Limb Health in Broiler Breeding: History Using Genetics to Improve Welfare

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Primary Audience: Breeders, Researchers, Veterinarians, Flock Supervisors

SUMMARY

Recent years have seen commercial broilers reach market weights at systematically younger ages. These broilers have more efficient growth rates and higher meat yields due to advances in breeding programs and improvements in poultry husbandry, health, and nutrition. Nonetheless, some critics have voiced concerns with possible negative impacts on the skeletal integrity of broilers. To address these concerns, we provide in this paper time trends of breeding values for 11 to 14 yr for 5 skeletal (limb) health traits in broilers of 3 pedigree pure lines. Results presented are based on well over a million chickens per line. Of the 5 traits, 4 had low heritabilities with the other being low to moderately heritable. Yet through intense and persistent selection, incidence of limb issues has not worsened and has declined in 4 of the traits.

Key words: selection, tibial dyschondroplasia, femoral head necrosis, *valgus*, *varus*, rotated limb

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DESCRIPTION OF PROBLEM

Without variation, the expression of a trait will be uniform and genetic change via artificial selection is moot. Nongenetic approaches to certain limb conditions can result in "staircase" responses such as alleviating rickets, curly toes, and perosis by adding fish oil, riboflavin, and choline to the diet [1, 2]. In contrast, genetic changes in traits where there is no single major gene effect are achieved via selection with incremental effects resulting from changes in the residual genetic variation. For there to be genetic change, the trait must be identifiable and measurable. Complexity in selection for bilateral traits (left vs. right) can be compounded by the type (directional, fluctuating) of asymmetry [3]. Moreover, from a breeding perspective, the genetic response of a trait will be influenced by measurement (subjective, objective), sex (male, female), and type of genetic variation (additive, non-additive). Additional complexity may involve epigenetics, maternal effects, and other traits involved in the process as well as the environment per se.

Commercial broiler breeding programs are complex. Selection goals in these programs include a multitude of traits that may be traced back to the responsible organs in the chickens. For simplicity, they may be classified as supply organs (e.g., gastrointestinal tract and circulatory, respiratory, and immune systems) and demand organs (e.g., muscle, adipose, feathers, skeletal). Neither demand nor supply organs develop simultaneously with the former depending on the development of the latter [4].

The broiler of today is generally described as a chicken that reaches market weight at an early

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age, has a high proportion of skeletal muscle, and efficiently utilizes feed with high livability. The emergence of the commercial broiler that features these traits occurred mainly since the end of World War II [4] and is associated with a relative decrease in size of internal organs and modification of body structure [5–8]. Although skeletal muscle and the axial skeleton are of mesodermal origin, their downstream developmental paths differ [9]. Thus, selection for traits such as body weight and breast yield can influence skeletal integrity particularly the limbs [10–12].

Skeletal abnormalities are included among the plethora of traits measured in broiler breeding programs. Of particular relevance are those involving the limbs—bilateral structures with a complexity of measurement criteria ranging from subjective to definitive identification and age at expression. Singly and in combination, limb abnormalities may reflect a syndrome phenotypically expressed at various times in life. In a breeding program some traits will be defined as thresholds while others are scored by degree of severity. Here, we provide heritabilities and phenotypic time trends for 5 skeletal traits in 3 pedigree pure line populations.

MATERIALS AND METHODS

Analyzed were time trends for 5 limb traits in 3 pedigree pure lines over a period ranging from 11 to 14 yr, depending on the trait. The average generation interval was 43 wk, resulting in more generations than years in the program because commercial breeding programs rely on overlapping generations. Specifically, pedigree pure lines are routinely replaced as each small cohort reaches a time at which they are replaced by a subsequent cohort. As such, the generation interval is reduced, and final changes in average genetic merit of the flocks are perceived as a sloped line. The numbers of individual chickens where data were collected were approximately 1475,000, 1530,000 and 1395,000 for Lines 1, 2, and 3, respectively. As common for commercial broiler breeding programs, the 5 traits described below are just a small segment of the multitude of traits measured. Moreover, because of the extended time period of data collection there can be observer effects and slight modification in protocols, particularly for traits where measures are subjective and there is degree of penetrance in the ontogeny of expression. These caveats may be especially relevant when expression is in one limb and not the other.

