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Abstract:	Background The walking ability of many broilers is characterised by slight or definite defects categorised as gait scores (GS) 1 and 2. The present study aimed to examine potential relationships between gait scores and indicators of body morphology, leg pathology, tibia strength and wooden breast in Ross 308 broilers assessed as GS≤2. Methods At 38 days of age, gait score and live body weight of 179 birds was recorded. Each bird was examined post mortem for signs of wooden breast, contact dermatitis and a range of leg pathologies. Weights of different body parts and tibia strength were quantified. Results Within sex, GS increased with increasing live body weight (P=0.020). There was a tendency for an effect of GS on prevalence of footpad dermatitis (P=0.086) and dislocated femoral joint cartilage (P=0.059) where both pathologies increased in frequency with increasing GS. Greater load was required to fracture tibia from GS2 than GS0 birds (P=0.040). Conclusions Within this relatively small data set, no strong relationships between GS≤2 and indicators of body morphology, leg pathology, tibia strength and wooden breast in Ross 308 broilers were found, except for the live terminal body weight. Further studies, involving larger data sets are required for full clarification.

Postmortem examination of fast-growing broilers with different degrees of identifiable gait defects

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ABSTRACT

Background The walking ability of many broilers is characterised by slight or definite defects categorised as gait scores (GS) 1 and 2. The present study aimed to examine potential relationships between gait scores and indicators of body morphology, leg pathology, tibia strength and wooden breast in Ross 308 broilers assessed as GS≤2.

Methods At 38 days of age, gait score and live body weight of 179 birds was recorded. Each bird was examined post mortem for signs of wooden breast, contact dermatitis and a range of leg pathologies. Weights of different body parts and tibia strength were quantified.

Results Within sex, GS increased with increasing live body weight (P=0.020). There was a tendency for an effect of GS on prevalence of footpad dermatitis (P=0.086) and dislocated femoral joint cartilage (P=0.059) where both pathologies increased in frequency with increasing GS. Greater load was required to fracture tibia from GS2 than GS0 birds (P=0.040).

Conclusions Within this relatively small data set, no strong relationships between GS≤2 and indicators of body morphology, leg pathology, tibia strength and wooden breast in Ross 308 broilers were found, except for the live terminal body weight. Further studies, involving larger data sets are required for full clarification.

Key words: body composition, broiler, gait score, leg pathology, walking impairment

1. INTRODUCTION

Impaired walking ability, varying from slight changes in gait to obvious lameness or even lack of mobility, is common in broiler production (1, 2). Typically, the majority of the impacted birds have a slight or definite defect, categorised as gait scores (GS) 1 and 2 (3-5), but research has mainly focused on the causes and welfare consequences of GS≥3 (e.g. (6-9)).

Impairment of the gait can have several causes, including fast growth, heavy body weight, musculoskeletal developmental maturation, suboptimal body composition and different leg health issues. In a comparison of gait in genetically relaxed and selected strains of broilers, Corr et al. (10, 11) described how selected broilers reached heavier body weight at younger ages, had wider girths, walked more slowly, had a lower cadence and took shorter steps. The steps were wider and the toes pointed outwards, resulting in a wider walking base. The birds kept their feet in contact with the ground for longer periods, with longer percentage stance time, shorter percentage swing time and increased double contact time compared to the relaxed-bred birds. In addition, the ratio between leg length and thigh-muscle masses differed, leading to greater forces having to be exerted by shorter lever arms in order to move the body of the selected broiler strains, resulting in higher loads on bones that are still immature.

Similarly, Caplen et al. (12) showed clear differences in gait between commercial broilers and their ancestor, the jungle fowl, presumably related to body mass and conformation. In addition, the authors compared the gait of GS3 to GS0 broilers and found for example shorter stride length and duration as well as reduced velocity among the GS3 birds, likely linked to musculoskeletal abnormalities. At 6 weeks of age, Skinner-Noble and Teeter (13) found GS3 birds to be heavier than GS2 birds, whereas the GS2 birds had a larger breast angle and may thus have been out of balance or front-heavy as also suggested by Corr et al. (11). Similar findings were reported by Toscano et al. (14) based on the combination of gait scores (GS0-GS4) and anatomical properties of tibia and metatarsus. In addition, the body shape defined by various length measures and ratios of body parts led the authors to suggest that the centre of gravity differed between birds of different GSs.

