RISK FACTORS AFFECTING WING INJURIES OF BROILER CHICKENS AT A SLAUGHTER PLANT IN NEW BRUNSWICK, CANADA

A Thesis

Submitted to the Graduate Faculty

in Partial Fulfillment of the Requirements

for the degree of

MASTER OF SCIENCE

in the Department of Health Management

Faculty of Veterinary Medicine

University of Prince Edward Island

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Charlottetown, PEI

August 24, 2017

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ABSTRACT

An epidemiological study was conducted on risk factors affecting wing injuries of broiler chickens during catching and transportation to a slaughter plant in New Brunswick, Canada. The slaughter plant provided detailed information about the truck loads of chickens transported to the plant between January 2009 and July 2010. All of the information was collated into a single file. The data was divided into different handling events, with which each event representing a collection of loads coming from the same producer during a single time period (handling event). A multilevel model with three levels: producer (86), handling event (1694) and loads (4494) were fitted to the data. The final model included seven variables: weight, sex, season, catching team, time of day during catching, speed of catching and the interaction between speed of catching and time of day during catching. An increase in bird weight lead to an increase in the occurrence wing injuries ($P < 0.001$). The model shows that loads with mixed sex and pullets had higher percentage of wing injuries than loads with cockerels ($P<0.001$). Loading in the fall resulted in significantly decreased wing injuries compared to loading in the winter, spring and summer ($P<0.001$). There was significant difference in percentage of wing injuries between different catching teams ($P<0.001$). The effect of time of day was dependent on the speed of catching. However the percentage of injuries is always lower in the night time regardless of the speed of catching. In the afternoon the percentage of injuries were higher especially if the speed of catching was higher.

Acknowledgments

I would like to begin by thanking Dr. Michael Cockram and Dr. Crawford Revie for choosing me to study graduate studies at Atlantic Veterinary College (AVC), for their contribution towards the chapter, and for their immense dedication to making me understand several key concepts in animal welfare and epidemiology. I would also like to thank my supervisor Dr. Jeff Davidson for helping me to complete the chapters and giving it a finishing touch. Special thank goes to Dr. Henrik Stryhn for his immense input towards the main chapter. Because of his contribution the main chapter became more solid and strong.

I would like to thank my other two members of my committee: Dr. Dan Hurnik and Dr. Pierre-Yves Daoust for helping me complete my study smoothly. Special thanks to Bill Chalmers for editing my manuscript. I would also like to thank Jenny Yu for her help in use of the statistical software Stata. I would also like to thank Dr. Javier Sanchez whose course on epidemiology was very useful.

Most importantly I would like to thank the funding agency: The Sir James Dunn Animal Welfare Centre and The Canadian Poultry Research Council for investing in the project and securing my funding over the years. I would also like to thank the slaughter plant for providing the data for the project.

On the personal level, I would like to thank all the wonderful friends that I have made at AVC over the years. Without them the stay in the Island would not have been pleasant. I would like to thank Beibei, Brett, Derek, Danielle, Fela, Gabriel, Julian, Krishna, Matt, Omid, Raju, Poo, Shauna, Sithar and many others. I would also like to thank my parents and other family members back home in Nepal. Last but not the least I would like to thank my wife for showing me love and giving me encouragement.

Dedicated to

Pooja & Kabyanee

Table of Contents

LIST OF ABBREVIATIONS

%	Percentage
AAP	Ascorbyl-2-Polyphosphate
AIC	Akaike's Information Criteria
DPM	Deep Pectoral Myopathy
PSE	Pale, Soft and Exudative
HRV	Heart Rate Variability
DOA	Dead on Arrival
Kg	Kilogram
OBM	Outcome Based Measures

LIST OF TABLES

LIST OF FIGURES

Chapter 1

General Introduction

1.1 Introduction

Broiler chickens are reared in large groups on the floor with automatic provision of food and water, while contact with humans or other environmental stimuli are negligible. Before transporting the chickens for slaughter, they are manually caught and placed in crates; the crates are then loaded into trailers for the journey. It is normal practice for the chickens to be deprived of food for at least eight hours before transport to slaughter (Kettlewell and Turner, 1985). Broiler chickens are usually transported from growing sites to processing plants for slaughter at 5-8 weeks of age, when they weigh approximately 2 kg (Kettlewell and Turner, 1985). Although automated mechanical catching machines exist, they are not used very often in Canada. The process of manually handling chickens before slaughter has implications for animal welfare because it can cause injuries, lead to fear and stress, and reduce fitness, which can ultimately cause death of the birds before slaughter (Knowles and Broom, 1990; Nicol and Scott, 1990).

