ABSTRACT An experiment was conducted to evaluate potential differences for indicators of well-being in birds classified as having field gait score (FGS)2 and 3 and to evaluate potential causal factors affecting gait score. In 2 trials, birds with FGS2 and FGS3 were similar for most broiler traits (BW, feed conversion ratio) and fearfulness. Birds with FGS3, however, had improved breast conformation score in both studies and greater breast angle in the second trial compared with birds with FGS2. This improved breast conformation, along with differing ratios of length (hip to neck/hip to tail; \( P < 0.05 \)), appears to be highly related to gait score. In other words, varying a bird’s physical proportions necessitates that the bird’s gait changes to maintain center of gravity during locomotion. In trial 2, behaviors were measured to determine if gait score affected behavior. Birds with FGS3 rested more and stood less than those with FGS2. Similar pathological analysis and heterophil:lymphocyte ratio suggest that gait score differences are not due to increased physiological stress or stress-associated pain. The lack of difference in heterophil:lymphocyte ratio, respiratory quotient, and pathology, combined with differing ratios of body proportions and anatomical length ratios, suggests that behavior and gait differences between birds with differing FGS occur with similar levels of well-being.

INTRODUCTION

Today’s broiler production must increasingly address not only the “bottom line” for production efficiency but also animal well-being. Some aspects of well-being perceptions are straightforward and easily verifiable by scientific method, whereas other aspects are not (Duncan, 2001; Weeks and Butterworth, 2004). Examples of increased concern about animal well-being occur especially in countries throughout the European Union where the managerial and genetic background effects on bird well-being are increasingly challenged throughout the poultry production enterprise (Pfeiffer and Dall’Aqua, 2002). It is critical that perceptions of well-being be placed upon a firm foundation of physical reality.

Broiler gait score, defined as an index of perceived locomotion normality, has historically been a concern only to the point that it might be related to bird performance. Husbandry, managerial, and nutritional approaches, long known to affect lameness (Payne et al., 1932), have sought to optimize performance and were concerned with gait score to the extent that it was related to growth performance or reproduction. Under these criteria, bird gait score would be forced to remain within an acceptable range for the bird type and environment encountered. In recent years, however, a trend toward the separation of “gait score” from classical concerns to include “perceived criteria of well-being” has been initiated (Kestin et al., 1992; Corr et al., 1998; Berg and Sanotra, 2003). Indeed, some countries are evolving toward gait score criteria being used as an index of bird acceptability for production enterprises. Such approaches negate the possibility that perceived gait score criteria may be separate from actual bird well-being. Just as the birds’ performance capacity and yield characteristics have evolved over the years, so may their walking characteristic, for reasons separate from well-being.

Broiler lameness is a concern that merits much study (Mench, 2004); skeletal abnormalities have certainly been associated with leg disorders (Thorpe, 1994). Reports (Corr et al., 2003a,b) have suggested a significant cause as being an imbalance between body weight gain and skeletal differentiation.

The modern turkey can provide insight into genetic and environmental interactions upon improvement of gait score. Nestor et al. (1985) hypothesized that lack
of skeletal support relative to BW and breast mass negatively affected walking ability in large turkeys. To test this hypothesis, a line of turkeys (FL) was selected for increased shank diameter. In the first 5 generations of selection, the FL line had increased shank diameter and improved walking ability relative to the BW (F) line. This was achieved without a decrease in BW in the FL line. Walking ability [the turkey equivalent of broiler field gait score (FGS)], however, appeared to be affected by a line × rearing environment interaction (Emmerson et al., 1991). The interaction between line and environment was confirmed by Noble et al. (1996c), where males from the FL and F lines had similar walking ability when reared in confinement, but differed in walking ability when reared in large range pens. Among the most striking differences between the range and confinement environments was space per bird from 8 to 20 wk of age (5,521 cm² per bird in confinement vs. 283,519 cm² per bird in range rearing). When behaviors of birds reared in confinement or range conditions were examined, the number of bouts of different activities was generally similar (except drinking), but the average length of the bouts (especially eating, drinking, and resting) were longer under range conditions (Noble et al., 1996a). Increasing activity has been proposed as a managerial method to improve the walking ability of both turkeys (Noble et al., 1996b) and broilers (Bizeray et al., 2002), with only limited success. However, one must cautiously approach managerially induced alterations in bird behavior as a means (Bradshaw et al., 2002) to alter gait scores because bird motivation and desire for walking are also important (Bokkers and Koene, 2004). Well-intended but misapplied management could potentially create a bird activity stressor by exacerbating the gap between the bird’s desired activity level and that managerially altered environment (Nielsen et al., 2003).