Impaired walking ability has been linked to different pathological conditions of the bones, joints, skin and muscles. For example, nociceptors have been identified in the joint capsule of the ankle and in the skeletal muscles of the leg in poultry (15, 16), and, following inflammation, these nociceptors become sensitised and provide peripheral neural evidence of pain experienced during the disease or injury. Therefore, arthritis and inflammation of the joints, such as tenosynovitis, are likely to be painful and exacerbate walking impairment. Contact dermatitis, i.e. footpad lesions and hock burns, has, in some studies, been associated with impaired walking (5), and, in a case report of heavy weight broilers, Severyn et al. (17) suggested that wooden breast syndrome (WBS) has the potential to cause or contribute to significant walking difficulties as well.

The aim of this study was to examine potential relationships between gait scores and body morphology, leg pathology, tibia strength and wooden breast measures in conventional Ross 308 broilers assessed as GS≤2. This study was part of a larger experiment, where potential relations between GS≤2 and indicators of locomotor ability and pain (18) as well as behaviour in the home environment (19) were also investigated.

3. MATERIALS AND METHODS

3.1 Animals and Housing

The study was performed in four blocks during the period from April to October 2018 and involved two main factors: GS (0-2) and sex. The four blocks each consisted of 300 male and 300 female Ross 308 broilers acquired as day-old chicks from a commercial hatchery (DanHatch A/S, Sønderborg, DK) and wing-tagged with unique IDs on arrival to the experimental facilities at Aarhus University, AU-Foulum, Tjele, Denmark. Within each block, all birds were reared together until day 27 of age in a pen measuring 4 m × 9 m. Commercial conditions were simulated by keeping the stocking density at an estimated 40 kg/m^2 on day 34 of age. Feed was available for *ad libitum* intake and a 4-cm layer of wood shavings covered the floor.

At 27 days of age, all 600 birds within a block were individually weighed and gait scored according to the Bristol scale (20) by two experienced observers. In this scale, walking ability is scored as one of six categories (0-5), from completely normal to immobile. Broilers are scored as 0, 1, or 2 if the gait has no, a slight, or definite defect, respectively. More precisely, GS0 birds walk normally with no detectable abnormality; being dexterous and agile. GS1 birds have a slight defect, which is difficult to define, but it results in an uneven gait. In contrast, GS2 birds has a definite and identifiable gait defect, but neither GS1 nor GS2 birds seem to be hindered in their movement. Score 3 is given when the gait defect affects the manoeuvring and acceleration ability of the birds. Birds that only walk a couple of steps when urged, and those unable to stand or walk at all, are scored as 4 and 5, respectively. Prior to commencement of the study, the two observers had gait scored more than 4,000 broilers each. They were originally trained by ABR, who had been trained by one of the founders of the Bristol scale, using a mixture of video material of birds with known GS and live birds on multiple farm visits. Furthermore, observers had refreshed their gait scoring skills by observing videos of birds with known GSs and by gait scoring 100 broilers together, discussing the gait of each bird for agreement to be attained. For the analysis of agreement, 36 video examples were each scored on three separate occasions by each observer, approximately a week apart. Based on this, the observers had substantial levels of inter-observer agreement (kappa value 0.70) as well as from substantial to almost perfect levels of intra-observer agreement (kappa values 0.77 and 0.90) (21).

Based on the gait scoring, 12 male GS0, 12 female GS0, 12 male GS2 and 12 female GS2 birds were selected in each block if possible (Fig. 1). Any group with fewer than 12 individuals was supplemented with birds having the same GS, but from the opposite sex. Using this approach, 48 groups were formed per block and each experimental bird was housed with three companion GS1 birds in experimental pens (1 m × 1.6 m with a 4-cm layer of fresh wood shavings as bedding) from day 27. Experimental and companion birds were killed by CO_2 gassing at day 38 of age. Further details on housing, management and selection of experimental animals can be found in Riber et al. (19).

3.2 Ethical statement

According to Danish legislation, all experimental procedures were approved by the Danish Animal Experiments Inspectorate (Permit No. 2018-15-0201-01434). The study was conducted in accordance to Danish legislation BEK No. 1047 from 13/08/2018 and the EU Directive 2010/63/EU.

