The usual suspects: Co-occurrence of integument injuries in turkey flocks

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The present study investigated the prevalence and co-occurrence of integument injuries in Canadian turkeys. Participating farmers scored 30 birds in their flock for integument injuries to the head/neck (**HN**), back/tail (**BT**), and footpad (**FP**) using a simplified scoring system (0: no sign of injury, 1: mild injury, 2: severe injury). Information from 62 flocks was used to calculate the prevalence of any (score ≥1) and severe (score 2) injuries on a flock- and individual-level. Chi-square analyses were performed to determine the likelihood of integument injury co-occurrence. The prevalence of each type of injury varied between flocks. While the majority of flocks reported injuries, the within-flock prevalence was relatively low and largely comprised of mild cases (score 1). Given their higher prevalence, the data indicate that FP injuries are overall more widespread and more severe among Canadian turkey flocks than HN and BT injuries. Co-occurrence of different integument injuries was observed in 7% of birds and 58.1% of flocks reported at least one bird with co-occurring injury types. Despite the low prevalence of multiple injury types, birds with one type of injury were more likely to present with other injury types. Indeed, birds with HN injuries were 4 times more likely to have BT injuries, and birds with FP injuries were 1.5 times more likely to have BT injuries compared to birds that do not have these respective injuries. The data increase our understanding of the co-occurrence of these common integument injuries which can help inform a holistic management approach to rear turkeys with healthy skin and feather cover.

Key words: Comorbidity, Footpad dermatitis, Injurious pecking, Management, Meleagris gallopavo

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INTRODUCTION

Efforts to improve animal welfare are multi-faceted due to the interconnectedness of behavior and health conditions, the influence of environmental conditions, and the variability in how individual animals may experience welfare. To account for this complexity, current welfare protocols (in poultry e.g., Welfare Quality, 2009; AWIN, 2015) measure a multitude of animal-based outcomes, often at a group level or as a composite animal-based measure (EFSA, 2012). Animal welfare risks depend on 1) the probability of exposure to risk factors, 2) the probability of welfare consequences under exposure to these factors, and 3) the duration and intensity of the welfare consequences (EFSA Panel on Animal Health and Welfare (AHAW), 2012).

Various approaches have been used in turkey production to identify risk factors for integument injuries, including pecking injuries and footpad dermatitis (Sherwin et al., 1999; Moinard et al., 2001; Mayne et al., 2007; Da Costa et al., 2014; Leishman et al., 2021, 2022). Injuries can be defined in different ways including bodily damage caused by transfers of energy (e.g., Langley and Brenner, 2004), damage inflicted to the body by an external force (e.g., Studdert et al., 2012), or disturbance or damage to the structure or function of any part of the body by an external force (e.g., Youngson, 2005). Farmers identify integument injuries as an important concern for the turkey production sector (van Staaveren et al., 2020b) and, unsurprisingly, surveys of the general public also indicate that injuries are viewed as unacceptable (Bir et al., 2019). In turkeys, integument injuries can occur due to injurious pecking to the feathers and skin which can lead to open wounds and cannibalism, consequently leading to mortality. Injurious pecking consists

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of aggressive pecking toward the head, neck and/or snood, and forceful feather pecking/pulling at the plumage of the back, tail and wings (Dalton et al., 2013; Erasmus, 2018; van Staaveren and Harlander, 2020). Aggressive pecking can escalate to severely injured animals that have to be culled due to an unfavorable prognosis or mortalities (Bartels et al., 2020). Footpad dermatitis is another prominent type of injury which is associated with hyperkeratosis, inflammation and swelling of the footpad and can cause necrotic lesions (Mayne, 2005; Shepherd and Fairchild, 2010; Erasmus, 2018). There is some evidence that footpad and pecking injuries can heal when causative factors are removed in the case of footpad dermatitis (Chen et al., 2016; Freeman et al., 2020), or when turkeys are isolated in the case of injurious pecking (Bartels et al., 2020). However, these measures are often not possible in practice causing probably painful injuries to persist. In addition to the injuries themselves being important welfare issues, they also can provide access points for secondary infections (Agunos et al., 2013), further exacerbating the birds' health and welfare condition.

The co-occurrence of these health and welfare conditions is an area of research that has been historically overlooked. Comorbidities in animals can lead to confounding effects that dilute the conclusions to specific research questions (Franco et al., 2018). Previous work has devised techniques to capture the co-occurrence of clinical/physical and behavioral/psychosocial outcomes in research laboratory or zoo settings (Honess and Wolfensohn, 2010; Justice et al., 2017), or to report on the impact of welfare impairments and a shortened lifespan (Teng et al., 2018). The co-occurrence of conditions can impact animal survival. For example, horses with multiple chronic diseases (e.g., laminitis, pituitary pars intermedia dysfunction, equine metabolic syndrome) pose between 6 to 21 fold higher hazard of death compared to healthy horses (Welsh et al., 2016). Information regarding the co-occurrence of disease or injuries could, therefore, influence human decision-making in the treatment or management of animals under their care.