The literature lacks reports of how birds differing in FGS potentially also differ in their well-being, anatomical, physiological, and metabolic characteristics. Whereas birds in the 2 tails of the FGS distribution would be expected to differ in well-being characteristics, the appropriate “break-point” of acceptable FGS remains unknown. The objectives of the current study were 3-fold. The first objective was to determine how birds with FGS2 and FGS3 differ in BW, feed intake, feed conversion ratio (FCR), and metabolism. The second objective was to determine if broilers with FGS2 and FGS3 gaits differed in traits related to well-being including behavior, fear response as measured by tonic immobility (TI; Benoff and Siegel, 1976), evidence of chronic pain by pathological examination of the sciatic nerve and surrounding tissue, and heterophil:lymphocyte ratio (H:L) as a measure of long-term physiological stress (Gross and Siegel, 1983). The third objective was to examine various morphological measurements as a potential explanation for differences in FGS. The study reported herein utilized male and female broilers with FGS2 and FGS3.

**MATERIALS AND METHODS**

**General Protocol**

This experiment consisted of 2 trials. Birds were reared commercially to 6 wk of age under typical field conditions. At 6 wk, birds were evaluated in the field for gait score (Kestin et al., 1992), and a sample of equal numbers of male and female birds from FGS2 and FGS3 was obtained. Using the scoring system proposed by Kestin et al. (1992), FGS4 is reserved for broilers with visible leg pathology, and FGS1 represents a smooth, fluid gait, practically impossible for a modern high-yielding broiler to achieve. For this reason, birds with FGS2 and FGS3 were utilized, as their scores represent a potential break-point between the extreme values. Once evaluated for FGS, these birds were taken to the poultry research facility for use in the studies reported herein. The lighting program used was 12L:12D in the FCR cages (Skinner-Noble et al., 2003) and metabolism chambers (Belay and Teeter, 1993). Use of FCR cages allowed a more rigorous statistical test for potential differences in FCR. Use of metabolism chambers allowed precise measurements of metabolism, which could be affected as well-being is altered. Before use in these experiments, birds were examined for leg deformities, and any birds with obvious leg deformities were removed before initiation of the study.

**Trial 1**

A total of 64 birds were used in this trial, with equal numbers of males and females with FGS2 and FGS3. Birds were individually placed into FCR cages with either a wire floor or litter floor with soft wood shavings litter. The starting BW, ending BW, feed consumed, and FCR were recorded for a 7-d FCR test. Fearfulness was assessed by TI at the end of the FCR testing period using a modification of the procedure of Benoff and Siegel (1976). In this procedure, birds were gently restrained on their sides for 15 s until they remained in place for 3 s. If birds righted themselves before 3 s, another attempt was made (Skinner-Noble et al., 2003). Birds were allowed up to 3 attempts to achieve TI and allowed a maximum duration of 180 s.

**Trial 2**

A total of 96 birds were used in trial 2. Twenty-four were females with FGS2, 24 were females with FGS3, 24 were males with FGS2, and 24 were males with FGS3.

Group 1 consisted of 24 birds (6 per sex and FGS combination) and they spent 62 h in metabolism chambers, with feed removed the last 24 h. This group was housed individually and was visually isolated from their conspecifics. Following time in metabolism chambers, these birds were placed into FCR cages on the floor for a 4-d FCR trial. This group did not eat feed consistently while in the metabolism chambers (attributed to visual isolation from their conspecifics). Because of the
lack of consistent eating and adaptation to the cham-
bers, this group was excluded from carcass composition
analysis, fearfulness, and blood sampling for H:L.

Group 2 consisted of 48 birds (12 of each sex–FGS
combination) placed individually into FCR cages on
the floor for a 64-h FCR test, followed by 72 h housed
in pairs by FGS in metabolism chambers (the last 24
h without feed). Then, TI was measured, blood was
collected by brachial vein puncture for H:L, birds were
slaughtered, and composition analysis was determined
by x-ray densitometry. X-ray densitometry quantifies
whole-body fat, protein, and bone, but does not eas-
ily quantify distribution of bone and muscle across the
body. Once scanned, these birds were measured for a
variety of physical measures to determine if physical
structure of the bird or specific physical measures could
be causally related to gait score.

Birds in group 3 were placed into FCR cages on the
floor for 168 h (7 d), followed by TI measurement and
blood collection by brachial vein puncture for H:L.