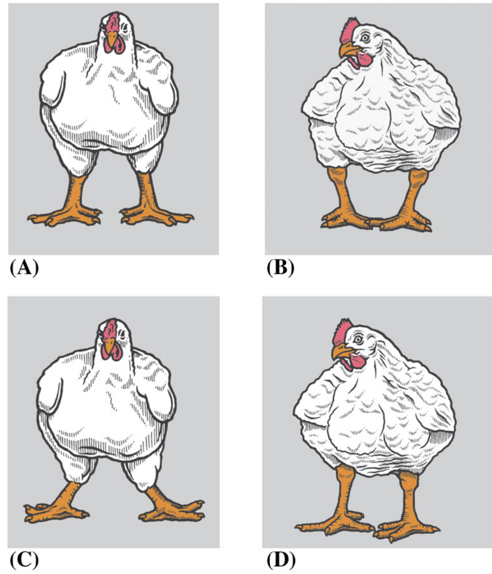

Figure 1. Examples of a normal chickens and chickens with three deformities. (A) Normal Chicken, (B) Bowed-out, (C) Bowed-in, (D) Rotated.

The subjective traits measured were 3 angular bone deformities—bowed-in, bowed-out, or rotated. Bowed-in limbs (Latin: valgus) refer to deformities in which the limb is abnormally angled or turned inward and bowed-out limbs (Latin: varus) are those deformities where an outward angulation of the limb is present. These deformities normally occur at the intertarsal joint, and may impact one or both legs. Rotated limbs display a gyration of the limb, resulting in an unnatural positioning of the feet. Examples of a normal chicken and chickens with these 3 deformities are shown in Figure 1. Data collection for these traits was via individual visualization by trained and experienced personnel. Tibial dyschondroplasia [13, 14] was measured in a non-invasive manner in live chickens using low-intensity x-ray imaging technology equipment [15]. A chicken with a normal proximal tibia presented no cartilaginous growth in either tibia while those that showed an abnormal presence

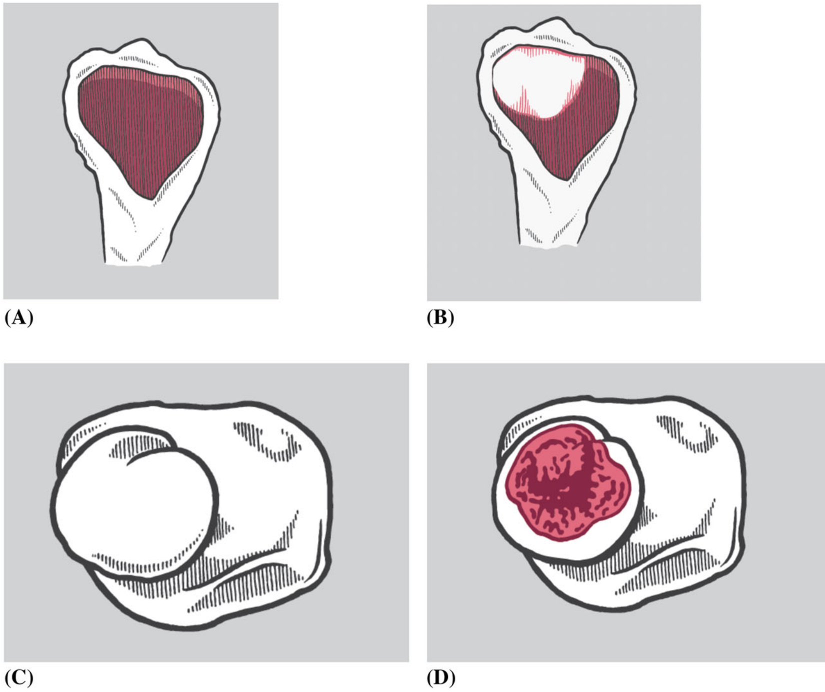

Figure 2. Examples of tibia dyschondroplasia vs. normal tibia and a normal femur vs. femoral head necrosis. (A) Normal Tibia, (B) Defective Tibia, (C) Normal Femur, (D) Defective Femur.

of cartilage in the head or growth plate of the tibia were scored as defective (Figures 2A and 2B). Femoral head necrosis [16] was based on a smaller sample size and required euthanasia of chickens. This process involved making a cut to separate the entire lower limb from the upper carcass and inspecting the condition of the proximal end of the femur and covering cap. Healthy chickens had an intact femur cap while those where the cap had separated from the head of the femur and those individuals with erosions of the head of the femur were considered to be defective (Figures 2C and 2D).