In poultry, respiratory pathogens are concurrently diagnosed, and diseases such as necrotic enteritis and coccidiosis are frequently reported together (Pierson et al., 1996; Marien et al., 2007; Agunos et al., 2013). The treatments of multiple diseases or infections are evidently more complex than a single disease. More recent interest in breast muscle myopathies also shows that conditions such as white striping, wooden breast, and spaghetti breast can co-occur and this can lead to the incorrect assignment of biochemical features to the individual myopathy (Bailey et al., 2020). Despite these reports, the co-occurrence of other welfare conditions is far less frequently reported in similar detail, likely due to their perceived lower relevance compared to economically important diseases and food quality/safety issues. Nevertheless, prevalence of footpad injuries has been associated with breast lesions, hock burns, and focal ulcerative dermatitis (reviewed by Mayne, 2005). Visualizing relationships between animal-based welfare outcomes is recommended (EFSA, 2012) and this practice could shed light on biological connections and the overall welfare of animals. Few studies have reported correlations between welfare conditions in turkeys at a flock level (Allain et al., 2013; Marchewka et al., 2019). In particular, the literature indicates that turkeys with footpad injuries are less mobile, which can contribute to other welfare issues, such as reduced ability to reach feed/water, to escape aggressive pecking or feather pecking, and the worsening of contact dermatitis (Erasmus, 2018). This hypothesis stems from previous work correlating footpad dermatitis and feather pecking in turkeys (Allain et al., 2013); however, this association was not identified by others (Marchewka et al., 2019). Recent anecdotal behavioral observations also suggested that once victims of pecking injuries lay down, or were less mobile, they attracted more pecking from multiple conspecifics (Bartels et al., 2020). Given the paucity of available research, Erasmus (2018) called for further investigation into the relationship between injuries in turkeys to better manage the welfare of turkey flocks. To the best of the authors' knowledge, no other studies have confirmed the reported associations or further elaborated on the relationship between injuries in turkeys to date. Consequently, this study merged and analysed data from previous studies (van Staaveren et al., 2020a; Leishman et al., 2021, 2022) to evaluate the co-occurrence of injuries located on three different body areas (footpad, head/neck, back/tail) in turkeys.

MATERIALS AND METHODS

A cross-sectional study surveying turkey farmers across Canada was conducted to gain insight into the turkey production sector and identify risk factors for footpad dermatitis and integument injuries (van Staaveren et al., 2020a; Leishman et al., 2021, 2022). Invitations to participate in the study were sent out to commercial turkey farmers by the Turkey Farmers of Canada (April 2019). Survey packages contained a cover letter, health scoring guide with detailed instructions on how to assess their flock, and a return envelope with a unique code to collect all responses anonymously. All documents were made available in English and French, and farmers could opt to return the response by mail or submit answers online via Qualtrics (Qualtrics, Provo, UT). Reminders were sent out through the Turkey Farmers of Canada until the end of data collection in December 2019. This study was approved by the University of Guelph Research Ethics Board (REB 19-02-015) and the University of Guelph Animal Care Committee (AUP 3782).

The survey instructed farmers to assess injuries to the head/neck (**HN**) area, back/tail (**BT**) area, and footpad (**FP**) of 30 turkeys from their flock with the help of visual aids provided in the packages (Leishman et al., 2021, 2022). Farmers were asked to select turkeys by dividing the barn in a front, middle, and back section and randomly select an equal number of birds in each of

Table 1. Detailed scoring system used by farmers to assess injuries to the head/neck (HN), back/tail (BT), and footpad (FP) in turkeys adapted from Leishman et al. (2021, 2022).

Injuries	Description
Head/neck (HN)	
Score 0	No injuries present on the head, snood, wattle, or neck
Score 1	Presence of scratching and/or pecking injuries (<2 cm) on the snood, wattle, head, or neck
Score 2	Presence of scratching and/or pecking injuries (≥2 cm) on the snood, wattle, head, or neck
Back/tail (BT)	
Score 0	No injuries or feather damage present on the body (excluding head, snood, wattle, neck, legs, and feet)
Score 1	Presence of injuries or feather damage on the body which is <5 cm in length (excluding head, snood, wattle, neck, legs, and feet)
Score 2	Presence of injuries or feather damage on the body which is ≥5 cm in length (excluding head, snood, wattle, neck, legs, and feet)
Footpad (FP)	
Score 0	No signs of footpad dermatitis. Intact, soft skin without swelling or black/necrotic areas on the footpad. Litter can be brushed off footpad easily
Score 1	Hard or dense skin. Small black/necrotic areas on less than 25% of the footpad. Litter cannot be removed easily from footpad
Score 2	Large black/necrotic areas and/or swelling on greater than 25% of the footpad. Litter adhered to footpad and cannot be removed easily

them to achieve a representative picture of the entire barn. The body areas for injury evaluation were selected based on the different motivational backgrounds that are likely to cause each injury, for example, injuries to the HN area are often a result of aggressive behavior, while injuries to the BT area are likely a result of feather pecking (Dalton et al., 2013; van Staaveren and Harlander, 2020). Both recent and older (scabbed) injuries were recorded. Signs of footpad dermatitis were recorded as FP injuries. Farmers were instructed to gently remove any loose litter from the FP prior to evaluating injuries. The severity of each injury type was scored on a scale of 0 to 2, with 0 indicating no injuries, 1 indicating mild injuries, and 2 indicating more severe injuries (Table 1). Additional information on flock characteristics, housing and management was captured as part of the overall project and is reported elsewhere (van Staaveren et al., 2020a; Leishman et al., 2021, 2022).

