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Optical Flow Patterns in Broiler Flocks Reflect Both Group Activity and Individual Behavioral Differences

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ABSTRACT

Critiques of flock-level welfare metrics often argue that group averages hide the situation of individual animals. Here, we demonstrate that optical flow measures collected from broiler groups can yield information not only about mean flock activity but also about the distribution of movement types within the group. The mean reflects overall motion, while variance, skew and kurtosis capture differences among individuals. We linked optical flow statistics to the behavior and welfare of 16 sampled birds per flock using two runway tests and a water (latency-to-lie) assessment. In the runway tests, average completion time was positively associated with skew and kurtosis of day-28 optical flow (i.e., slower individuals typically came from flocks with elevated skew and kurtosis). In the water test, mean standing duration showed a positive association with mean and variance of flock optical flow (i.e., the most mobile birds usually derived from flocks with higher mean flow). Thus, flock-level patterns carry meaningful information about the activity profiles of different proportions of individuals.

Keywords: Broiler chickens, Group welfare, Animal welfare, Flock behavior, Optical flow, Precision livestock farming, Latency-to-lie

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Introduction

Automated tools for evaluating welfare are becoming increasingly common in livestock sectors [1–5], yet commercial poultry operations present specific challenges because they contain such large populations. The difficulty of identifying and tracking thousands of birds has led to automated approaches that assess welfare at the group level rather than for each bird. Systems using whole-flock video analyses [6–10] or sound-based assessments [11,12] can provide valuable information about general flock conditions but not about particular individuals. These group-based strategies have been criticized for neglecting the welfare of single animals [13,14]. The purpose of this study is to demonstrate that group-derived automated metrics can still offer insight into individual welfare even without bird-specific identification.

Automated systems are valuable because they gather continuous, detailed data that human observers cannot match. They allow stockpeople to monitor animals around the clock and to identify flocks that may require closer inspection or intervention. Consequently, even without individual identification, such systems can enhance individual bird welfare by improving management responsiveness.

More importantly, group-level systems can capture more than simple averages. For instance, optical flow in broiler flocks reflects not only mean activity but also within-flock variation [6,15]. Measures such as skew describe whether most birds are more or less active than the mean [16], while kurtosis indicates the presence of unusually high numbers of extreme movement events. In broilers, kurtosis reflects the activity of the most active birds [15] and is linked with key welfare outcomes such as gait problems, mortality and foot or leg lesions [17–20]. Although optical flow does not provide data for each bird individually, it can indicate what proportion of birds exhibit particular activity levels.

We evaluated whether flock-level optical flow metrics (mean, variance, skew, kurtosis) correspond to average performance in tests measuring individual movement. Two tests assessed the time an individual needed to traverse a runway, with and without obstacles. Runway transit time is used to assess both social motivation and locomotor capacity [21–23]; here we interpret it broadly as an activity index. The third test—the latency-to-lie assessment—measured how long a bird remained standing in shallow water, a behavior associated with gait health and lameness [24, 25]. We predicted that birds moving fastest in the runway tasks and staying upright longest in water would originate from flocks with high mean flow and low skew and kurtosis.

Materials and Methods

Ethical considerations

All broilers were managed within Swiss commercial production systems operating under the BTS welfare scheme, which covers over 90% of national broiler output. Each unit included enclosed outdoor annexes ("winter gardens") accessible via popholes. These openings remained shut until birds reached ≥22 days of age; after that, BTS rules required opening them whenever temperatures reached at least 13 °C (days 22–29) and at least 8 °C (from day 30 onward). Additional BTS criteria included a daylight level of no less than 15 lux (supplemented as necessary) and the provision of raised platforms from day 10, adding 10% extra usable space. Cameras were fitted only when the sheds were empty to avoid affecting the birds. Ethical authorization was issued by the Canton of Bern (BE97/16, 30 September 2016), and all legal requirements relating to animal care were fulfilled.

Animals and farms

From the five farms used in a prior investigation [19], three were selected; all three had previously produced both Campylobacter-positive and Campylobacter-negative flocks at slaughter. These sites were operated by a single company (Bell AG, Zell, Switzerland). Day-old Ross 308 chicks of mixed sex were placed "as hatched" and reared up to a permitted maximum of 30 kg/m^2, which includes the surface area contributed by elevated platforms. Altogether, 20 flocks were enrolled, although complete optical-flow datasets were obtained for 18. Flock sizes ranged between 11,934 and 24,000 birds (mean 18,533.7; STD 3923.0; n = 20). Flocks were grown either to 30 days (2 flocks), 36 days (14 flocks, thinned or not), or 37 days (4 flocks with thinning).