This review outlines a number of issues pertaining to the effects of manual handling of broiler chickens before transportation, with special reference to the birds' welfare. The review starts with a brief introduction to how broiler chickens are manually handled during catching. Section 1.3 shows how we can assess welfare of broiler chickens during handling. Fear and physiological responses due to handling are discussed in Section 1.4. Injuries are one of the welfare issues during handling and are discussed in Section 1.5. The relationship between mortality and handling is the focus of Section 1.6, and Section 1.7 examines meat quality and its relationship to handling. Section 1.8 discusses the thermal environment during handling, and Section 1.9 the fitness of birds before transportation. Section 1.10 describes stockpersons' attitudes, which can play major role in how the birds are handled. The final section describes the objectives of the project.

1.2 Broiler Handling

Depopulation of birds from growing sites to the processing plant usually occurs at night or early morning to ensure a constant supply of chickens to the slaughter plant (Kettlewell and Turner, 1985). The handling procedure and equipment differs between species. For instance, in contrast to turkeys and ducks, broiler chickens cannot be herded. Spent hens are usually caught from cages, which is in contrast to broiler chickens, which are usually caught from the floor. Catching broiler chickens by hand is the most labour intensive part of the poultry industry. During manual catching, birds are usually caught by one hand, carried with three or four birds per hand, and dropped into transport crates (Bayliss and Hinton, 1990). Five to seven catchers are expected to catch about 4000 birds per hour (Kettlewell and Turner, 1985). During catching, the movement of catchers and handlers makes the environment very dusty.

There are three main types of crating equipment used for manual catching and loading of broiler chickens: loose crates, fixed crates, and modular systems (Kettlewell and Turner, 1985). Loose crates are the oldest type of crating equipment, where the birds are placed in small containers with a small aperture. These containers can either be taken into the barn or attached to the trucks. Fixed crates are built on the truck as an integral part of it. In fixed crate systems, birds are carried from the barn to persons standing on the trailers, to be placed inside the crates, loading from top to bottom. Modules are a fairly new type of catching system for poultry, and one of the major types of modular systems is the loose drawer system, which consists of a number of plastic drawers positioned in a metal framework. The number of drawers can vary. In such systems, the crates are carried to the appropriate location in the barn by a forklift truck. The large aperture in modular systems means fewer injuries to the birds. When one company changed from fixed crate systems to modular systems, the incidence of dead on arrival (DOA) chickens decreased from 0.54 percent to 0.20 percent (reviewed in Bayliss and Hinton, 1990). When several companies adopted modular systems in the U.K., during the eighties, there was a significant decrease in DOA chickens, from 0.33 percent in 1980 to 0.12 percent in 1985 (reviewed in Bayliss and Hinton, 1990).

Catching broiler chickens by hand is likely to cause pain to the birds, especially when they are inverted and carried by the leg (Weeks, 2000). In a study done in United Kingdom, where they usually do manual handling, among 1324 DOA chickens, it was found that about 27 percent had dislocated hips, which mainly occurs while the birds are inverted (Gregory and Austin, 1992).

1.3 Welfare Assessment during handling

In order to make the science of animal welfare more practical, animal welfare assessment is now done mainly at the group or farm level. Current animal welfare assessment uses mostly outcome-based measures (OBMs), such as injuries or physical condition, supported by resource-based measures, such as types of catching system used, barn temperature, and so on (Butterworth et al. 2011). During assessment of animal welfare, different parameters are selected and weighted according to level of importance. The parameters may be selected by a diverse range of people, which may include the layman, veterinarians, farmers, and animal welfare scientists. These different parameters can be integrated using different methods to come up with a level of animal welfare at a particular farm (Spoolder et al. 2003). However, animal welfare is a social construct and any kind of animal welfare assessment is based on value assumptions, which must be stated clearly while assessing animal welfare (Fraser, 2003).