The prevalence of HN, BT, and FP injuries was calculated at the flock- and individual-level. The flock-level prevalence was calculated as the percentage of birds within each of the 30 birds sampled within a flock with a score ≥1 (any injuries) or score of 2 (severe injuries) within the HN, BT, and FP injury types. Additionally, the number of injury types present on each bird was determined where a bird could have between zero injuries to maximum all 3 different injuries present simultaneously (HN, BT, and FP). When birds were observed with more than 1 type of injury, the combination of co-occurring injuries (i.e., HN + BT, HN + FT, BT + FT, HN + BT + FT) was also assessed to determine which combination was most frequently observed. Relationships between HN, BT, and FP injuries were investigated. Spearman correlations at the flock-level were estimated to determine whether a higher prevalence of one type of injury was associated with a higher prevalence of another type of injury within a flock. An association between the prevalence of injuries may be due to injuries co-occurring in the same birds within a flock or due to different birds being affected by different injuries (e.g., when flock management conditions function as shared risk factors for different injuries). To further assess this relationship, we investigated if birds with one type of injury were also more likely to have another type of injury using a Chi-square analysis (PROC FREQ with chisq and oddsratio option) which provided the odds ratio (OR) and the 95% confidence interval (95% CI) (SAS Institute Inc, 2013). The odds ratio is calculated as the ratio of the odds of presenting with a second injury type when a first injury type is present to the odds of presenting with a second injury type when a first injury type is not present. An OR >1 indicates a higher odds of having a second injury type when a turkey presents with the first injury type compared to a when a turkey does not present with the first injury type. All 2-pair combinations of injuries were assessed (i.e., HN + BT, HN + FT, BT + FT). Due to the low number of birds with severe injuries (score 2), the prevalence of any (score ≥1) injury at a flock and at the individual levels were considered. All data analyses were performed in SAS v9.3 (SAS Inst. Inc., Cary, NC) with a significance level of $P < 0.05$.

RESULTS

A total of 101 questionnaires were returned, representing a 20% response rate. Complete surveys with health scoring produced information for 63 flocks comprised of 40 hen flocks and 23 tom flocks. One hen flock was removed from the analysis as it was an older breeder flock. Flock ages ranged from 3 to 23 weeks. Tom flocks tended to be older than hen flocks (toms: 11.4 ± 0.90 weeks vs. hens: 9.4 ± 0.57 weeks, $F_{1,60} = 3.74$, $P = 0.0580$), and were heavier (9.6 ± 0.33 kg) than hen flocks (6.0 ± 0.25 kg, $F_{1,56} = 77.44$, $P < 0.001$). Detailed analyses on risk factors for HN, BT, or FP injuries were previously reported (Leishman et al., 2021, 2022) and were out of the scope of the current study.

Flock-Level Injuries

The average prevalence of injuries (score ≥1) to the HN and BT was relatively low (<10%), compared to FP injuries, which affected nearly 40% of the assessed birds (Table 2). Most HN, BT, and FP injuries were mild (score 1) as there was a low prevalence of severe (score 2) injuries. However, it is noteworthy that considerable variation was observed between flocks, exemplified by the range in prevalence for all three injury types (Table 2). Most flocks had at least one bird with any HN, BT, or FP injuries (score ≥1), but flocks with at

Table 2. Prevalence of injuries to the head/neck area (HN), back/tail area (BT), and footpad (FP) in 62 turkey flocks.

	HN injuries	BT injuries	FP injuries
Prevalence (%) of any injuries (score ≥1)			
Mean (SD)	6.0 (8.37)	9.7 (14.30)	38.1 (33.90)
Range	0–40	0–96.7	0–100
Prevalence (%) of severe injuries (score 2)			
Mean (SE)	0.8 (0.34)	0.6 (0.26)	9.5 (2.57)
Range	0–16.7	0–10	0–100
No. of flocks[1]			
Without any injury (score 0)	25 (40.3%)	18 (29.0%)	8 (12.9%)
With any injury (score ≥1)	37 (59.7%)	44 (71.0%)	54 (87.1%)
With severe injury (score 2)	8 (12.9%)	6 (9.7%)	24 (38.7%)

[1]The number of flocks with and without any injury totals 62 flocks (i.e., 100%), while the number flocks with severe injury (score 2) form a subset of the number of flocks with any injury (score ≥1). Percentage within brackets represents the percentage out of the 62 total flocks.

least one bird with severe HN or BT injuries (score 2) were relatively uncommon (Table 2). In contrast, it should be noted that approx. 40%, 30% and 13% of flocks did not have any birds with signs of HN, BT, or FP injuries, respectively (Table 2).

When considering the number of co-occurring injury types, only 2 flocks (3.2%) had no injuries at all in any of their assessed birds (i.e., all birds with score 0 for each injury type), while birds in 24 flocks (38.7%) presented only one type of injury. Most flocks (28 flocks, 45.2%) reported a maximum of 2 co-occurring injury types, and 8 flocks (12.9%) reported birds with all three injury types at the same time. The flock-level prevalence (score ≥1) of HN injuries was positively correlated to that of BT injuries ($r = 0.53$, $P < 0.001$), while the prevalence of FP injuries was not correlated to the prevalence of either HN ($r = -0.12$, $P = 0.3728$) or BT ($r = 0.10$, $P = 0.4530$) injuries.

Individual-Level Injuries

The 62 flocks included in this study covered the assessment of a total of 1,860 birds. Most birds showed no signs of HN, BT, or FP injuries (Figure 1), however, FP injuries were the most common out of the 3 recorded injuries. Most birds presenting with an injury were assigned score 1, representing a mild injury. Less than 1% of birds had severe HN or BT injuries and less than 10% of birds had severe FP injuries.

The low numbers of birds severely affected (score 2) compared to the larger number of flocks reporting a severe injury suggests that there are a few severe cases within multiple flocks. Indeed, the 15 birds with severe HN injuries were spread across 8 flocks, the 11 birds with severe BT injuries were spread across 6 flocks, and the 176 birds with severe FP injuries were spread across 24 flocks. This distribution translates to approximately 2 birds with pecking related injuries and approximately 7 birds with feet-related injuries per assessed sample of birds within a flock.