3.3 Data collection

Immediately before being killed, the experimental birds were gait scored and individually weighed by the same two observers as on day 27 (Fig. 1). During the post-mortem analysis, the data on body morphology, i.e. weight of the different body parts, and wooden breast abnormalities were collected by one observer and the data on pathology by another. Both were blinded to the gait score of the birds. The pectoralis major muscles were exposed and removed from each carcass and visually assessed for wooden breast abnormalities on a scale from 0 to 3 developed for the present study based on Petracci et al. (22) and Dalgaard et al. (23). The presence of white striations on the surface of the muscle awarded a score of 1. Bulging hard areas of the muscle resulted in a score of 2. If both conditions were present, the breast was given a score of 3. If neither condition was present, a score of 0 was given. Footpad dermatitis was scored on a three-point scale from 0 (no injury) to 2 (severe injury) (24). Hock burns were scored on a four-point scale from 0 (no injury) to 3 (heavy crust formation on >10% of the hock) (25).

The femur was gently twisted out of the hip joint on the right and left side. The condition of the femoral joint cartilage was noted on a dichotomous scale as of whether it was still attached to the joint head, separated from the joint head or adhered to the hip joint (26). Next, Femoral Head Necrosis was recorded as present if one of two criteria was met: (1) lesion in the growth plate following separation of the articular cartilage (26) or (2) focal yellow areas of caseous exudate or lytic areas following incision on the femoral head (27). Then, the tibiotarsus was cut free at the knee and hock joint, and joints and bone assessed for tenosynovitis (present or absent) seen as swollen joints and tendon sheaths with increased exudate (28). For the assessment of tibial dyschondroplasia, a cut was made parallel to the longitudinal axis of the bone along the medial surface, starting below the proximal joint. Tibial dyschondroplasia was scored on a dichotomous scale and observed as the presence of a cartilaginous plug in the proximal tibiotarsus (29). The angularity of the tibia was then assessed by placing the tibia on the medial side along a vertical line, noting whether or not there was a rotation along the longitudinal axis (30). Finally, the presence or absence of varus or valgus deformity was noted by assessing whether the distal part of the tibia rotated around the broad axis (30, 31).

Once the tibia was completely free of muscle and cartilagenous tissue, it was measured in length, weighed and then frozen at -20 °C and stored for later measurement of bone strength. Observers also noted the weight, including bone and soft tissue, of the following body parts: right and left thigh, right and left upper thigh, right and left foot, right and left pectoralis major muscle, right and left pectoralis minor muscle, abdominal fat and the rest of the carcass.

The tibial bones were randomly divided into four equally sized subsamples, which were analysed for bone strength on four consecutively workdays by an observer blinded to the gait score of the birds. Each subsample of tibia was cleaned by overnight submersion in a room temperature demineralised water solution with 0.04% Lipix (lipase CAS-No 9001-62-1; Novozymes, Bagsværd, Denmark) and 0.03% Savinase (subtilisin protease CAS-No 9014-01-1; Novozymes, Bagsværd, Denmark). Each tibia was placed in its own bath to ensure ID. After the enzyme bath, muscles and cartilages were removed with the help of a scalpel and the bones allowed to dry (approx. 30 minutes). Bone strength was measured at room temperature (21 °C), using a regularly calibrated FTC TMS-Touch Texture Analyser fitted with a 1000 N intelligent loadcell (Food Technology Corporation, Sterling, Virginia, US). Measurements were performed at 48 mm/min and all bones were placed in a similar position. Bone strength was assessed halfway along the length of the bone as the peak load at fracture, i.e. the total load in N, required to induce fracture. The bone strength analyser also provided data on displacement (mm), i.e. the vertical distance travelled by the loadcell to the point of fracture.

A pilot study including 100 broilers was performed prior to commencement of the experiment in which all procedures were tested. The protocols were discussed prior to, during and following the pilot study and refined accordingly. The observer responsible for body morphology has several years of experience from practice and research within cutting techniques used on broilers as well as assessing wooden breast abnormalities. A poultry pathologist with experience from both practice and research was responsible for the data collection on pathology.

3.6 Statistical analyses

Statistical analyses were performed using the software R (version 3.4.4) and Stata (version 11.2) at a significance level of 5% and with Tukey post hoc analyses for significant factors. As gait is dynamic, i.e. a characteristic of the broiler that changes with age, the gait score on the day of the post mortem examination (day 38 of age) was used for analyses, including GS1 birds in their own category. Birds with GS 3 (n = 4), 4 (n = 1) or with missing data (n = 8) were excluded, leaving 179 birds for analyses (Fig. 1). Initially, models included GS, sex and their interaction as fixed factors. Block was added as a random effect if possible, otherwise as a fixed factor. Furthermore, the models included live body weight at day 38 unless otherwise stated.