Pathology

The sciatic nerve and surrounding muscle tissue were
removed and examined macroscopically and histologi-
cally for evidence of painful inflammation or pathology
for the birds from group 2 (48 birds total). These data
were collected by S. L. Vanhooser at Texas A&M Uni-
versity.

Broiler Performance

Broiler performance traits considered were BW at 6
wk and FCR traits (feed intake, weight gain, and FCR).
Feed conversion was for a 96-h test period for group 1,
a 65-h test period for group 2, and a 168-h period for
group 3. Breast and leg conformation were subjectively
scored from 1 to 5 (poor to superior, respectively) on all
the birds at the termination of the experiment.

Physical Measures

Several physical measures were made as potential
causal factors affecting gait score. Shank length was
measured from the hock joint to the foot pad. Shank
width and depth are measures of diameter measured
at the dewclaw. Shank width is measured from side to
side, whereas shank depth is measured from front to
back. Breast length was measured from the clavicular
notch to the tip of the keel. Breast width was measured
from shoulder joint across the breast to shoulder joint.
Breast angle (degrees) was measured at the clavicular
notch. Middle and back toe length were measured from
the toe web to the base of the claw. Hip to tail length
was measured from the prominence of the hip joint to
the base of the tail. Hip to neck length was measured
from the prominence of the hip joint to the base of
the neck. Neck to beak length was measured from the
base of the straightened neck to the tip of the beak.
Breast muscles were dissected from the birds used in
the examination for pathology. These dissected muscles
were then measured from top (muscle near the neck) to
bottom (the tip of the keel) and cut at a point one-half
the distance from one end to the other. This was done
to determine if breast muscle distribution was a factor
affecting gait score. Additionally, ratios of length and
ratios of mass were examined for differences attribut-
able to sex and gait score.

Metabolism

Metabolic chamber facilities and procedures utilized
for bird housing and indirect calorimetry measurements
have been documented elsewhere (Belay and Teeter,
1993). Briefly, the system utilizes the differential con-
centrations of incoming and outgoing O2 and CO2 to
calculate bird O2 consumption and CO2 production.
The equation developed by Brouwer (1965) was subse-
cuously used to calculate bird heat production from CO2
production and O2 consumption measurements. Respira-
tory quotient (RQ) was quantified as the ratio of the
CO2 production and O2 consumption. Quantifying met-
abolism allowed for examination of an additional trait
indicating physical or physiological distress. The 24-h
fast at the conclusion of the metabolism measurement
permitted an approximation of basal metabolism.

Composition

Composition was measured by x-ray densitometry at
the conclusion of each period in the metabolism cham-
bers for group 2. This allowed correlation of body com-
position (as lean and fat) with metabolism.

Behavior Observations

Behavior observations were conducted as scan sample
behavior observations on d 3 and 6 of the experiment.
In this methodology, birds were observed 5 times every
2 h during the light phase by recording which activities
birds were performing. Birds were classified as eating,
drinking, standing, resting, walking, pecking, preening,
dustbathing, or any other behavior. These observation
times were 0800, 1000, 1200, 1400, and 1600 h. Groups
2 and 3 were observed on d 3 of the experiment, and
groups 1 and 3 were observed on d 6 of the experiment.
The 2 observation days (3 and 6) were analyzed separ-
ately.

H:L

Blood samples were collected by brachial vein punc-
ture at the conclusion of the experiment according to
the method of Gross and Siegel (1983). The stained
slides were scanned until 100 total heterophils and lym-
phocytes were counted.

Data Analyses: Trial 1

Data were analyzed in 2 ways: first, by ANOVA with
FGS, sex, and their interaction as the sources of vari-
ance (GLM procedure of SAS; version 6.09, SAS Institute, Cary, NC). Second, data were used in correlation analysis, using the Spearman rank correlation coefficient.

**Data Analyses: Trial 2**

Broiler performance traits (groups 1, 2, and 3), TI traits, and H:L ratio (groups 2 and 3) were analyzed by ANOVA (GLM procedure, SAS Institute) with sex, FGS, group, and all possible interactions as the sources of variation. The H:L ratio was transformed to arcsine square root before analysis and backtransformed to the original scale for presentation. Carcass and morphological data were analyzed by ANOVA with sex, FGS, and their interaction as the sources of variation (only group 2 birds had these traits measured). To assess validity of examining morphological and mass ratios, initial statistical analysis for these variables examined the distribution by means of the SAS univariate procedure and the Kolomogorov D statistic (SAS Institute). Only ratios with normal distribution were examined further.

