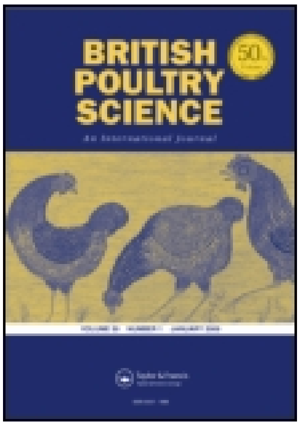

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Prevalence of keel bone deformities in Swiss laying hens

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Abstract 1. The goal of this study was to evaluate the prevalence of keel bone deformities of laying hens in Switzerland. The keel bones of 100 end-of-lay hens from each of 39 flocks (3900 in total) were palpated.
2. On average, 25·4% of the hens had moderately or severely deformed keel bones and the overall prevalence including slight deformities was 55%.
3. Variation between flocks was considerable. Thus, the prevalence of moderately or severely deformed keel bones ranged from 6 to 48%, and the overall prevalence including slight deformities ranged from 20 to 83%.
4. Aviary housing was associated with a higher prevalence of total, and severe or moderate deformations, compared with floor pens.
5. There were no significant differences in the number of deformities between the different plumage colours, hybrids or perch materials.

INTRODUCTION

Keel bone deformities are a widespread problem in commercial laying hens (Sandilands *et al.*, 2009). In a UK study on 10 flocks of end-of-lay-hens, the prevalence of birds with fractures varied from 50% to 78%, with the keel as the most frequently damaged bone accounting for 90% of the fractures (Wilkins *et al.*, 2004). This is congruent with observations made by Clark *et al.* (2008) who found S-shaped keel bone deformations in 36% to 88% of birds in 6 flocks. This problem is not new, as keel bone deformities have been reported since the 1930s (Carstens *et al.*, 1936). Due to its exposed anatomical location, the keel is particularly prone to damage. In moderately and severely deformed keel bones, fracture calluses were always evident upon histological examination, pointing to a traumatic etiology (Fleming *et al.*, 2004; Scholz *et al.*, 2008). Keel bone fractures involve acute and chronic pain and, therefore, include an animal welfare component which needs to be considered.

Two major aspects need to be taken into account when considering possible causes of keel bone lesions. Laying performance may affect calcium metabolism and lead to brittle bones (Hocking *et al.*, 2003). Correspondingly, osteoporosis is one of the major causes for bone brittleness in laying hens (Whitehead and Fleming, 2000). Besides nutritional and genetic factors affecting the animal's constitution, inadequate housing may affect behaviour and lead to traumatic fractures. Due to the restriction on free moving space, caged birds have weaker bones than birds kept in alternative housing systems (Fleming *et al.*, 1994; Knowles and Wilkins, 1998; Newman and Leeson, 1998; Fleming *et al.*, 2006). Yet, despite the superior bone breaking strength in hens kept in alternative housing systems, the prevalence of keel bone lesions is higher when housing systems are equipped with perches. Thus, collisions and landing accidents are likely

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to play a significant role in the etiology of keel bone trauma (Gregory *et al.*, 1991; Appleby *et al.*, 1993; Tauson and Abrahamsson, 1994). According to the Swiss legislation adopted in 1992, only non-cage houses with perches are permitted for laying hens. All housing systems must provide at least 14 cm of elevated perches per hen. By 2012, the EU requires all conventional cages to be replaced by furnished ('enriched') cages, or alternative systems equipped with perches. Therefore, non-cage systems will increase in number. To date, no investigation has been conducted on the prevalence of keel bone deformities in Switzerland. The goal of the present study, therefore, was to provide reliable data on the prevalence of keel bone deformities in laying hens and to correlate these findings with housing systems. These figures shall be used as a basis for improving alternative housing systems and animal welfare.