Live body weight and the weight of individual body parts were analysed with a linear mixed effects model, using the aggregated weight for bilateral body parts. The variance was allowed to depend on GS for the analysis of the carcass weight and on sex for the analysis of live body weight, thigh, foot, *pectoralis major* and *pectoralis minor*.

Presence of wooden breast, footpad dermatitis and hock burns (score > 0 on either right or left side) were analysed with a mixed effects logistic regression. This binary model was also applied for dislocation of the femoral joint cartilage, femoral head necrosis and angularity of the tibia. In addition, presence of femoral pathologies (dislocation of the femoral joint cartilage, and/or femoral head necrosis) and any other leg pathologies observed was analysed by this model. Due to low representation in the data set, the results on tenosynovitis, varus/valgus deformities and tibial dyschondroplasia could not be analysed separately. Therefore, only descriptive statistics are presented for these variables.

Bone strength assessments (i.e. peak load at fracture and displacement) were averaged across side, left and right tibia, and analysed using a linear mixed effects model. Instead of body weight, these models included the weight, width and length of the bones. In the model for peak load at fracture, the variance was allowed to vary across all six combinations of sex and GSs.

RESULTS

The interaction between GS and sex was found to be significant for live terminal body weight ($\chi^2 = 7.78$; $P = 0.020$). GS increased with increasing live terminal body weight in both sexes but to a larger degree in males than females (Fig. 2). The post mortem weight of the different body parts are presented in Table 1. No effects of the interaction between GS and sex or of the main factor GS were found for the weights of any of the body parts. However, sex affected weight of thigh, feet, *pectoralis major*, *pectoralis minor* and abdominal fat. Male broilers had heavier thighs and feet, while the females had heavier breast muscles and more abdominal fat.

Tables 2 and 3 present the frequency and prevalence of the pathologies assessed within and across GS and sexes, respectively. Neither for the single pathologies nor for the pooled pathologies was the interaction between GS and sex found to be significant (LRT $\chi^2 < 4.24$; $P > 0.12$). There was a tendency for an effect of GS on footpad dermatitis (LRT $\chi^2 = 4.89$; $P = 0.086$) and on dislocated femoral joint cartilage (LRT $\chi^2 = 5.66$; $P = 0.059$) where both pathologies increased in frequency with increasing GS. No effects of sex were found for any of the single pathologies or the pooled pathologies (LRT $\chi^2 < 1.74$; $P > 0.19$).

The prevalence of tenosynovitis was 3.4% (N = 6) of which no cases were observed in GS0 broilers, 50% (n = 3) in GS1 and 50% (n = 3) in GS2 broilers. With regards to sex, 67% of the cases were observed in females (n = 4) and 33% in males (n = 2). The prevalence of varus and valgus deformities was 5.0% (N = 9) of which no cases were observed in GS0 broilers, 44% in GS1 (n = 4) and 57% in GS2 (n = 5). With regards to sex, 57% of the cases were observed in females (n = 5) and 44% in males (n = 4). The prevalence of tibial dyschondroplasia was 2.8% (N = 5) of which no cases were observed in GS0 broilers, 60% in GS1 (n = 3) and 40% in GS2 (n = 2). With regards to sex, 80% of the cases were observed in females (n = 4) and 20% in males (n = 1).

The results for the load at fracture showed no effect of interaction between GS and sex (LRT $\chi^2 = 0.87$; $P = 0.65$). However, there was a main effect of GS (LRT $\chi^2 = 6.01$; $P = 0.0496$) with bones from GS2 birds requiring more load to fracture compared to bones from GS0 birds (EM means ± SE: 407.7N ± 20.8 and 382.1N ± 21.5, respectively. $P = 0.040$). GS1 birds had intermediate load at fracture and did not differ from GS0 or GS2 birds (EM means ± SE: 399.7N ± 20.5; $P > 0.05$). There was also an effect of sex (LRT $\chi^2 = 13.30$; $P = 0.0003$) with female bones requiring significantly more load to cause a fracture compared to male bones (EM means ± SE: 419.4N ± 20.6 and 373.7N ± 21.5, respectively).