Behavior data were analyzed within each observation day due to the different groups included in the observations. Before analysis, proportion data were transformed to arc sine-square root, and backtransformed to the original scale for presentation. The sources of variation in the ANOVA (GLM procedure, SAS Institute) were time of day, sex, FGS, and all possible interactions. Unless otherwise stated, all data were analyzed using SAS software (version 6.09, SAS Institute), means and means separation were calculated using the LSMEANS procedure, and significance was accepted as $P < 0.05$.

**RESULTS**

**Trial 1: Broiler Performance**

Birds with the 2 gait score classes were similar for performance traits (Table 1). Birds with FGS3 had greater breast scores (more desirable breast conformation) than those with FGS2. This indicates that birds with FGS3 may be out of balance or front heavy compared with birds with FGS2. This was supported by correlation analysis (Table 2), confirming that birds with greater FGS have more desirable breast conformation. No relationships were observed between fearfulness and FGS, indicating no adverse well-being implications for that trait.

**Trial 2: Broiler Performance**

As in trial 1, birds from the 2 gait score groups were generally similar for broiler performance traits (Table 3), with the exception of BW and breast conformation.

### Table 1. A comparison of traits measured in males and females with field gait score (FGS) 2 and 3 in trial 1

<table>
<thead>
<tr>
<th>Item</th>
<th>FGS 2</th>
<th>FGS 3</th>
<th>FGS 2</th>
<th>FGS 3</th>
<th>FGS 2</th>
<th>FGS 3</th>
<th>FGS 2</th>
<th>FGS 3</th>
<th>FGS 2</th>
<th>FGS 3</th>
<th>FGS 2</th>
<th>FGS 3</th>
<th>FGS 2</th>
<th>FGS 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starting BW (g)</td>
<td>2,187</td>
<td>2,247</td>
<td>2,508</td>
<td>2,600</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Ending BW (g)</td>
<td>2,536</td>
<td>2,575</td>
<td>2,970</td>
<td>3,052</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
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<td></td>
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</tr>
<tr>
<td>Feed intake (g)</td>
<td>764</td>
<td>728</td>
<td>966</td>
<td>918</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>BW gain (g)</td>
<td>349</td>
<td>327</td>
<td>462</td>
<td>452</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>FCR (g:g)</td>
<td>2.24</td>
<td>2.25</td>
<td>2.18</td>
<td>2.12</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Breast score</td>
<td>2.87</td>
<td>3.10</td>
<td>3.36</td>
<td>3.93</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TI inductions (n)</td>
<td>2.50</td>
<td>2.00</td>
<td>2.09</td>
<td>2.43</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TI durations (log s)</td>
<td>1.19</td>
<td>1.35</td>
<td>1.35</td>
<td>1.19</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proportion inducible to TI</td>
<td>0.75</td>
<td>0.80</td>
<td>0.81</td>
<td>0.71</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

1FCR = feed conversion ratio (g of feed/g of gain); breast score = a subjective score of breast conformation indicating poor (1) to superior (5) breast conformation; TI = tonic immobility.

* $P < 0.05$; ** $P < 0.01$; NS = $P > 0.10$.

### Table 2. Spearman (rank) correlation coefficients among traits measured in males and females with field gait score (FGS) 2 and 3 in trial 1

<table>
<thead>
<tr>
<th>Trait</th>
<th>Starting BW</th>
<th>Ending BW</th>
<th>Feed intake</th>
<th>BW gain</th>
<th>FCR</th>
<th>Breast score</th>
<th>TI inductions</th>
<th>Log TI duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>FGS</td>
<td>0.24†</td>
<td>NS</td>
<td>0.57**</td>
<td>0.47**</td>
<td>−0.26†</td>
<td>0.37**</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Starting BW</td>
<td>—</td>
<td>0.95**</td>
<td>NS</td>
<td>0.70**</td>
<td>−0.47**</td>
<td>0.62**</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Ending BW</td>
<td>—</td>
<td>0.75**</td>
<td>NS</td>
<td>0.86**</td>
<td>−0.44**</td>
<td>0.51**</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Feed intake</td>
<td>—</td>
<td>—</td>
<td>NS</td>
<td>−0.81**</td>
<td>−0.28*</td>
<td>0.38**</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>BW gain</td>
<td>—</td>
<td>—</td>
<td>NS</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>FCR</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Breast score</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>TI inductions</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>—</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

1FCR = feed conversion ratio (g of feed/g of gain); breast score = a subjective score of breast conformation indicating poor (1) to superior (5) breast conformation; TI = tonic immobility.