Behaviour tests for individual welfare assessment

All behavioral trials were performed without knowledge of optical-flow outputs or abattoir findings. Birds were 23–28 days old on the day of evaluation (mean 25.5; STD 1.32). Approximately 20 birds were separated inside the barn using a catching frame (114 × 114 × 60 cm^3) while still able to see the flock. Individuals showing obvious illness or severe gait issues were removed from consideration. Sixteen birds chosen at random from the frame were marked with colored paint on the head, wings, or tail and then tested individually in the runway tasks. Afterward, each bird was weighed, sexed, and assessed for pododermatitis and hockburn using the Welfare Quality Protocol® analogue scale [26], which uses a 100-mm line anchored at 0 (no lesions) and 100 (maximum severity), with reference points corresponding to the standard images (e.g., 10 mm indicating original score 1). The scorer did not know how the birds had performed in the runway. A fecal sample was collected from each bird for unrelated analyses before returning it to the frame. Once all birds had completed the runway procedures, the water test was conducted in groups of four.

Runway tests

The runway was 342 cm long with opaque sidewalls except at the distant end, where the separated conspecifics were visible **(Figure 1)**. The opaque wall ended one body-length before the pen, marking the finish point. Each bird was transported to the starting end and released; the time it took to reach the finish was noted, with a 5-min timeout. The procedure was repeated immediately, but this time a 14-cm line of bricks was placed across the runway approximately 50 cm from the release point. Again, time to the finish was recorded with a 5-min limit.

Figure 1. Schematic of the runway: the bird was released at the near end and timed until it advanced to within one body length of its group in the holding pen, indicated by the end of the green screen

Water test

The assessment followed the "latency-to-lie" protocol [24, 25]. Four birds were placed in a shallow tray of warm water and observed for 15 minutes. The time at which each bird first sat was documented. Birds that remained standing throughout received the maximum score of 900 s.

Optical flow for group level behaviour assessment

Two Samsung IP cameras (SNO-6084RP) were mounted 5 m above floor level, one on each side of the barn, roughly one-third of the building's length from the entrance. Cameras were installed between flocks and connected to a Synology NAS Disk Station (DS 115j) through an HP 9982A ethernet switch. Video was collected continuously (24 h/day) from placement until a few days before depopulation at 4 frames/s and at a 320 × 240 pixel resolution.

Movement quantification from video output

Flock activity was derived from camera recordings by tracking frame-to-frame changes in pixel brightness—an approach known as optical flow—which captures how luminance shifts across both spatial and temporal dimensions [27, 28]. These localized brightness changes were combined to estimate the overall movement represented by the summed velocity vectors. For instance, if a stationary group of white birds against a dark floor remains motionless, brightness remains constant and no flow is generated. When individuals shift position, areas of white become darker or vice versa, producing measurable flow.

Although optical flow can be calculated at the single-pixel scale, each frame here was segmented into 1200 blocks (40 × 30 array, each block 8 × 8 pixels) for computational efficiency. Flow values were computed for each block every 0.25 s. These block-level velocities were then merged for each frame to yield whole-image descriptors: mean flow (overall activity), followed by variance, skew, and kurtosis to characterize patterns of variation. A more detailed methodological explanation can be found in [20].

To condense output, data from one camera running at 4 frames/s were grouped into batches of 3600 frames, producing averages for the four optical-flow parameters over 15-min intervals. Median values were used within these summaries to remove extreme artefactual readings. These 15-min summaries were then further averaged to generate daily values (08:00–20:00 h) for behavioral comparisons. To ensure comparability across flocks, optical-flow metrics were taken from the same age point for all birds. Day 28 was chosen because all behavioral tests had been completed by that time, allowing undisturbed flow measurements. All flocks were still intact at this age (see Section 2.2).

Statistical analysis

The first stage of analysis examined how individual characteristics—body weight, sex, and lesion scores for hockburn and pododermatitis—affected the time needed to travel the runway with or without obstacles. Completion times were log-transformed, and individuals failing to finish (i.e., times >300 s) were excluded. Hockburn and pododermatitis were treated as binary (0 vs. >0). A generalized linear model (Proc Glimmix, SAS Institute Inc., Cary, NC, USA) was used, and model residuals were tested for normality. All interaction terms were included unless they exceeded a p-value of 0.2.