Overall, approximately 50% of the total 1,860 birds assessed in the survey had no signs of HN, BT, or FP injuries (Figure 2A). Most injured birds presented with one type of injury, while 7% of birds had 2 or 3 co-occurring injury types. In birds with co-occurring injury types, the combination of BT and FP injuries was most common (Figure 2B), followed by HN and FP injuries, and HN and BT injuries. While only approximately 1% of birds presented with all three injury types, they represented approximately 10% of the 131 birds with multiple injuries (Figure 2).

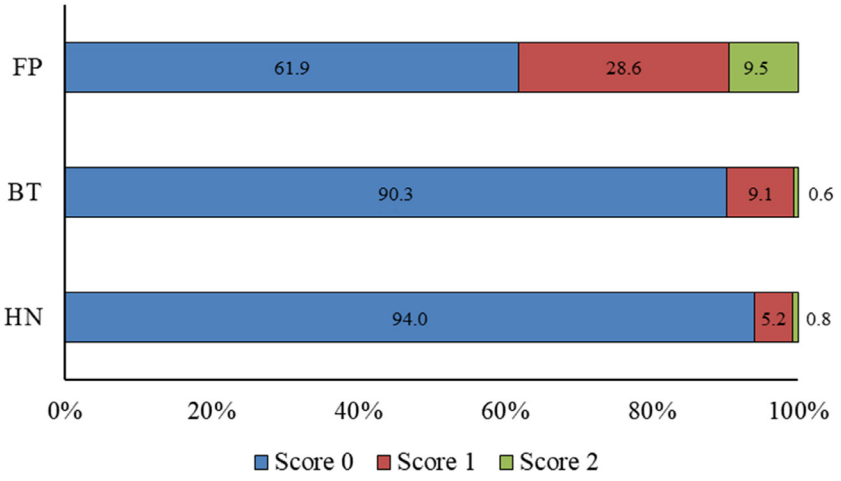

Figure 1. Distribution of injuries to the head/neck area (HN), back/tail area (BT), and footpad (FP) in 1,860 turkeys according to severity where score 0 indicates no injury, score 1 mild injury, and score 2 severe injury.

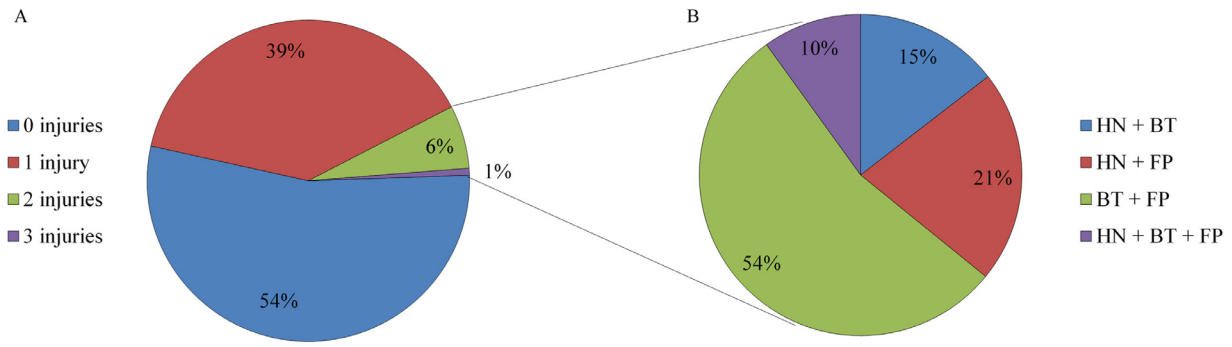

Figure 2. A) Number of co-occurring injury types (head/neck, back/tail, footpad) present in turkeys (n = 1,860) and B) the breakdown of the injury combinations to the head/neck area (HN), back/tail area (BT), or footpad (FP) observed in birds that had more than 1 injury (n = 131).

The presence of HN injuries was associated with BT injuries ($X^2 = 49.5$, $P < 0.001$). Indeed, the odds of having BT injuries was 4.4x (95%CI: 2.81−6.83) higher in birds with HN injuries (28.8%) than in birds without HN injuries (8.5%). No association was found between the presence of HN and FP injuries ($X^2 = 0.06$, $P = 0.8008$) as 36.9% of birds with HN injuries compared to 38.1% of birds without HN injuries presented with FP injuries (OR = 0.95, 95%CI: 0.64−1.41). In contrast, BT injuries were associated with FP injuries ($X^2 = 6.3$, $P = 0.0124$). Birds with FP injuries were more likely to also have BT injuries (OR = 1.5, 95%CI 1.09−2.02) compared to birds that had no FP injuries (11.8% vs. 8.3%).

DISCUSSION

This study investigated the prevalence of injuries to the head/neck (HN), back/tail (BT), and footpad (FP) in Canadian turkey flocks to attempt to explain the co-occurrence of three important health and welfare indicators. These injuries are proposed to be caused by aggressive bird-to-bird pecking (HN injuries), bird-to-bird feather pecking/pulling with subsequent tissue pecking (BT injuries), and footpad dermatitis is associated with several factors such as litter management, stocking density and diet (Sherwin et al., 1999; Moinard et al., 2001; Mayne, 2005; Mayne et al., 2007; Da Costa et al., 2014; Leishman et al., 2021, 2022). Using data from 1,860 birds from 62 flocks, we found that birds with HN injuries were 4 times more likely to have BT injuries. Birds with FP injuries were 1.5 times more likely to have BT injuries compared to birds without these respective injuries.