The following animal-based parameters could be used to assess welfare during handling of broiler chickens while transporting chickens to slaughter plants:

1.3.1 Injuries

Physical injuries can be observed in broiler chicken carcasses at slaughter plants. Broiler chickens may suffer from bruising of the breast, wings, and legs, as well as fractures of wings and legs and dislocations of hips (Mayes, 1980; Griffiths and Nairn, 1984). Injuries can occur when catchers are not careful while collecting birds, and are often related to how they are handled. Reasonable estimates can be made at the slaughterhouse as to whether the injuries occurred during catching. For instance, the color change caused by bruising can indicate the ages of the injuries (Hamdy et al. 1961). The percentage of birds that have different kinds of injuries could be used to assess welfare. We should also note that some injuries may cause more pain than others.

1.3.2 Mortality

The number of birds that do not survive transportation, usually ascertained from company records, is one indicator of poor welfare. The mortality rate is calculated in counts or percentage and is usually associated with a particular load of chickens. Death during transportation of broiler chickens is primarily due to severe physical injury, thermal stress, or poor health status before transportation (Nicol and Scott, 1990). Problems that result in the death of few birds, for example between 0.01 and 0.2 percent, may be an indicator of a serious welfare problem occurring during catching and transportation. For example

European Union has targeted the percentage of injuries to be less than 0.5 percent (Whitting et al. 2007).

1.3.3 Good human-animal relationships, and the absence of general fearfulness

Fear is a negative affective state and should be avoided as much as possible. Any interactions between humans and animals will predict future interactions between them (Hemsworth and Coleman, 2011). The lack of interaction between humans and chickens during modern chicken production means that they are likely to be fearful of humans during catching. A good stockperson anticipates their behaviour while catching and uses it as a guide. Fear can be caused not only by the presence of humans during the catching process but also by other factors such as loud, sudden noises and rapid movements (Nicol and Scott, 1990; Broom, 2000; Campo et al. 2005). The presence of a good human-animal relationship and the absence of fear can be observed in both chickens and catchers during catching.

1.4 Fear and physiological response of broiler chickens during handling

1.4.1 Fear response of broiler chickens during handling

Animal welfare involves the affective state of an animal (Dawkins, 1990; Duncan, 1996). A component of good animal welfare is the absence of negative affective states like fear and pain. The handling of broiler chickens, which involves exposure to a novel environment for the chickens, may be fearful to the animals. Fear is “a motivational state, induced by perception of real danger and potential danger” (Boissy, 1995). Although reduced fear of humans is a characteristic of domesticated animals (Price, 1984), chickens still perceive the presence of humans as an alarming predatory encounter (Suarez and Gallup, 1981). Active defence reactions (being active, showing threat), active avoidance reactions (flight, hiding, escape), and movement inhibition are some responses to fear in chickens.

Fear of humans can be aggravated in modern chicken production because the creation of large production units and mechanization of various treatments reduces the likelihood of habituation to the stockman. One approach used in several studies to reduce fear of humans is regular handling by humans. There are three types of handling that may be done to the chickens. One of them is pleasant handling, for instance stroking them gently and giving them rewards afterwards. Another one is negative handling, such as treating them in a rough manner after handling them. The final one is neutral handling, where the chickens are handled without any negative or positive rewards. Regular neutral handling of chickens by humans during rearing phases can have an effect on the later responses of chickens to humans by attenuating the fear response (Murphy and Duncan,1978; Jones and Faure, 1981; Jones et al. 1991; Jones and Waddington, 1992; Jones and Waddington, 1993; Zulkifli et al. 2002). Jones (1993) found that young chickens briefly handled daily, from day one of their rearing, showed similar behavioural responses to familiar and unfamiliar handlers wearing similar and unfamiliar clothing. To be effective, such handling can be done at any age, regardless of the age (10 days) at which they are more adapted to learn new things (Jones and Waddington, 1993). It has been found that regular handling by humans during the growing phases reduces fear through habituation to humans rather than reducing the underlying fearfulness of the animal (Jones et al. 1991; Jones and Waddington, 1992). The effectiveness of such methods in reducing fear is, then, questionable.

