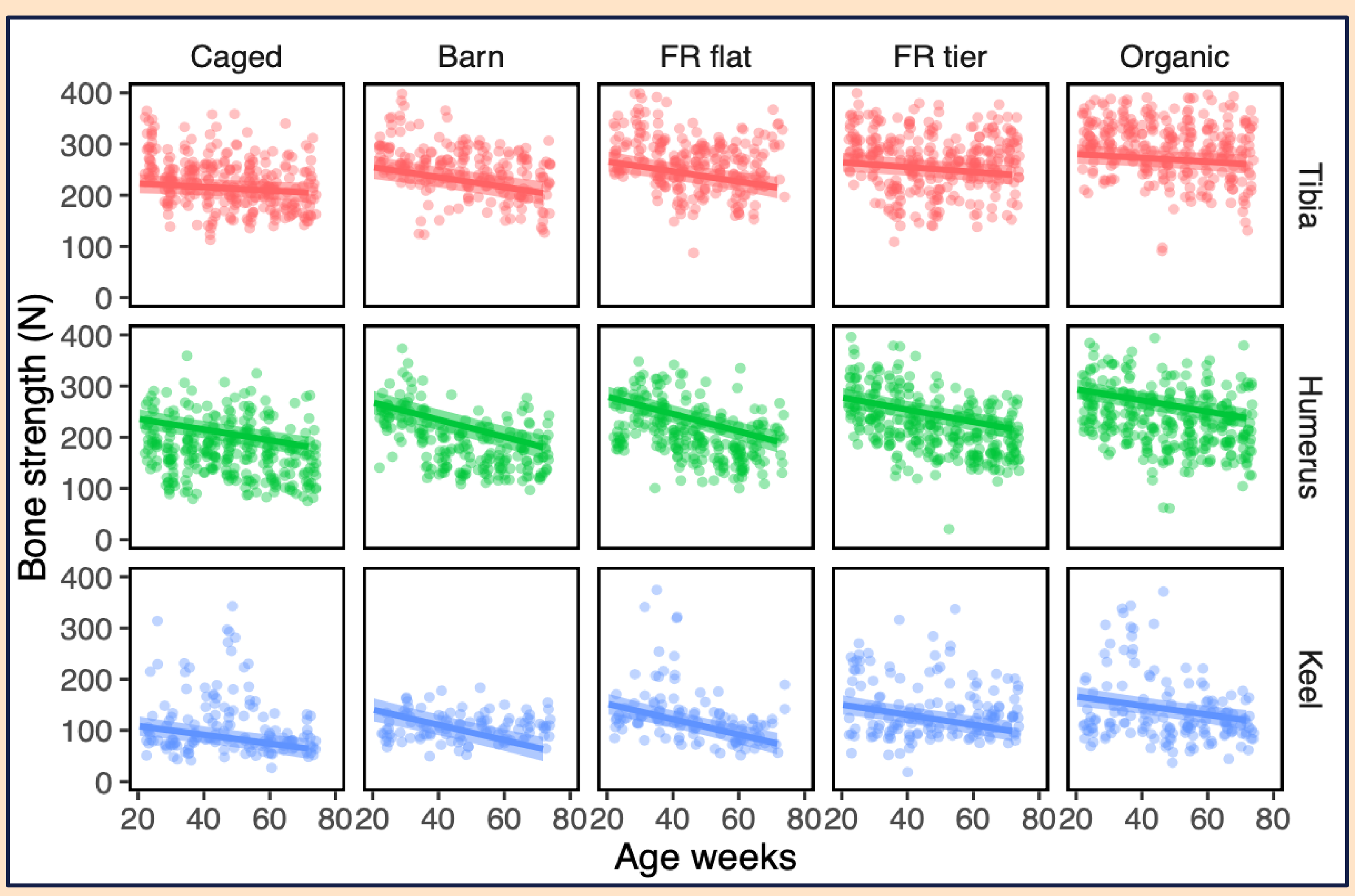

Fig. 1 Mean fitted bone strength of UK laying hens (solid line) and 95% confidence intervals (shaded area) over age (weeks) modelled with a Gaussian LMM, with farm and individual bird fitted as random terms in the model. Data is split by housing system and bone type.

Conclusion

It was found that bone weight can act as a good predictor of bone strength within the model. Although age was not found to have a main effect on bone strength but did trend, it is overall accepted that as age increases bone strength decreases due to osteotic activity (Whitehead and Fleming, 2000). As somewhat expected, bone strength from caged systems was significantly weaker than free-range or organic. These results were thought to be caused by the effect of exercise differences within different systems. Surprisingly, the barn and flat deck free-range systems declined quicker than caged systems. It is possible that more exercise can lead to more bone fractures/damage whilst reducing the effects of osteoporosis. Caged systems could also be suggested to have overall lower bone strength than other systems and therefore show less of a decline in poor bone health. The faster decline in the keel and humerus bones compared to the tibia could be due to the different locomotory functions each bone has and differing amounts of exercise per each bone and tibia could be the most commonly exercised. Increased medullary bone content in the keel or humerus compared to the tibia could also influence the rate of decline – more medullary bone, less strength. Furthermore, the effect of keel bone damage throughout lay could have affected the rate of keel strength decline.

It was concluded that using a range of bones to assess skeletal integrity is essential, as bone form and function differ, thus bone parameters are affected differently. Future work should increase the factors used within the model. Ultimately, modelling bone health data could be used as a tool to predict future bone health and act as an early warning system in flock management.

References

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