This study is one of only a few reports investigating the co-occurrence of HN, BT, and FP injuries in turkeys, despite frequent reference to the theory that birds with certain injuries may be more likely to be victims of other injuries (Allain et al., 2013; Erasmus, 2018; Bartels et al., 2020). We used a combination of flock-level and individual-level analyses to provide in-depth insight into this long-held hypothesis. Most studies attempting to correlate different injuries, do so at the flock-level (Allain et al., 2013; Villarroel et al., 2018; Marchewka et al., 2019), which may not provide the granularity required to identify etiology and distribution. Consequently, it is not possible to discern whether the same birds are being affected or these conditions are co-occurring within flocks but affecting different birds. If we found a correlation at the flock level, but were unable to replicate this at the individual bird level, it would suggest that it is not the same birds that are affected. Understanding whether the same birds are affected by different injuries could be advantageous in the development of management strategies. A total of 131 birds out of the 1,860 birds assessed (7%) presented with a combination of injuries. The most frequently observed combination was BT and FP injuries, which is in line with the idea that birds with FP injuries are more likely to be victims of severe feather/tissue pecking (Allain et al., 2013; Erasmus, 2018; Bartels et al., 2020).

Interestingly, we found no flock-level correlation between the prevalence of FP and HN or BT injuries. Birds with FP injuries are less mobile (Da Costa et al., 2014) which may have different implications. These birds may be less likely to perform injurious pecking themselves, thereby reducing the overall prevalence of pecking injuries, or as more frequently suggested, they may be more likely to become victims of injurious behavior (Allain et al., 2013; Erasmus, 2018). Only one study has reported empirical data supporting a positive correlation between prevalence of foot swelling and feather pecking injuries in turkey flocks using slaughterhouse assessments (Allain et al., 2013). The same study could not assess correlations with HN injuries due to the low prevalence of this condition (Allain et al., 2013), which was also the least frequently observed injury in the current study. It is noteworthy that assessing birds at the slaughterhouse allows for better visibility of injuries (especially for FP injuries) in addition to being able to capture information from a large number of animals at the end of production. In contrast, the present study relied on farmer-reported prevalence for a variety of flock ages, which may explain the deviation in results (discussed more in-depth further). While not specifically investigating FP injuries, Marchewka et al. (2019) found no correlations between the prevalence of immobile/lame turkeys and head, tail or wing wounds or featherless areas. It is possible that these relationships are

more difficult to detect at the flock-level or under barn conditions due to for example, overcrowding, poor lighting, or dirty birds. Nevertheless, we report that on an individual-level birds with FP injuries tended to be 1.5 times more likely to have BT injuries compared to birds without FP injuries, further supporting that birds with injuries to the FP are indeed more likely to be victims of pecking behavior (Allain et al., 2013; Erasmus, 2018; Bartels et al., 2020).

We further report that flocks with a higher prevalence of HN injuries also had a higher prevalence of BT injuries. This suggests that while aggressive pecking and feather pecking might have different motivational backgrounds (Dalton et al., 2013; van Staaveren and Harlander, 2020), both pecking behaviors are likely to co-occur in the same flock. In contrast, Allain et al. (2013) reported a negative correlation between evidence of feather pecking and severe injuries (>5 cm linear scratch) on the carcass, while Marchewka et al. (2019) found no correlations between head and tail/wing wounds in hen or tom flocks. Several considerations must be noted when interpreting these findings. First, injuries may be caused by injurious pecking, scratching or a combination of both (Marchewka et al., 2019) but they may also occur due to transport or processing at the slaughterhouse (Allain et al., 2013; Villarroel et al., 2018). Second, in the case of Allain et al. (2013) body areas on which injuries were located (back, flank, wings, hips, neck and head) were not differentiated. These considerations may explain the inconclusive data regarding flock-level correlations between injuries in the literature. Interestingly, our individual-level analysis, which provides more detail, shows that birds with HN injuries were 4 times more likely to have BT injuries compared to birds that did not have HN injuries. This provides the first empirical data to suggest that birds that are injured due to injurious pecking are at a high risk of being targeted for both aggressive (HN injuries) and feather pecking (BT injuries).

Some limitations of the current study should be acknowledged. The co-occurrence of the injuries based on severity could not be assessed due to the low number of severe scores recorded. Moreover, the cause for injury co-occurrence is still unknown. While understanding the root cause of each condition is important to efficiently manage them, a definite conclusion on injury etiology can not be drawn based on the current study and literature (Allain et al., 2013; Villarroel et al., 2018; Marchewka et al., 2019). Shared risk factors in housing and management may trigger the injuries in these flocks. For example, poor litter quality has been associated with HN injuries (Marchewka et al., 2019), BT injuries (Leishman et al., 2022), and FP injuries (Ekstrand and Algers, 1997; Bergmann et al., 2013; Da Costa et al., 2014), which may contribute to co-occurrence of these injuries. Alternatively, there may be specific bird characteristics that make individuals more likely to be a victim, similar to actors and receivers of feather pecking in laying hens (van Staaveren and Harlander, 2020) or tail biting in pigs (Brunberg et al., 2013; Verbeek et al., 2021). Experimental and/or longitudinal studies are needed to determine if there is a causative order in these relationships. Nevertheless, our observational research raises the awareness that birds may incur some types of injuries simultaneously, which may be overlooked if the focus remains on the most visible injury (e.g., HN injuries are likely observed before FP injuries in their initial stages). Co-occurring injuries also require different intervention or culling strategies compared to a single injury. For example, a farmer may attempt to reduce pecking behavior by reducing light intensity. However, the behavior may be driven by footpad dermatitis due to the barn's litter quality, which reduces mobility and causes some birds to be victimized by others. As a result, combining management strategies to reduce footpad dermatitis and pecking by conspecifics may be the most beneficial and effective approach. Therefore, a holistic management strategy demands thorough inspection of birds to reduce injuries in turkey flocks.