MATERIALS AND METHODS

Data were collected between October 2008 and December 2009. Keel bones from a total number of 3900 end-of-lay hens from 39 flocks on 37 Swiss commercial layer farms were analysed. The flock sizes varied from 1200 to 12000 birds (mean 4334). The sizes of eight flocks were unknown. Farm owners of the flocks were contacted by telephone in order to inquire about breed, colour, age, housing system, outdoor access, material of perches and flock size. This information was not authenticated. Thus the data reflect the farmers' statements. In the present study, two farms were included twice because more than one flock was slaughtered during the 14 months of the investigation. Since the corresponding flocks came from different hen houses, they were considered to be independent. Perch materials included wood, plastic and metal. Whenever more than one material was used in one hen house, perch material was categorised as 'other'. Samples were collected at three different locations: birds from 33 flocks were examined at two different commercial poultry abattoirs and the 6 remaining flocks were analysed on-site during depopulation. None of the flocks was palpated both at the abattoir and on the farm. A hundred birds were randomly selected from each flock and the keel bones were examined by palpation. At the abattoir, birds were checked immediately after the defeathering process. On the farms, palpation on live birds was performed before they were loaded onto the transporter. All the birds were assessed by the same examiner (S.K.). Palpation was performed by running two fingers down the edge of the keel bone in order to detect alterations like S-shaped deviations, bumps, depressions or proliferations. The following scoring system was used: 4 = normal keel bone, 3 = slight deformation, 2 = moderate deformation, 1 = severe deformation. Before the start of data collection, S.K. learned the palpation method from B. Scholz, who had used the same method in previous studies. Both examiners scored the same birds, until identical results were obtained.

Table 1. *Number of flocks of different hybrids (total 39 flocks)*

White hybrids	*n*	Brown hybrids	*n*	Others	*n*
LSL	11	LB	7	Silver	3
HN	5	BN	3	Sperber	1
		Bovans	1	Mixed flocks	8

Hybrids: LSL = Lohman Selected Leghorn Classic, LB = Lohmann Brown Classic, Silver = Lohmann Silver (http://www.ltz.de) HN = H&N Nick Chick, BN = H&N Brown Nick (http://www.hn-int.com) Bovans = Bovans Goldline (http://poultrykeeper.com/hybrids/bovans-goldline/), Sperber= Sperber (http://www.geisser-trupro.ch/junghennen.php?r=3).

To evaluate the repeatability of the palpation method, 30 laying hens of one flock were marked with leg bands at the age of 48 weeks, and a helper wrote down the palpation result and band number. About two hours later, the examiner palpated the 30 tagged birds again and the two results were compared. To evaluate the constancy of the palpation score, those hens were scored again 6 and 12 weeks after the initial palpation.

Statistical analysis

The interactions between different housing parameters and hybrids were tested using Fisher's Exact Test. Since the percentages of the scores were normally distributed and fulfilled the assumptions of parametric tests, they were analysed by general linear models using Type 3 Sums of Squares of PROC GLM and its CONTRAST statement (SAS® 9·1). Non-significant interactions were pooled. All effects were considered fixed. When colour was included as a factor, flocks of mixed colours and rare colours (Lohmann Silver and Lohmann Sperber) were excluded. The classification of hybrids is shown in Table 1. One farm neither belonged to the floor pen systems nor the aviaries. In analyses involving type of housing, this farm was excluded. Therefore, sample sizes vary between the different analyses. The agreement between the repeatedly measured scores of the same hens was given as the weighted kappa coefficient in the Procedure FREQ of SAS 9·1. The weighted kappa coefficient differs from the simple coefficient by weighting the scores according to the frequencies in the second scoring event.

Table 2. *Number of systems with different perches (total 39 flocks)*

System (N)	Perch type			
	Wood	Plastic	Metal	Other
Aviary & outd (25)	1	12	8	4
Aviary no outd (7)	3	2	1	1
Floor & outd (5)	4	0	1	0
Floor no outd (1)	1	0	0	0
Other (1)	1	0	0	0

Floor = floor pen system, outd = outdoor access.

RESULTS

The number of flocks by breed, housing system and composition of perches are shown in Tables 1 and 2. Of the 39 flocks, 41% consisted of white hybrids, 28·2% of brown hybrids and the remaining 30·8% were either mixed flocks or neither brown nor white. The housing types were either aviary systems (82 %) or deep litter floor pens (15·4%). A majority (77%) of all flocks had access to an outdoor run (Table 2). A significant association between perch material and housing system was apparent. In floor pen systems, which tended to be older, 83% had wooden perches, whereas aviaries were usually equipped with metal and plastic perches ($\chi^2 = 16{\cdot}78$, $N = 39$, $P = 0{\cdot}003$) (Table 2). The different companies manufacturing the aviaries used different materials for perch construction ($\chi^2 = 19{\cdot}98$, $N = 39$, $P < 0{\cdot}0001$).