Because flocks could not all be tested on exactly the same day, age and mass were confounded in these rapidly developing birds. Mass was therefore used instead of age, as published findings indicate weight is more influential on mobility than small differences in age [29].

The second analytical step related the five individual-level measures (three behavioral outcomes plus hockburn and pododermatitis scores) to the flock-level optical-flow measurements. For comparability, the 16 birds sampled per flock were averaged to produce a single flock-level value for each variable. Unlike the first analysis, this step used continuous lesion scores. Since parametric assumptions could not be guaranteed for either dataset, associations were assessed using Spearman Rank Correlations [30].

Results

Movement characteristics of flocks

Optical-flow summaries for the 18 Swiss flocks at 28 days are presented in **Table 1**. All groups showed strong positive kurtosis, indicating distributions with sharper peaks and/or extended tails relative to a normal distribution—values beyond ±3 are considered non-normal [15]. Skewness was also positive in every flock, meaning that movement values were concentrated on the lower-activity side of the distribution with a tail extending toward higher flow.

Table 1. Day-28 daily mean optical-flow metrics for 18 flocks, with standard errors in brackets

Variance	Kurtosis	Mean	Skew
0.216 (±0.215)	30.109 (±3.25)	0.24 (±0.24)	4.762 (±4.77)

Runway tests

Of 319 birds tested, 46 failed to complete the unobstructed runway within 5 minutes, and 79 failed when obstacles were added; these individuals were assigned a value of 300 s. For the obstacle runway, completion time declined as body mass increased ($F_{1,282} = 3.93$, $p = 0.049$), and females tended to take longer ($F_{1,282} = 3.47$, $p = 0.064$). The same tendencies were present without obstacles, although not statistically significant (mass: $F_{1,282} = 3.63$, $p = 0.058$; sex: $F_{1,282} = 3.42$, $p = 0.066$). Pododermatitis and hockburn showed p-values >0.9 and were excluded from the final models.

For overall runway performance, body mass significantly reduced time to finish ($F_{1,236} = 5.93$, $p = 0.016$), while males again tended to move faster ($F_{1,236} = 3.06$, $p = 0.082$). Pododermatitis ($F_{1,236} = 0.68$, $p = 0.41$) and hockburn ($F_{1,236} = 2.79$, $p = 0.10$) remained non-significant.

Latency to lie (Water Test)

Of the 304 birds tested, 193 managed to stay standing until the end, which was recorded as 900 seconds. Birds with a higher body mass tended to sit down more quickly than lighter birds, regardless of sex. No significant differences were found between sex, pododermatitis, or hockburn and the time taken to sit (body mass: $F1,275$ =

3.97, $p = 0.047$; sex: $F_{1,275} = 0.11$, $p = 0.74$; pododermatitis: $F_{1,275} = 2.27$, $p = 0.13$; hockburn: $F_{1,275} = 0.08$, $p = 0.78$).

Correlations between individual tests and flock optical flow data

The relationships between the three individual behavior tests and the optical flow values of the respective flocks on day 28 are presented in **Table 2**. In the runway tests, a strong positive correlation was found between the time it took for birds to pass through the runway and the skewness and kurtosis of the flocks they came from. Birds with longer times were from flocks with higher positive skew and kurtosis. For the water test, there was a significant positive correlation between standing time and both the mean and variability in optical flow. The birds that remained standing longest were from flocks with higher average movement rates.

Table 2. Spearman correlations between behavior tests and optical flow (OF)

	Variance OF	Kurtosis OF	Mean OF	Skew OF
Runway test 1 (without obstacles)	0.008	0.608 $p < 0.01$	−0.0781	0.711 $p < 0.001$
Runway test 2 (with obstacles)	−0.05	0.625 $p < 0.005$	−0.196	0.697 $p < 0.0025$
Water test	0.574 $p < 0.01$	−0.343	0.573 $p < 0.01$	−0.308
Hockburn	0.147	0.508 $p < 0.025$	−0.021	0.508 $p < 0.025$
Pododermatitis	−0.003	0.426 $p < 0.05$	0.023	0.398

Discussion

The optical flow data for the broiler chicken flocks revealed a positive skew **(Table 1)**, indicating that most of the birds were less active, with only a few showing higher movement levels. The distribution also showed positive kurtosis, suggesting that, at any given time, a small number of birds displayed much more activity than the rest. This aligns with studies suggesting that broiler chickens are typically sedentary, with a small percentage of birds being actively walking or running at any given moment [31-33].