Due to the cross-sectional nature of this study, comparing the prevalence of injuries with other studies is difficult and it should be acknowledged that an estimation of prevalence was not the true aim of this study. The sample size required to estimate prevalence with a high level of confidence depends on the flock size, true prevalence, and trade-offs with feasibility (Main et al., 2012). Rather than adapting the sample size for different flock sizes (Main et al., 2012), the sample size was kept consistent and small (30 birds) for participants as flock size ranged between approx. 2,000 to 11,500 birds. This was due to the survey being part of a large questionnaire requiring farmers to answer questions on housing and management, assess flock health including lifting heavy turkeys, and in pilot discussion with industry it was believed that requesting a larger sample size would reduce the willingness of farmers to participate (Leishman et al., 2021, 2022). That said, certain programs do request larger samples sizes to be assessed for example, turkey farmers in Germany assess 50 birds within their flocks for footpad dermatitis and pecking injuries (Knierim et al., 2016). Additionally, despite clear instructions on how to assign scores, select birds randomly at different locations in the barn, and to remove any loose litter from the feet, it cannot be stated for certain that all farmers followed these instructions in the same way which potentially biased the results. Training of farmers or dedicated auditors to collect the injury scores after determining suitable intra- and interobserver reliabilities would have been ideal, but was not feasible in the current study.

Overall, the relatively large proportion of flocks with at least one injury and the relatively low within-flock prevalence suggests that a few birds incur these injuries in many flocks, as opposed to many birds affected in a few flocks. The former scenario could indicate that low levels of injuries may be generally accepted or normalized depending on the threshold of individual farmers (Grandin, 2003; Palczynski et al., 2016), especially when the issue is difficult to prevent or manage as is the case with these pecking and footpad injuries. However, the

large range in prevalence of the 3 injury types suggests that in some flocks, nearly all of the sampled birds were affected. This may signal farms where the injury has become endemic, though the small number of birds sampled means this should be interpreted with caution. However, it may be especially true for FP injuries, possibly due to issues with litter management affecting all birds similarly. The variation in the prevalence of injuries between flocks has been heavily researched in attempts to elucidate risk factors for HN, BT, or FP injuries (Sherwin et al., 1999; Moinard et al., 2001; Mayne et al., 2007; Kyvsgaard et al., 2013; Da Costa et al., 2014). Overlooking potential co-occurring injuries, may make it difficult to ascertain true risk factors or inaccurately attribute risk factors to one injury (Franco et al., 2018). Considering that single/multiple factors may lead to single/multiple outcomes (EFSA Panel on Animal Health and Welfare (AHAW), 2012), assigning priority to risk factors for co-occurring injuries may allow for targeting the most important factors in the housing and management of turkeys.

Overall, both mild and severe HN and BT injuries were consistently less prevalent than FP injuries. Similarly, the prevalence of FP injuries in various European and US studies is typically high, and it is not uncommon for up to 100% of the flock to be affected at slaughter (Ekstrand and Algers, 1997; Krautwald-Junghanns et al., 2011; Allain et al., 2013; Da Costa et al., 2014). The prevalence of FP injuries in the current study was generally lower than found in the aforementioned studies which can be due to the previously discussed difficulty in on-farm assessment in terms of injury visibility and potential for bias in selection of birds. Furthermore, there were no restrictions on flock age to encourage participation. Consequently, relatively young flocks were included in the current study which may have skewed the overall prevalence of injuries as all conditions increase with age (Sherwin et al., 1999; Busayi et al., 2006; Bergmann et al., 2013; Da Costa et al., 2014; Dalton et al., 2016). Signs of feather (BT injuries) or aggressive pecking (HN injuries) ranged between 1 to 24% and 0 to 1%, respectively, in slaughter assessments of 60 turkey flocks in France (Allain et al., 2013). These prevalence ranges are similar to those for severe HN and BT injuries in the current study. It is probable that pecking injury (HN, BT) detection is a priority since it is linked to mortality (van Staaveren et al., 2020b). In summary, the data presented herein suggest that FP injuries are a more widespread and more severe concern among Canadian turkey flocks than HN and BT injuries.

CONCLUSION

In conclusion, this study reported the prevalence of integument injuries to the head/neck (HN), back/tail (BT), and footpad (FP) area at the flock-level and bird-level in Canadian turkey flocks. FP injuries were most common, followed by BT and HN injuries. All three injury types had a higher flock-level prevalence compared to the bird-level prevalence, indicating that many flocks are affected with a small number of cases in each flock. We further report that birds with HN injuries or FP injuries were more likely to have BT injuries. These relationships between different integument injury types (e.g., pecking injuries and footpad injuries due to dermatitis) highlight the need for a holistic approach in management practices to ensure an intact integument in turkeys.

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DISCLOSURES

BW was an employee of Hybrid Turkeys at the time of the study. Hybrid Turkeys helped to disseminate an invitation to voluntarily participate in the study among its farm managers. The funders had no further role in the design of the study and collection, analysis, and interpretation of data and in writing the manuscript. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

REFERENCES

Agunos, A., C. Carson, and D. Léger. 2013. Antimicrobial therapy of selected diseases in turkeys, laying hens, and minor poultry species in Canada. Can. Vet. J. = La Rev. Vet. Can. 54:1041–1052.