* $P < 0.05$; ** $P < 0.01$; | $P < 0.10$; NS = $P > 0.10$. 

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The FGS3 birds were heavier than the FGS2 birds, and had more desirable breast conformation. The FGS2 and FGS3 birds did not differ in fear response. Correlation responses were similar to those observed in trial 1 (Table 4).

**Behaviors**

Preliminary analyses indicated that time of day effects were present (and expected) for eating and resting, but did not interact with other sources of variation; thus, time of day and its interactions were excluded from subsequent analyses. Behaviors of birds from FGS2 and FGS3 were similar in the 2 d observed, with a notable exception. In both days birds with FGS3 rested more and stood less than those with FGS2 (Table 5). Assessment of H:L ratio and pain associated pathology was used to ascertain if the increased resting frequency for FGS3 birds was associated with bird discomfort.

**H:L Ratio**

Gait score was not a significant source of variation affecting H:L ratio (Table 6), which indicates that there was no physiological stress associated with FGS3 compared with FGS2. Sex and group interacted to affect H:L ratio. Males placed in FCR cages for the week had lower H:L values than females or males that were moved from FCR cages to metabolism chambers. This indicates that males respond favorably to spending time in FCR cages, whereas similar responses are not evident in females. This would be expected because selection for improved FCR is generally at increased selection intensity for males compared with females.

**Pathology**

There was no evidence of pathology of either the sciatic nerve or its surrounding muscle (data not shown). Differences in FGS, therefore, do not appear to be a result of documentable pain or pathology and instead appear to reflect a behavioral modification to adapt to the specific breast conformation.

**Measures of Mass and Yield**

Male birds were larger and exhibited greater breast mass, but not proportion, than females (data not shown). Neither the proportion of breast to the front half of the breast nor the amount of front half breast differed between FGS2 and FGS3 birds (data not shown). Males contained more \((P < 0.01)\) lean tissue, protein, fat, and ash, with no effect of FGS (data not shown).

**Measures of Length and Conformation**

Physical measurements and conformation traits helped determine potential causal factors of gait score (Table 7). Breast angle was greater for FGS3 birds than

<table>
<thead>
<tr>
<th>Item</th>
<th>Start BW (g)</th>
<th>End BW (g)</th>
<th>Feed intake (g)</th>
<th>BW gain (g)</th>
<th>FCR (g:g)</th>
<th>Breast score (5)</th>
<th>Leg score (5)</th>
<th>Prop. inducible to TI</th>
<th>TI durations (log s)</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex</td>
<td>Group (G)</td>
<td>Sex (S)</td>
<td>H × G</td>
<td>H × S</td>
<td>FGS × G</td>
<td>FGS × S</td>
<td>FGS × S × G</td>
<td>ANOVA</td>
<td></td>
<td>Probability</td>
</tr>
<tr>
<td>Fem.</td>
<td>Female 2</td>
<td>2,183</td>
<td>2,133</td>
<td>487</td>
<td>304</td>
<td>1.67</td>
<td>2.67</td>
<td>3.33</td>
<td>2.44</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>Female 3</td>
<td>2,213</td>
<td>2,385</td>
<td>534</td>
<td>322</td>
<td>1.65</td>
<td>3.22</td>
<td>3.11</td>
<td>2.44</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>Male 2</td>
<td>2,563</td>
<td>2,810</td>
<td>677</td>
<td>453</td>
<td>1.50</td>
<td>3.33</td>
<td>3.11</td>
<td>2.28</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>Male 3</td>
<td>2,711</td>
<td>2,927</td>
<td>632</td>
<td>446</td>
<td>1.48</td>
<td>3.61</td>
<td>3.06</td>
<td>2.50</td>
<td>NS</td>
</tr>
</tbody>
</table>

Group (G) = feed conversion ratio (g of feed/400 g of gain); breast score = a subjective score of breast conformation indicating poor (1) to superior (5); leg score = a subjective score of leg conformation; TI = tonic immobility; Probability: *P < 0.05; **P < 0.01; ***P < 0.001; NS = P > 0.10.
for FGS2 birds, whereas percentage breast yield was similar. This indicated that breast shape and not breast mass per se appears to be associated with gait score.

**Measures of Proportions**

Physical measurement relationships were examined as ratios (Table 8). Numerous ratios of various mass and length combinations were examined with a representative portion presented herein. Although few differences were noted for absolute length measures, numerous significant \( P < 0.01 \) differences between FGS2 and FGS3 birds were noted for ratios of length and mass to length. Again, it appears that shape and proportion are associated with gait score differences.