Concerning displacement of the bone before fracture, the interaction between GS and sex was not significant (LRT $\chi^2 = 0.60$; $P = 0.74$). There was also no significant main effects of GS (LRT $\chi^2 = 0.33$; $P = 0.85$; GS0: 2.89mm ± 0.08; GS1: 2.93mm ± 0.05; GS2: 2.92mm ± 0.06) or sex (LRT $\chi^2 = 2.43$; $P = 0.12$; females: 2.86mm ± 0.06; males: 2.96mm ± 0.67).

DISCUSSION

In the present study, focusing on broilers with no, slight or definite gait defects (GS≤2), no significant relationships were found between GS and body morphology, and only tendencies of relationships were found between GS and some pathologies. In contrast, GS seemed to be related to tibia strength and, within sex, GS increased with increasing live body weight. Morphological differences were found between sexes and the tibia from females required more load to fracture than did those from males.

Morphological aspects have been suggested to be important for the walking ability of modern broilers. The selection for high productivity by rapid growth, high feed efficiency and increased terminal body weight (32) has led to birds of a much different body conformation than the wild type, for example seen as largely increased breast muscles (pectoral hypertrophy) (33). In the present study, body morphology was described by quantification of the live terminal body weight and weight of the thigh, upper thigh, feet, *pectoralis major*, *pectoralis minor*, abdominal fat and weight of the remaining carcass. Within sex, GS2 birds were heaviest, GS1 intermediate and GS0 were the lightest birds, confirming the findings of previous studies showing that GS increase with increasing live terminal body weight (34-40). When the weight of the single body parts was compared, no differences between gait scores were found. Hence, based on this data set, birds of GS2 were heavier at day 38 of age but no signs of disproportionate growth of the different body parts as compared to birds of GS<2 were found.

The study included examination of bone strength in terms of load at fracture, i.e. the peak force required to fracture the tibial bone, and displacement, i.e. how much the bone bends before it breaks when force is applied. Female birds showed a higher tibia strength than males and similarly for birds of GS2 as compared to GS0, with GS1 being intermediate. Reasons underlying the difference in tibia strength between gait scores are not clear but may be related to the differences in body weight, as the GS2 birds were heavier, and, therefore, increased bone strength may reflect physiological adaptation to greater load bearing (41). Higher tibial strength in females may reflect estrogenic and growth rate effects on bone mineralisation (42, 43).

One aim of this study was to examine possible relations between selected pathologies and GS≤2 of the broilers, but only tendencies for increasing frequency of footpad dermatitis, dislocated femoral joint cartilage and femoral pathologies with increasing GS were found. Dislocated femoral joint cartilage is rather poorly understood (44), but if it develops into the severe stage of femoral head necrosis, birds are reluctant to walk and the condition is considered painful (45). This may be part of the explanation to why GS2 birds in the present study were slower in a runway with obstacles compared to GS0 birds (18). A positive association between GS and footpad dermatitis has been shown in several other studies (4, 5, 46, 47). It has previously been suggested that correlations between walking impairment and underlying pathologies are weak (48-50). The choice of a highly controlled experimental environment during the latter part of the study entailed that birds in the present study were only kept in conditions mimicking commercial resource availability until they were 27 days of age, after which they had access to more space and cleaner flooring conditions than would be the typical commercial situation. It is likely that the environment during late rearing has decreased the prevalence of some of the pathologies, e.g. footpad dermatitis and hock burns, but the conditions were similar across the three different experimental gait score groups. Furthermore, it allowed a very high degree of control with the physical and social environment of the birds – something that cannot be achieved during commercial rearing.

As mentioned above, the present study was part of a larger project examining welfare consequences of having slight or definite gait defects, including behaviour in the home environment and performance in runway and Conditioned Placed Preference tests. The purpose of including body morphology and pathology in the study was to improve the understanding of factors underlying gait defects in these birds – knowledge, which potentially could be employed to improve animal welfare. However, the lack of significant relationships between GS and body morphology and many of the pathologies, with only tendencies of relationships found between GS and some pathologies, indicates that the observed differences between birds of GS≤2 in behaviour and locomotor ability did not have a clear morphological or pathological explanation. Nevertheless, a synergistic effect from two or more parameters that on their own are too slight to be significant cannot be excluded.