The comparison of each of these 5 conditions was the phenotypic trend for daily gain deviations adjusted over years to a common market age of 42 d. These changes in age at scoring were made to accommodate adjustments in broilers reaching market weight. All body weight adjustments were data driven in order to minimize the step effects of age changes. Data were analyzed with a mixed animal model that included a fixed effect of contemporary group and genetic relationships between individuals. Heritabilities were computed by restricted maximum likelihood, and breeding values were obtained by best linear unbiased prediction using the DMU statistical package [17]. Breeding values were converted from their original units in percentage of incidence to genetic standard deviation units. This conversion facilitated rapid evaluation for effectiveness of the selection program on the limb traits.

RESULTS AND DISCUSSION

Broiler breeding selection programs may consider 50 or more traits in their decisions. Multiple traits are related to welfare and their importance in a program will depend on a complex balance of selection goals, genetic relationships between traits, and how pressing the need is to address welfare and production issues.

Changes in the incidence of defects over time can be environmental, genetic, or a combination of the 2. Genetic changes are dependent on the heritability of the trait and selection intensity placed on that trait. Correlated responses are also possible as the selection for one trait

Table 1. Heritabilities and their standard errors of five limb traits in three pure lines.

	Line			
Trait	1	2	3	Mean
Bow in	0.14 ± 0.005	0.10 ± 0.003	0.11 ± 0.004	0.12
Bow out	0.10 ± 0.004	0.13 ± 0.004	0.14 ± 0.005	0.12
Rotated	0.09 ± 0.004	0.02 ± 0.001	0.04 ± 0.002	0.05
Femur head necrosis	0.26 ± 0.015	0.29 ± 0.016	0.30 ± 0.015	0.28
Tibial dyschondroplasia	0.13 ± 0.007	0.16 ± 0.007	0.18 ± 0.008	0.16

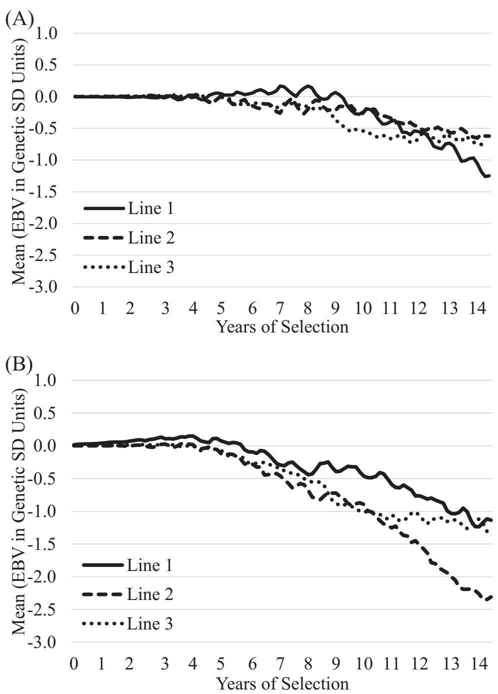

Figure 3. Genetic trends of three chicken pure lines, expressed as deviation from expected breeding values (EBV), over fourteen years of selection to improve bone deformities. (A) Bowed-out, (B) Bowed-in.