**Heat Production**

Feed consumption for some of the birds placed within the metabolic chambers was erratic; however, all birds consumed enough feed to avoid losing weight. When feed was removed during the last 24 h of chamber housing, heat production (HP) declined steadily (data not shown) to a near basal metabolic rate level as inferred from the bird’s RQ (data not shown). The last 3 h of chamber housing in the dark (fasting hours 19 to 21), followed by 3 h of chamber housing in the light (fasting hours 21 to 24) were the time intervals used to examine fasted metabolism. The larger FGS3 birds exhibited greater HP than FGS2 birds independent of lighting; however, when HP was expressed per unit of BW as kilograms or kilograms\(^{0.67} \), the effects of FGS were eliminated. Heat production and RQ increased \( P < 0.01 \) during the lighted fasting hours (h 21 to 24) when compared with the earlier dark phase. The increased HP is attributable to the elevated activity noted by the birds during this period, and the elevated RQ indicates that the proportion of HP as carbohydrate was increased. With the lights on, the fasted birds were standing and

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### Table 4. Spearman (rank) correlation coefficients among traits measured in males and females with field gait score (FGS) 2 and 3 in trial 2

<table>
<thead>
<tr>
<th>Trait</th>
<th>FGS</th>
<th>Starting BW</th>
<th>Ending BW</th>
<th>Feed intake</th>
<th>BW gain</th>
<th>FCR</th>
<th>Breast score</th>
<th>Leg score</th>
<th>TI inductions</th>
<th>Log TI duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starting BW</td>
<td>NS</td>
<td>0.73**</td>
<td>0.24*</td>
<td>0.33**</td>
<td>NS</td>
<td>0.47***</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Ending BW</td>
<td>NS</td>
<td>0.34**</td>
<td>0.26*</td>
<td>0.87***</td>
<td>0.33**</td>
<td>0.30*</td>
<td>0.48***</td>
<td>NS</td>
<td>0.34**</td>
<td>−0.22†</td>
</tr>
<tr>
<td>Feed intake</td>
<td>NS</td>
<td>0.33**</td>
<td>0.26*</td>
<td>0.87***</td>
<td>0.33**</td>
<td>0.30*</td>
<td>0.48***</td>
<td>NS</td>
<td>0.34**</td>
<td>−0.29*</td>
</tr>
<tr>
<td>BW gain</td>
<td>NS</td>
<td>—</td>
<td>NS</td>
<td>0.34**</td>
<td>0.26*</td>
<td>0.30*</td>
<td>0.48***</td>
<td>NS</td>
<td>0.34**</td>
<td>−0.29*</td>
</tr>
<tr>
<td>FCR</td>
<td>NS</td>
<td>—</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Breast score</td>
<td>0.28*</td>
<td>—</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Leg score</td>
<td>NS</td>
<td>—</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
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<tr>
<td>TI inductions</td>
<td>NS</td>
<td>—</td>
<td>NS</td>
<td>—</td>
<td>—</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>−0.44***</td>
</tr>
</tbody>
</table>

\( \dagger P < 0.10; \* P < 0.05; \** P < 0.01; \*** P < 0.001; NS = P > 0.10. \)

---

### Table 5. Least squares means of behavior traits observed in male and female broilers with field gait score (FGS) 2 and 3 in trial 2, phases 1 and 2