Based on the above, it is clear that, in order to get the full picture of relationships between gait scores and pathologies, follow-up studies involving larger animal numbers and several flocks kept under commercial conditions are needed. In addition, future investigations into the underlying causes of gait defects in broilers should include assessment of the function and pathology of the skeletal muscles of the leg and pelvis, as the integrated actions of the musculoskeletal system are essential for normal posture, locomotion and gait (51). Very little research has been carried out in broilers investigating leg and pelvic limb skeletal muscle function and pathology in relation to growth rate, body mass, body morphology and muscle loading (52). Better understanding of leg and pelvic skeletal muscle function in fast-growing broiler chicken breeds may shed more light on the underlying causes of change in gait.

CONCLUSIONS

The present study examined potential relationships between gait scores and morphology in the form of carcass component weights, selected leg pathologies and tibial strength in fast-growing broilers assessed as GS≤2. As previously shown, within sex, GS increased with increasing live body weight. It was expected that GS would increase with increasing size of the breast muscles, but neither this nor any other morphological traits were found to significantly influence GSs in this interval. Regarding leg pathologies, tendencies of relationships with GSs were found, thereby confirming results of earlier studies. Interestingly, GS2 birds had stronger tibia than GS0 birds, but the causation and implications of this for broiler health and welfare need to be further investigated.

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Contributorship Statement

ABR: Conceptualisation (responsible), data curation, funding acquisition (responsible), methodology (responsible), project administration (responsible), writing – original draft preparation (responsible), writing – review and editing (responsible). MSH, JM, DAS: Conceptualisation, methodology, writing – review and editing. LF: Formal analysis (responsible), writing – review and editing. FMT: Methodology, investigation, data curation (responsible), writing – review and editing.

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Figure captions

Fig 1. Graphical presentation of 1) the distribution of GS and sex of the 192 experimental birds (48 per block) selected from the 2400 birds (600 per block) on day 27 and 2) the distribution of GS and sex of the experimental birds on day 38, where the birds were gait scored, weighed, killed and examined post mortem. Four birds (2 F, 2 M) were excluded from analysis due to a development into GS3, one male was excluded due to a development into GS4, and data were lost for additional eight birds (4 F, 4 M), resulting in a total of 179 experimental birds examined post mortem.

Fig. 2. Live terminal body weight of the sexes across GS. Different letters indicate significant differences in the model including the interaction between GS and sex ($P < 0.05$) (N = 179. GS0 M = 2, GS0 F = 17, GS1 M = 23, GS1 F = 64, GS2 M = 48, GS2 F = 25).

Table 1. Weight of the different body parts (estimated marginal means (g) and standard error) across sex and GS presented along with the test statistics for the interaction between GS and sex and for the main effects of sex and GS (in the additive model without the interaction).

Body part	Weight ± SE (g)					Test statistics		
	Gait Score			Sex				
	GS0	GS1	GS2	Females	Males	GS*sex[1]	GS[3]	Sex[2]
Thigh	220.0±3.1[a]	220.6±1.6[a]	219.2±1.9[a]	**213.8±1.7[a]**	**226.0±2.4[b]**	χ^2=0.09 P=0.96	χ^2=0.33 P=0.85	**χ^2=14.5 P<0.001**
Upper thigh	322.7±5.0[a]	315.1±2.8[a]	316.9±3.2[a]	320.0 ± 3.1[a]	316.4±3.4[a]	χ^2=0.15 P=0.93	χ^2=2.84 P=0.24	χ^2=0.62 P=0.43
Feet	93.7±1.3[a]	94.1±0.7[a]	92.7±0.9[a]	**85.4±0.8[a]**	**101.7±1.1[b]**	χ^2=2.57 P=0.28	χ^2=1.46 P=0.48	**χ^2=107.6 P<0.001**
Pecto-ralis major	504.9±8.2[a]	503.3±5.0[a]	513.1±5.7[a]	**516.5±5.2[a]**	**497.8±6.4[b]**	χ^2=0.03 P=0.98	χ^2=2.46 P=0.29	**χ^2=6.67 P=0.010**
Pecto-ralis minor	104.7±1.9[a]	104.2±1.1[a]	102.0±1.3[a]	**107.5±1.2[a]**	**99.7±1.5[b]**	χ^2=0.47 P=0.79	χ^2=2.47 P=0.29	**χ^2=17.4 P<0.001**
Abdo-minal fat	28.2±2.0[a]	27.0±1.1[a]	25.1±1.2[a]	**30.0±1.2[a]**	**23.5±1.3[b]**	χ^2=3.68 P=0.16	χ^2=2.24 P=0.32	**χ^2=16.8 P<0.001**
Car-cass	1442.2±7.7[a]	1439.5±5.0[a]	1440.3±7.0[a]	1438.9±5.2[a]	1442.5±6.3[a]	χ^2=2.48 P=0.29	χ^2=0.11 P=0.94	χ^2=0.16 P=0.69