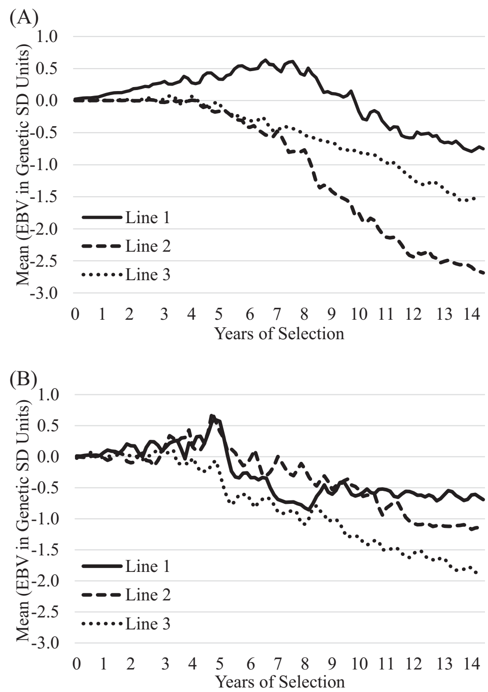

Figure 4. Genetic trends of 3 chicken pure lines, expressed as a deviation from expected breeding values (EBV), over 14 yr of selection to improve tibia health. (A) Rotated tibia. (B) Tibial dyschondroplasia.

may result in genetic change for another trait. As seen in Table 1, the heritability for bowed-in and bowed-out was consistent and low in all lines ranging from 0.10 to 0.14. Moreover, for a rotated limb, the highest heritability was 0.09 in Line 1. Yet as seen in Figure 3 and 4A, change for these traits, while essentially nil in earlier years, declined in later years with the rate of decline being line dependent. Some of the lag observed in earlier years is a feature of the statistical methods that do not express early changes in average breeding values until there is a meaningful separation from the base population. The results provide evidence that even for low-heritability traits persistent selection is necessary, and in no case was the condition worsened, even as the body weights and feed efficiency of the populations improved. Age at selection changed over the years because chickens within a line became heavier at younger ages. Thus, body weight and feed conversion data were adjusted to 35 d and 2,268 g of body weight. Average annual genetic gains and standard deviations [18] during the 14 yr were 44.9 ± 0.4, 43.6 ± 0.4, and 58.4 ± 0.5 g for Lines 1, 2, and 3, respectively. Respective values for annual gains in feed conversion ratios were 1.94 ± 0.02, 2.03 ± 0.02, and 2.60 ± 0.02.

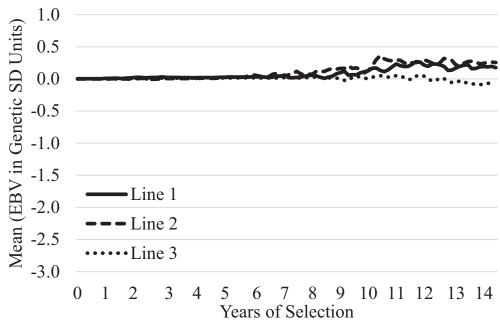

Figure 5. Genetic trends of 3 chicken pure lines, expressed as a deviation from expected breeding values (EBV), for femoral head necrosis (selection for this trait began in the sixth year).

Although heritabilities for tibial dyschondroplasia ranged from only 0.13 in Line 1 to 0.18 in Line 3, the downward genetic trends for Lines 1 and 3 continued while that for Line 2 reflected a plateau after a reduction of 1 genetic standard deviation (Figure 4B). Femoral head necrosis, with heritabilities ranging from 0.26 to 0.30 in the 3 lines, is more of a conundrum because there was little change over the years (Figure 5). This plateau in incidence reflects the dilemma when the limb assessment requires sacrifice of the individual for accurate identification of the condition. Thus, although femoral head necrosis may have a higher heritability than that of other traits, selection is not on that individual, but on its siblings, which results in the higher heritability being compromised because of lower accuracy of the breeding value. It should also be noted that this trait was not included in the selection indexes in the early years of this timeline.

CONCLUSIONS AND APPLICATIONS

1. The dramatic changes in growth and meat yield that have occurred during the past 14 yr have resulted in broilers that reach market weight at younger ages.
2. The data presented here for 5 bilateral limb traits suggest that inclusion of limb-associated traits in selection decisions are essential to ensure that limb health is improved and welfare is not compromised.
3. These long-term trends clearly show that skeletal integrity cannot only be maintained but improved in selection programs that routinely measure and include emphasis on limb health traits.

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18. The gains are on an annualized basis. For example, over 14 years, the cumulative gain in body weight was 14×44.9 g for Line 1. The respective change in feed conversion ratio would be $1.94 \times 12 = 28$ points for Line 1.

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