<table>
<thead>
<tr>
<th>Item</th>
<th>FGS</th>
<th>Day 3</th>
<th>Sex</th>
<th>Eat</th>
<th>Drink</th>
<th>Stand</th>
<th>Rest</th>
<th>Walk</th>
<th>Peck</th>
<th>Preen</th>
<th>Dustbathe</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Female</td>
<td>0.57</td>
<td>0.52</td>
<td>7.62</td>
<td>70.93</td>
<td>0.43</td>
<td>0.65</td>
<td>0.60</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Female</td>
<td>0.89</td>
<td>0.80</td>
<td>4.37</td>
<td>77.43</td>
<td>0.12</td>
<td>0.12</td>
<td>1.46</td>
<td>0.00</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Male</td>
<td>0.80</td>
<td>1.57</td>
<td>8.23</td>
<td>67.99</td>
<td>0.02</td>
<td>0.65</td>
<td>1.12</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>Male</td>
<td>1.04</td>
<td>0.38</td>
<td>3.83</td>
<td>75.03</td>
<td>0.11</td>
<td>0.65</td>
<td>1.60</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sex</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sex</td>
<td>FGS</td>
<td>NS</td>
<td>NS</td>
<td>**</td>
<td>*</td>
<td>NS</td>
<td>NS</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>Day 6</td>
<td>Sex</td>
<td>1.45</td>
<td>0.38</td>
<td>11.97</td>
<td>60.47</td>
<td>0.72</td>
<td>0.81</td>
<td>1.11</td>
<td>0.01</td>
<td>0.00</td>
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<td>Female</td>
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<td>5.21</td>
<td>69.69</td>
<td>0.18</td>
<td>0.50</td>
<td>3.33</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Male</td>
<td>0.83</td>
<td>0.59</td>
<td>9.65</td>
<td>69.50</td>
<td>0.15</td>
<td>0.36</td>
<td>1.43</td>
<td>0.00</td>
<td>0.01</td>
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<tr>
<td></td>
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<td></td>
<td>Male</td>
<td>0.84</td>
<td>0.50</td>
<td>3.48</td>
<td>79.38</td>
<td>0.42</td>
<td>0.44</td>
<td>0.85</td>
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<td>Probability</td>
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<td>NS</td>
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<td>NS</td>
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<td>FGS</td>
<td>NS</td>
<td>NS</td>
<td>**</td>
<td>*</td>
<td>NS</td>
<td>NS</td>
<td></td>
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<td>*</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

\( \* P < 0.05; \** P < 0.01; NS = P > 0.10. \)
moving around their metabolic chambers. Gait score did not significantly affect fasted HP per unit of BW or metabolic BW, or RQ during any of the light-dark phases (P > 0.10). If physiological stress were causing the birds to alter their behavior, it did not appear to be affecting resting HP (an indicator of basal metabolism) or HP during the light phase (when activity would be expected). One would expect that the altered behavior observed might affect HP. When motivated to search for food (as after a 21-h fast), there was no difference in HP between birds differing in FGS. This indicates no inherent differences in metabolism between FGS2 and FGS3 birds.

DISCUSSION

Birds from FGS2 and FGS3 were similar in most of the traits measured. Most notably different, however, was breast conformation expressed as a subjective breast score or as an objective breast angle measure. Body shape defined by various length measures and, most notably, ratios of various body parts to one another suggest that bird center of gravity between birds with different FGS is different. Body shape and breast conformation appear to be important factors affecting gait score. Mench (2004) suggested that “Some gait impairment may be simply due to conformation, but more serious impairment is generally found to be associated with infectious or non-infectious skeletal disorders.” Data from the current experiment do not indicate that there are skeletal disorders associated with FGS3 and that this difference in gait score is simply associated with different broiler conformation.

There was no evidence, as suggested by Mench (2004), that birds with FGS3 were stepped on, had breast blisters, hock burns, or were otherwise injured more than those with FGS2, as no injuries were noted either in the field or upon arrival at the university for testing. No differences were noted in bird metabolism, pathology, or H:L ratio, suggesting that FGS differences are not due to increased physiological stress. The lack of difference in H:L ratio, RQ, and pathology, combined with differing ratios of body proportions and anatomical length, suggest that behavior and gait differences between birds with the 2 FGS classifications occur with similar levels of well-being. Similarly, no differences were observed in TI between birds with FGS2 and FGS3. Whereas use of TI as a measurement of fearfulness (and thus well-being) has been questioned (Murphy, 1978) and TI can be affected by many factors (see review in Noble et al., 1996a), its use in the present report does not contradict other assessments of well-being.

<table>
<thead>
<tr>
<th>Item</th>
<th>FGS</th>
<th>BRL (cm)</th>
<th>BRW (cm)</th>
<th>BRA (°)</th>
<th>FL (cm)</th>
<th>HTON (cm)</th>
<th>NTOB (cm)</th>
<th>HTOT (cm)</th>
<th>SL (cm)</th>
<th>MTL (cm)</th>
<th>BTL (cm)</th>
<th>TTL (cm)</th>
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<td>Sex</td>
<td>Female 2</td>
<td>17.03</td>
<td>19.26</td>
<td>136</td>
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<td>15.50</td>
<td>9.72</td>
<td>7.43</td>
<td>6.23</td>
<td>2.07</td>
<td>8.29</td>
</tr>
<tr>
<td></td>
<td>Female 3</td>
<td>16.81</td>
<td>19.56</td>
<td>140</td>
<td>35.95</td>
<td>19.28</td>
<td>16.66</td>
<td>9.49</td>
<td>7.30</td>
<td>6.09</td>
<td>2.15</td>
<td>8.04</td>
</tr>
<tr>
<td></td>
<td>Male 2</td>
<td>17.60</td>
<td>19.88</td>
<td>157</td>
<td>35.93</td>
<td>19.44</td>
<td>16.48</td>
<td>8.83</td>
<td>7.64</td>
<td>6.56</td>
<td>2.20</td>
<td>8.76</td>
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<tr>
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<td>Male 3</td>
<td>17.58</td>
<td>20.43</td>
<td>144</td>
<td>37.14</td>
<td>20.23</td>
<td>16.91</td>
<td>8.43</td>
<td>7.65</td>
<td>6.58</td>
<td>2.29</td>
<td>8.88</td>
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</table>