An average of 25·4% of the birds showed moderate or severe deformities of the keel bone (grades 1 and 2). The average proportion of damaged keels including slight deformities (grade 3) was 55%. However, variation between flocks was substantial (Figure). In the most affected flock, 48% of the birds exhibited moderate or severe deformities, whereas only 6% showed moderate or severe deformities in the least affected flock (Figure).

The repeatability of the palpation method was very high (Table 3). The kappa value was 0·95 and only one out of 30 hens was not scored identically in the second palpation. Six weeks later, only 22 of the 30 banded hens could be palpated, and 20 were palpated 12 weeks later. Some of the hens died and some could not be found. Four of the hens missing at the second date were found and scored at the third date. The repeatability of the scoring declined but remained high even when the time lag was 12 weeks. In six instances, hens were scored worse at a subsequent palpation, while only three times did a hen show an improved score.

The prevalence of keel bone deformities or fractures did not vary between flocks palpated during depopulation, and flocks palpated after the defeathering process at the abattoir (deformities: $F_{1,37} = 0{\cdot}14$, $P = 0{\cdot}72$, fractures: $F_{1,37} = 1{\cdot}22$, $P = 0{\cdot}28$) (Table 4). Aviary housing was associated with a higher prevalence of total ($F_{1,37} = 4{\cdot}26$, $P = 0{\cdot}046$) and severe and moderate deformations ($F_{1,37} = 4{\cdot}85$, $P = 0{\cdot}034$) than floor pens. Access to an outdoor run was neither significant for the total number of deformations, nor for severe or moderate deformations. Aviary systems from different companies had a different prevalence (Table 4). When only white and brown hybrids were included, companies differed in the total number of deformed keel bones ($F_{2,40} = 7{\cdot}86$, $P = 0{\cdot}001$, $N = 21$). The company with the highest prevalence differed from the other two ($F_{1,40} = 14{\cdot}72$, $P = 0{\cdot}001$, $N = 21$). There were no significant differences in the prevalence of moderate and severe deformities between companies.

No significant differences were detected between the different colours or hybrids, neither for moderate and severe, nor for the total number of deformities (Table 4). The perch material was not significantly associated with the number of moderate and severe or total count of deformities.

DISCUSSION

The present study revealed a prevalence of moderate or severe keel bone deformities in more than 25% of laying hens. When including slight deformities, the prevalence rose to 55%. Investigated flocks included the most commonly used hybrids in Switzerland (Häne *et al.*, 2000). Keel bone status was assessed by palpation of either live birds, or during slaughtering immediately after defeathering. This method is well suited to determine the keel bone status and has been successfully used in other studies (Wilkins *et al.,* 2004; Scholz *et al.,* 2008). The scoring method to assess keel bone deformities was reliable, as shown by the high kappa coefficient between repeated measurements. The changes in scores when the time lag between the palpations was 6 or 12 weeks could either be due to different assessments, or to a change in the condition of the keel bone. Our data set is too limited to investigate the second possibility.

In a recent study by Scholz *et al.* (2008), 162 macroscopically altered keel bones were analysed further by histological assessment. Light microscopy showed that all moderate or severe deformities of keel bones were associated with fractures and callus formation. In addition, this observation applied to half of the slight deformities as well. Fleming *et al.* (2004) also found fracture callus formation in most deformed