We hypothesized that birds showing more activity in the individual tests would come from flocks with higher mean optical flow but lower skewness and kurtosis [6,17-20]. Since the runway and water tests assessed activity differently, the hypothesis predicted opposite patterns for these two tests. The runway test evaluated how quickly a bird reached the end of the runway, with more active birds completing it faster. Thus, we expected a negative correlation between the time to complete the runway and the mean optical flow of the flock, but a positive correlation with the skew and kurtosis of the flock's optical flow. This prediction was partially supported **(Table 2)**. The average times for the 16 birds in the runway test were positively correlated with the skew and kurtosis of the flock's movement, though the negative correlation with the mean optical flow did not reach significance, although it was in the expected direction. This could be because skew and kurtosis are more sensitive to the movement of the most active birds, whose behavior was better captured by the runway test, while the mean optical flow was more influenced by the less active birds. Some birds (15.5% in Test 1 and 28.5% in Test 2) did not complete the runway within the time limit, causing their times to be recorded as over 300 seconds, which might have diluted the results.

For the water test, our predictions were the opposite. This test measured how long birds could remain standing, with more active birds standing longer. We predicted a positive correlation between standing time and the mean optical flow of the flock, which was confirmed **(Table 2)**. A significant positive correlation was found between standing time and mean optical flow, though the expected negative correlation with skewness and kurtosis was not significant, even though it was in the expected direction. This could be due to the water test's better ability to distinguish between birds that were least able to stand, while not as effective at differentiating the most active birds, as the majority (65.5%) remained standing at the end, resulting in their times being recorded as >900 seconds.

In summary, while the runway and water tests supported our predicted correlations with flock optical flow, some results did not reach significance due to the failure of some birds to complete the tests.

Negative welfare outcomes, such as increased mortality, lameness, and hockburn, are linked to flocks with lower mean optical flow and higher skewness and kurtosis values [6,15,18-21]. The results from the behavior tests confirm that flocks exhibiting low mean optical flow and high skewness/kurtosis are more likely to contain individuals that are slow movers, taking longer to complete the runway and sitting down quickly after standing in water. High kurtosis is indicative of slow-moving behavior, as in flocks of mostly inactive birds, where a few active individuals stand out as an anomaly, creating a "tail" or high kurtosis in the movement distribution. As more birds in a flock become active, movement becomes more uniform, and the kurtosis value decreases.

The lack of any significant impact from pododermatitis or hockburn on the behavior tests may be due to insufficient statistical power, possibly caused by the small sample size (only 16 birds per flock), minimal variation within flocks, or other factors, such as body mass variation, which may have obscured the effects of pododermatitis and hockburn. The runway test not only measures physical ability but also motivation, which could be influenced by factors like anxiety. More anxious birds might have been quicker to approach others, but we did not assess anxiety directly, so we cannot draw conclusions about its role.

The overall activity level within a flock has been suggested as an indicator of flock welfare and health [34], and it can be detected using the mean optical flow [6,7,10]. However, interpreting mean flock activity alone can be challenging in welfare assessments, as it may be influenced by breed or environmental factors such as lighting. More importantly, it does not provide insight into the welfare of individual birds within the flock [13]. Our findings suggest that optical flow skewness and kurtosis provide additional details about the distribution of activity within a flock. A flock with high mean activity but low skew and kurtosis (where most birds exhibit similar levels of activity) indicates that most individuals are active. Conversely, a flock with high skew and kurtosis suggests that the majority of birds are inactive, with only a small minority displaying significant activity. Our results indicate that optical flow skew and kurtosis can be used to distinguish flocks based on the proportion of active versus less active birds.

Conclusions

The optical flow patterns generated by chicken flocks provide a useful group-level measure of flock behavior, without the need to track individual birds. However, by conducting individual behavior tests on a sample from different flocks, we have demonstrated that these group-level patterns also offer valuable insights into the proportions of active and inactive birds within the flock, bridging the gap between group-level and individual behavior assessments in poultry welfare.

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Conflict of Interest: None

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Ethics Statement: None

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