ANOVA

<table>
<thead>
<tr>
<th>Item</th>
<th>Sex</th>
<th>Probability</th>
<th>** NS</th>
<th>** NS</th>
<th>** NS</th>
<th>** NS</th>
<th>** NS</th>
<th>** NS</th>
<th>** NS</th>
<th>** NS</th>
<th>** NS</th>
</tr>
</thead>
</table>

Table 6. Analysis of variance of heterophil:lymphocyte (H:L) ratio data

Table 7. Measures of length morphology in male and female broilers with field gait score (FGS) 2 and 3 in trial 2

<table>
<thead>
<tr>
<th>Source</th>
<th>Probability</th>
</tr>
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<tr>
<td>Sex</td>
<td>*</td>
</tr>
<tr>
<td>Field gait score (FGS)</td>
<td>NS</td>
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<tr>
<td>Sex × FGS</td>
<td>NS</td>
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<tr>
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<td>0.0522</td>
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<td>Sex × group</td>
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<tr>
<td>FGS × group</td>
<td>NS</td>
</tr>
<tr>
<td>Sex × FGS × group</td>
<td>NS</td>
</tr>
</tbody>
</table>

*a,bMeans with no common superscripts differ (P < 0.05).

1Group = feed conversion testing only (FO), or feed conversion testing for 4 d followed by 3 d in metabolism chambers (FM).

**P < 0.05; NS = P > 0.10.
Although differences between FGS2 and FGS3 birds were not noted for FCR, it would be anticipated that birds resting more would exhibit different FCR (McKinney and Teeter, 2004; Skinner-Noble et al., 2005), unless their energy expenditure, independent of activity, is similar. If this were so, then energy expenditure for per activity task might be greater for the FGS3 birds because of their conformational differences. It may be that the differing physical conformations alter the energy expenditure for similar types of movement and that the birds’ motivation is to minimize energy waste.

The results of this study did not indicate that FGS2 and FGS3 birds differ in their well-being. The fact that birds with FGS2 and FGS3 differ in resting and standing confirms the work of Mench (2004), indicating that those behaviors are different for birds with different gait scores. This appears, however, to be an adaptive response to the birds’ differing physical conformations and not a physiological stress response.

### REFERENCES


### Table 8. Measures of morphological length ratios in male and female broilers with field gait score (FGS) 2 and 3 in trial 2.1

<table>
<thead>
<tr>
<th>Item</th>
<th>FGS</th>
<th>Ratio 1</th>
<th>Ratio 2</th>
<th>Ratio 3</th>
<th>Ratio 4</th>
<th>Ratio 5</th>
</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Female 2</td>
<td>2.14</td>
<td>4.75</td>
<td>3.75</td>
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<td>1.25</td>
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<tr>
<td>Female 3</td>
<td>2.18</td>
<td>5.07</td>
<td>4.07</td>
<td>0.37</td>
<td>1.50</td>
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<tr>
<td>Male 2</td>
<td>2.22</td>
<td>5.11</td>
<td>4.11</td>
<td>0.34</td>
<td>1.38</td>
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<td>Male 3</td>
<td>2.42</td>
<td>5.46</td>
<td>4.46</td>
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<td>1.57</td>
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<td></td>
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<td></td>
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</tr>
<tr>
<td>Sex</td>
<td>**</td>
<td>**</td>
<td>**</td>
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<td>Sex × FGS</td>
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<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

1Ratio 1 = hip-to-neck/hip-to-tail; ratio 2 = total bird length/hip-to-tail; ratio 3 = front bird length/hip-to-tail; ratio 4 = back toe length/middle toe length; ratio 5 = (front bird length/hip-to-tail) × (back toe length/middle toe length).

**P < 0.05; NS = P > 0.05.”