Allain, V., D. Huonnic, M. Rouina, and V. Michel. 2013. Prevalence of skin lesions in turkeys at slaughter. Br. Poult. Sci. 54:33–41.

AWIN. 2015. AWIN Welfare assessment protocol for turkeys. doi: 10.13130/AWIN_TURKEYS_2015.

Bailey, R. A., E. Souza, and S. Avendano. 2020. Characterising the influence of genetics on breast muscle myopathies in broiler chickens. Front. Physiol. 11:1041.

Bartels, T., R. A. Stuhrmann, E. T. Krause, and L. Schrader. 2020. Research Note: Injurious pecking in fattening turkeys (Meleagris gallopavo f. dom.)—video analyses of triggering factors and behavioral sequences in small flocks of male turkeys. Poult. Sci. 99:6326–6331.

Bergmann, S., N. Ziegler, T. Bartels, J. Hübel, C. Schumacher, E. Rauch, S. Brandl, A. Bender, G. Casalicchio, M.-E. Krautwald-Junghanns, and M. H. Erhard. 2013. Prevalence and severity of foot pad alterations in German turkey poults during the early rearing phase. Poult. Sci. 92:1171–1176.

Bir, C., M. Davis, N. Widmar, S. Zuelly, and M. Erasmus. 2019. Perceptions of animal welfare with a special focus on Turkeys. Front. Vet. Sci. 6:413.

Brunberg, E., P. Jensen, A. Isaksson, and L. J. Keeling. 2013. Brain gene expression differences are associated with abnormal tail biting behavior in pigs. Genes, Brain Behav. 12:275–281.

Busayi, R. M., C. E. Channing, and P. M. Hocking. 2006. Comparisons of damaging feather pecking and time budgets in male and female turkeys of a traditional breed and a genetically selected male line. Appl. Anim. Behav. Sci. 96:281–292.

Chen, J., G. Tellez, and J. Escobar. 2016. Identification of biomarkers for footpad dermatitis development and wound healing. Front. Cell. Infect. Microbiol. 6:26.

Da Costa, M. J., J. L. Grimes, E. O. Oviedo-Rondón, I. Barasch, C. Evans, M. Dalmagro, and J. Nixon. 2014. Footpad dermatitis severity on turkey flocks and correlations with locomotion, litter conditions, and body weight at market age. J. Appl. Poult. Res. 23:268–279.

Dalton, H. A., B. J. Wood, and S. Torrey. 2013. Injurious pecking in domestic turkeys: development, causes, and potential solutions. Worlds. Poult. Sci. J. 69:865–876.

Dalton, H. A., B. J. Wood, T. M. Widowski, M. T. Guerin, and S. Torrey. 2016. Changes in leg health, skin, and plumage condition in domestic male turkeys of varying body weights. Appl. Anim. Behav. Sci. 178:40–50.

EFSA. 2012. Scientific opinion on the use of animal-based measures to assess welfare in pigs. EFSA J. 10:2512.

EFSA Panel on Animal Health and Welfare (AHAW). 2012. Guidance on risk assessment for animal welfare. EFSA J. 10:2513.

Ekstrand, C., and B. Algers. 1997. Rearing conditions and footpad dermatitis in Swedish turkey poults. Acta Vet. Scand. 38:167–174.

Erasmus, M. A. 2018. Welfare issues in turkey production. Pages 263−291 in Advances in Poultry Welfare. Mench, J.A., ed. Food Science, Technology and Nutrition. Elsevier.

Franco, N. H., P. Sandøe, and I. A. S. Olsson. 2018. Researchers' attitudes to the 3Rs—An upturned hierarchy? PLoS One 13: e0200895.

Freeman, N., F. A. M. Tuyttens, A. Johnson, V. Marshall, A. Garmyn, and L. Jacobs. 2020. Remedying contact dermatitis in broiler chickens with novel flooring treatments. Animals 10:1761.

Grandin, T. 2003. Transferring results of behavioral research to industry to improve animal welfare on the farm, ranch and the slaughter plant. Appl. Anim. Behav. Sci. 81:215–228.

Honess, P., and S. Wolfensohn. 2010. The extended welfare assessment grid: a matrix for the assessment of welfare and cumulative suffering in experimental animals. Altern. Lab. Anim. 38:205–212.

Justice, W. S. M., M. F. O'Brien, O. Szyszka, J. Shotton, J. E. M. Gilmour, P. Riordan, and S. Wolfensohn. 2017. Adaptation of the animal welfare assessment grid (AWAG) for monitoring animal welfare in zoological collections. Vet. Rec. 181:143.

Knierim, U., R. Andersson, C. Keppler, S. Petermann, E. Rauch, B. Spindler, and R. Zapf. 2016. Mastputen. Pages 41−57 in Tierschutzindikatoren: Leitfaden fur die Praxis - Geflugel. 1st edition KTBL, Darmstadt, Germany.

Krautwald-Junghanns, M. E., R. Ellerich, H. Mitterer-Istyagin, M. Ludewig, K. Fehlhaber, E. Schuster, J. Berk, S. Petermann, and T. Bartels. 2011. Examinations on the prevalence of footpad lesions and breast skin lesions in British United turkeys Big 6 fattening Turkeys in Germany. Part I: Prevalence of footpad lesions. Poult. Sci. 90:555–560.