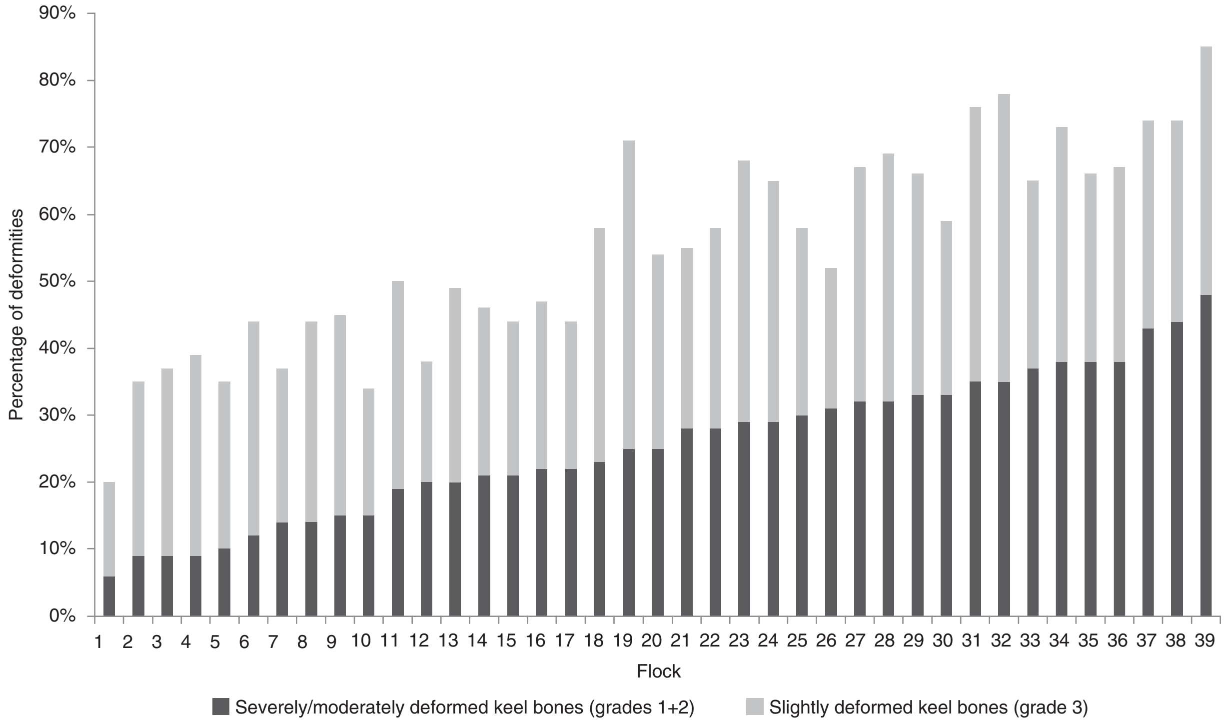

Figure. *The percentage of severely and moderately deformed keel bones in 39 flocks of laying hens.*

Table 3. *Repeatabilities measured as weighted kappa scores of multiple-palpated keel bones. Time lag 0 means that keel bones were palpated on the same day about 2 hours apart. Repeatabilities with time lag 6 weeks involve scorings made in week 48 and 56, and scorings made in week 56 and 62*

Statistic	Time lag			
	0	6 (weeks 48 + 56)	6 (weeks 56 + 62)	12 (weeks 48 + 62)
Kappa	0·95	0·71	0·54	0·79
P	0·0001	0·0001	0·02	0·0001
N	30	22	16	20

Table 4. *Proportion of birds with keel bone deformities determined by manual palpation classified by different locations, colours, systems of production, breeding company, type of perch and the presence or absence of outdoor access*

Effect (N)	Keel bone deformities			
	Grades 1&2 (%)	SE	Total (%)	SE
Location				
On farm (6)	0·30	0·03	0·59	0·04
Abbatoir (34)	0·25	0·02	0·55	0·03
Colour				
Brown hybrids (11)	27·0	0·03	54·6	0·05
White hybrids (16)	27·3	0·03	59·1	0·04
System	*		*	
Floor pen (6)	17·0	0·04	44·0	0·07
Aviary system (32)	26·6	0·02	56·5	0·03
Breeding company			*[1]	
A (16)	29·5	0·03	62·8	0·05
B (9)	25·5	0·03	49·8	0·04
C (4)	21·0	0·05	49·5	0·05
Perch material				
Wood (10)	22·0	0·03	52·1	0·04
Plastic (14)	27·4	0·03	59·7	0·05
Metal (10)	24·2	0·03	49·7	0·05
Outdoor access				
Yes (30)	26·3	0·02	56·5	0·03
No (9)	22·3	0·03	50·1	0·04