Sample sizes (n): males=73, females=106, GS0=19, GS1=87, GS2=73.
[1]df = 2; [2]df = 1; [3]df =2
Reported weights for thigh, upper thigh, feet, pectoralis major and pectoralis minor are average of the sum of left and right body part.
[a-b]Different letters and bold text within explanatory variable indicate significantly different values (P < 0.05) in the additive model.

Table 2. Pathological findings, frequency and percentage prevalence within and across GS categories presented along with the test statistics for the main effect GS.

Pathology	Gait score	Frequency	% within GS	% across GS	Test statistics[1]
	GS0	14	73.7	9.9	
Wooden breast	GS1	64	73.6	45.4	$\chi^2 = 0.16$ P = 0.93
	GS2	63	86.3	44.7	
	GS0	3	15.8	18.7	
Footpad dermatitis*	GS1	5	5.7	31.2	*$\chi^2 = 4.89$ P = 0.086*
	GS2	8	11.0	50.0	
	GS0	1	5.3	4.0	
Hock burns	GS1	7	8.0	28.0	$\chi^2 = 0.87$ P = 0.65
	GS2	17	23.3	68.0	
	GS0	1	5.3	6.7	
Angularity of the Tibia	GS1	5	5.7	33.3	$\chi^2 = 0.99$ P = 0.61
	GS2	9	12.3	60.0	
	GS0	12	63.2	10.3	
Dislocated femoral joint cartilage*	GS1	46	52.9	39.3	*$\chi^2 = 5.66$ P = 0.059*
	GS2	59	80.8	50.4	
	GS0	9	47.4	10.1	
Femoral Head Necrosis	GS1	38	43.7	42.7	$\chi^2 = 0.63$ P = 0.73
	GS2	42	57.5	47.2	
	GS0	12	63.2	10.1	
Femoral pathologies*[2]	GS1	47	54.0	39.5	*$\chi^2 = 4.91$ P = 0.086*
	GS2	60	82.2	50.4	
	GS0	15	78.9	11.1	
Any leg pathologies	GS1	58	66.7	43.0	$\chi^2 = 2.90$ P = 0.23
	GS2	62	84.9	45.9	

N = 179. GS0 = 19, GS1 = 87, GS2 = 73.

[1]*df = 2*

[2]Dislocated femoral joint cartilage AND/OR Femoral Head Necrosis

Italic text within explanatory variable indicate a tendency for values to differ ($0.05 \leq P < 0.10$).

**Pathologies which tended to differ across GSs are indicated with an asterisk.*

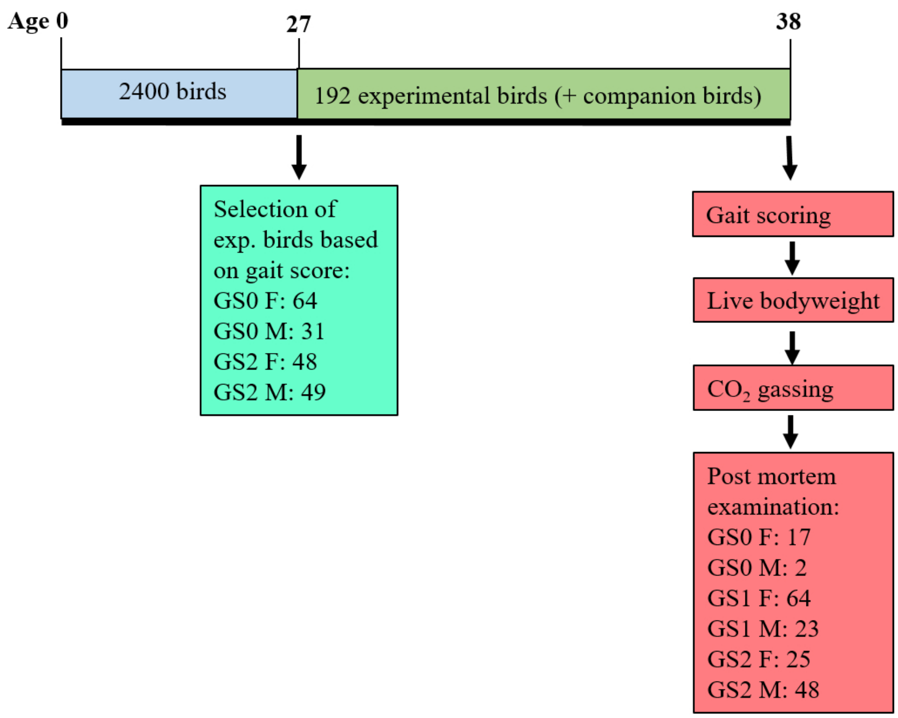
Table 3. Pathological findings, frequency and percentage prevalence within and across sex presented along with the test statistics for the main effect of sex.