Kyvsgaard, N. C., H. B. Jensen, T. Ambrosen, and N. Toft. 2013. Temporal changes and risk factors for foot-pad dermatitis in Danish broilers. Poult. Sci. 92:26–32.

Langley, J., and R. Brenner. 2004. What is an injury? Inj. Prev. 10:69–71.

Leishman, E. M., N. van Staaveren, V. R. Osborne, B. J. Wood, C. F. Baes, and A. Harlander-Matauschek. 2021. A cross-sectional study on the prevalence of footpad dermatitis in canadian turkeys. Front. Anim. Sci. 2:726907.

Leishman, E. M., N. van Staaveren, V. R. Osborne, B. J. Wood, C. F. Baes, and A. Harlander-Matauschek. 2022. The prevalence of integument injuries and associated risk factors among canadian turkeys. Front. Vet. Sci. 8:757776.

Main, D., S. Mullan, C. Atkinson, A. Bond, M. Cooper, A. Fraser, and W. Browne. 2012. Welfare outcomes assessment in laying hen farm assurance schemes. Anim. Welf. 21:389–396.

Marchewka, J., G. Vasdal, and R. O. Moe. 2019. Identifying welfare issues in turkey hen and tom flocks applying the transect walk method. Poult. Sci. 98:3391–3399.

Marien, M., A. Decostere, L. Duchateau, K. Chiers, R. Froyman, and H. Nauwynck. 2007. Efficacy of enrofloxacin, florfenicol and amoxicillin against Ornithobacterium rhinotracheale and Escherichia coli O2:K1 dual infection in turkeys following APV priming. Vet. Microbiol. 121:94–104.

Mayne, R. K. 2005. A review of the aetiology and possible causative factors of foot pad dermatitis in growing turkeys and broilers. Worlds. Poult. Sci. J. 61:256–267.

Mayne, R. K., R. W. Else, and P. M. Hocking. 2007. High litter moisture alone is sufficient to cause footpad dermatitis in growing turkeys. Br. Poult. Sci. 48:538–545.

Moinard, C., P. D. Lewis, G. C. Perry, and C. M. Sherwin. 2001. The effects of light intensity and light source on injuries due to pecking of male domestic turkeys (Meleagris gallopavo). Anim. Welf. 10:131–139.

Palczynski, L., H. Buller, S. Lambton, and C. Weeks. 2016. Farmer attitudes to injurious pecking in laying hens and to potential control strategies. Anim. Welf. 25:29–38.

Pierson, F. W., V. D. Barta, D. Boyd, and W. S. Thompson. 1996. Exposure to multiple infectious agents and the development of colibacillosis in turkeys. J. Appl. Poult. Res. 5:347–357.

SAS Institute Inc. 2013. SAS/STAT® 13.1 User's Guide - Chapter 40 The FREQ Procedure. Pages 2621−2823 in SAS/STAT® 13.1 User's Guide. SAS Institute Inc., Cary, NC, Cary, NC.

Shepherd, E. M., and B. D. Fairchild. 2010. Footpad dermatitis in poultry. Poult. Sci. 89:2043–2051.

Sherwin, C. M., P. D. Lewis, and G. C. Perry. 1999. Effects of environmental enrichment, fluorescent and intermittent lighting on injurious pecking amongst male turkey poults. Br. Poult. Sci. 40:592–598.

van Staaveren, N., and A. Harlander. 2020. Cause and prevention of injurious pecking in chickens. Pages 509−566 in Understanding the behaviour and improving the welfare of chickens. C. Nicol, ed. Burleigh Dodds Science Publishing, Cambridge, UK.

van Staaveren, N., E. M. Leishman, S. M. Adams, B. J. Wood, A. Harlander-Matauschek, and C. F. Baes. 2020a. Housing and management of turkey flocks in Canada. Animals 10:1159.

van Staaveren, N., E. M. Leishman, B. J. Wood, A. Harlander-Matauschek, and C. F. Baes. 2020b. Farmers' perceptions about health and welfare issues in turkey production. Front. Vet. Sci. 7:332.

Studdert, V., C. Gay, and D. Blood. 2012. Saunders Comprehensive Veterinary Dictionary. Elsevier Health Sciences, Edinburgh, UK.

Teng, K. T.-Y, B. Devleesschauwer, C. Maertens De Noordhout, P. Bennett, P. D. McGreevy, P.-Y. Chiu, J.-A. L. M. L. Toribio, and N. K. Dhand. 2018. Welfare-Adjusted Life Years (WALY): a novel metric of animal welfare that combines the impacts of impaired welfare and abbreviated lifespan. PLoS One 13: e0202580.

Verbeek, E., L. Keeling, R. Landberg, J. E. Lindberg, and J. Dicksved. 2021. The gut microbiota and microbial metabolites are associated with tail biting in pigs. Sci. Rep. 11:20547.

Villarroel, M., I. Francisco, M. A. Ibanez, M. Novoa, P. Martinez-Guijarro, J. Mendez, and C. de Blas. 2018. Rearing, bird type and pre-slaughter transport conditions of broilers II. Effect on foot-pad dermatitis and carcass quality. Spanish J. Agric. Res. 16:e0504.

Welfare Quality. 2009. Welfare Quality® Assessment protocol for poultry (broilers, laying hens). Lelystad, Netherlands.

Welsh, C. E., M. Duz, T. D. H. Parkin, and J. F. Marshall. 2016. Prevalence, survival analysis and multimorbidity of chronic diseases in the general veterinarian-attended horse population of the UK. Prev. Vet. Med. 131:137–145.

Youngson, R. M. 2005. Collin's dictionary of medicine. Harper Collins, Glasgow, UK.