*$P < 0{\cdot}05$; grade 1 = severely deformed keel, grade 2 = moderately deformed keel, grade 3 = slightly deformed keel (total = sum of grades 1, 2 and 3).
[1]Differences are only significant if exclusively white or brown flocks are analysed.

keel bones. Thus, at least a quarter of all Swiss laying hens were affected by fractures of the keel bone. Fractures may occur during the slaughtering process of caged laying hens (Gregory and Wilkins, 1989). The investigated lesions may not have occurred during the slaughtering process as there was no evidence of fresh injuries, and the prevalence of fractures and deformations did not differ between flocks palpated during depopulation and after defeathering at the abattoir. Fractures always cause acute and chronic pain. Deformities of the keel bone (grade three) might also cause pain, especially in cases where callus formation indicates healed fractures. There is no evidence to support the contention of reduced pain perception in birds. Anatomical, physiological and behavioural parameters rather suggest that pain sensation is similar in birds and mammals and that ethical considerations normally given to mammals need to be extended to birds (Gentle, 1992). This high proportion of keel bone lesions, therefore, touches upon welfare aspects and requires a thorough analysis of possible causes.

Housing systems and perches are considered to be important factors with respect to keel bone lesions in laying hens. Notwithstanding, little attention has been paid to the effect of housing systems on the risk of injury (Sandilands *et al.*, 2009). Perches especially could cause deformations and fractures. Tauson and Abrahamsson (1996) compared conventional cages with 'get away' cages equipped with perches. They observed keel bone deformations only in hens kept in cages with perches. They also found that plastic or rubber covered perches did not prevent keel bone problems. In a similar comparison, Appleby *et al.* (1993) found 4% deformities in hens kept in conventional cages, compared with 43% deformities in hens kept in enriched cages. Similarly, Abrahamsson *et al.* (1996) reported a significantly higher prevalence of keel bone deformities in get away and enriched cages equipped with perches, compared with conventional cages without perches. In the present study, all systems had perches. Our results did not reveal any significant differences between different perch materials, which is congruent with the observations reported by Tauson and Abrahamsson (1996). However, aviary housing had a higher prevalence than floor pens and this might be due to hens colliding with perches (Scott *et al.*, 1997, 1999). Despite these significant parameters, much of the variation between flocks remains unexplained. Other uncontrollable factors may have influenced the results. Thus farm management, feed, animal rearing, the behaviour of a flock, or the age of the hen houses might affect the incidence of fractures. These problems may have partly blurred relevant associations between housing factors and the number of deformed keel bones. Notwithstanding, our data indicate that the design of an aviary may be important. The one aviary system in which hens had to feed while perching was associated with a higher prevalence of keel bone deformities compared with aviaries in which hens fed from wire platforms. Also, the array of the perches might be of relevance. Moinard *et al.* (1998) demonstrated that the distance between neighbouring perches affects the prevalence of crashes, and that hens have more difficulties jumping downwards than jumping upwards. Similarly, Scholz (2009) showed a higher prevalence of keel bone deformities when perches were installed at two levels instead of one level only. Such considerations also apply to the design of the nest box area and other obstacles within the system and may have an impact on the occurrence of accidents. These factors should be investigated in experimental studies and be taken into account in future system development. The considerable range of 6% to 48%, in the prevalence of moderate and severe deformities in different flocks, supports the contention that housing and/or husbandry are important factors with regard to keel bone deformities. Importantly, our results provide evidence that breed type is not related to the problem of keel bone deformations. This is in concordance with other authors who did not find any variation in the incidence of fractures between different hybrids (Gregory *et al.*, 1990; Weitzenbürger, 2005). However, Clark *et al.* (2008) reported a different prevalence of bone fractures in various non commercial laying hen lines. The prevalence was not related to the rate of egg laying.

The present survey is the first report on the prevalence of keel bone deformities in Swiss laying hens and it strongly emphasises the need for further investigations addressing possible causes of this debilitating disorder.

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