Pathology	Sex	Frequency	% within sex	% across sexes	Test statistics[1]
Wooden Breast	F	79	74.5	56.0	$\chi^2 = 1.01$
	M	62	84.9	44.0	P = 0.32
Footpad dermatitis	F	8	7.5	50.0	$\chi^2 = 0.07$
	M	8	11.0	50.0	P = 0.79
Hock burns	F	8	7.5	32.0	$\chi^2 < 0.01$
	M	17	23.3	68.0	P > 0.99
Angularity of the Tibia	F	9	8.5	60.0	$\chi^2 = 0.78$
	M	6	8.2	40.0	P = 0.38
Dislocated femoral joint cartilage	F	63	59.4	53.8	$\chi^2 = 0.04$
	M	54	74.0	46.2	P = 0.84
Femoral Head Necrosis	F	47	44.3	52.8	$\chi^2 = 0.04$
	M	42	57.5	47.2	P = 0.85
Femoral pathologies[2]	F	64	60.4	53.8	$\chi^2 = 0.14$
	M	55	75.3	46.2	P = 0.71
Any leg pathologies	F	76	71.7	56.3	$\chi^2 = 1.74$
	M	59	80.8	43.7	P = 0.19

N = 179. Females = 106, males = 73.

[1]df = 1

[2]Dislocated femoral joint cartilage AND/OR Femoral Head Necrosis



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194x154mm (150 x 150 DPI)

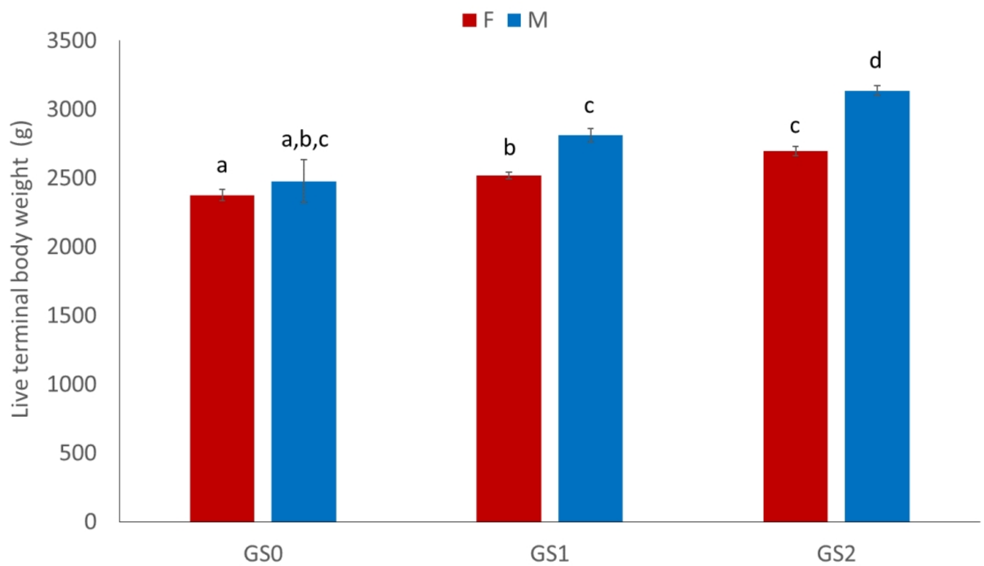

Fig. 2. Live terminal body weight of the sexes across GS. Different letters indicate significant differences in the model including the interaction between GS and sex (P < 0.05) (N = 179. GS0 M = 2, GS0 F = 17, GS1 M = 23, GS1 F = 64, GS2 M = 48, GS2 F = 25).

256x154mm (150 x 150 DPI)