Another approach that can decrease chickens' fear of humans is environmental enrichment during growing phases. Generally, chickens become immobile when they are extremely fearful, a response known as tonic immobility. A measure of how fearful they are due to stimuli is the time taken to come out of tonic immobility, which is known as latency to come out of tonic immobility. In several experiments, it has been shown that the addition of environmental enrichment, for example colorful balls, leads to the decrement of fear reactions by chickens, as measured by latency to come out of tonic immobility in open field tests and novel environment tests (Gveryahu et al. 1989; Nicol, 1992). Fear competes with and exerts an inhibitory effect on behavioural patterns motivated by other sympathetic nervous systems (Jones, 1987). Environmental enrichment can reduce the inhibitory effects caused by fear (Jones and Waddington, 1992). Environmental enrichments that can reduce fear include colored drawings taped to the wall (Jones and Waddington, 1992), manipulable objects like rubber stoppers, balls, and buttons (Jones and Waddington, 1992; Nicol, 1992), and music in the background (Gveryahu et al. 1989; Nicol, 1992).

A chicken's response to fearful stimuli is not only the outcome of its ontogeny but also of its background genome. Gallup (1974) selected domestic fowl in terms of tonic immobility and found huge differences in the duration of tonic immobility (differences of 2-3 hours) after only one generation of rearing chickens. Jones et al. (1992) showed that long tonic immobility chicks (high fear) have reduced activity levels when placed in a novel environment. Selection of high fear and low fear lines have also been done in Japanese Quail, and studies of inheritance of these traits in quail can give insights into the inheritance in broiler chickens (Jones et al. 1992). In quail, it has been shown that the distance run to reinstate social contact and behavior in an open field test was different in high and low tonic immobility lines with high tonic immobility lines reaching the social contact slower (Mills and Faure, 1991). This proves the point that there are distinct genetic differences in how the bird responds to fear. Previous handling and enrichment were found to be effective in reducing the period of tonic immobility in both high and low tonic immobility lines, but the effect was more pronounced in short tonic immobility lines (Jones et al. 1991). Long and short tonic immobility lines (shown by experiments) also differed in the amount of time required to catch the birds with short tonic immobility lines being easier to catch (Mills and Faure, 1991). This study proves that by selecting birds which are less fearful we can reduce the negative impact of handling process on chickens. Quail of different genetic lines were also found to differ in the amount of struggling exhibited when placed in a squeeze chute (Faure and Mills, 1998). Selection of low fearful behaviour sounds promising. Some people have reservations about altering the genetic composition of animals, but welfare scientists are increasingly recognizing the value of genetic selection as a way of improving animal welfare (Jones, 1996). If it could be shown that a simple behavioural test (for example, a tonic immobility test) elicits differences in response to other stimuli and stress, then such a test could be used as a marker for genetic selection (Jones, 1996). On a cautionary note, genetic selection of one trait may influence other traits, and genetic selection is not the ultimate solution to the destructive consequence of handling.

Another method used to reduce fear in domestic chicks has been the supplementation of ascorbic acid (Vitamin C) or its more stable phosphorylated form (ascorbyl-2-polyphosphate, APP) in the diet of domestic fowl. All species can synthesize ascorbic acid, but during stressful stimulation, for instance during catching, metabolic demand for Vitamin C may exceed its endogenous synthesizing capacity (Pardue and Thaxton, 1986). In both broiler chickens and Japanese quail it has been found that the addition of ascorbic acid to the diet seems to reduce tonic immobility duration, but does not have any effect on the concentration of corticosterone released during the catching and crating procedures (Satterlee et al. 1993; Satterlee et al. 1994). The reduction of tonic immobility can be seen even one day after letting chickens drink ascorbic acid (Jones et al. 1996). This study showed that to decrease the fear level of chickens during catching, broiler chickens can be fed with ascorbic acid in the days before catching them. However, the absence of reduction of corticosterone response, the lack of understanding of the precise physiological mechanism underlying its process, and inconsistency between studies (Pardue and Thaxton, 1986), makes treatment with ascorbic acid to reduce fear controversial

1.4.2 Physiological response of broiler chickens during handling

Physiological measurements can be an important tool for assessment of animal welfare, but interpretation can be difficult. Physiological parameters, like corticosterone, can be interpreted in concert with other physiological and behavioural parameters, while at the same time taking into account the animals' genetic, environmental, and temporal contexts (Blache et al. 2011). In broiler chickens, stress from handling is mainly due to the experience of negative emotions like fear. Although the exact relationship between emotional and physiological parameters is unknown, we can reasonably conclude that negative emotions like fear can activate neurological and endocrine systems, such as the sympathetic nervous and hypothalamo-pituitary-adrenal systems (Mormede et al. 2007; von Borell et al. 2007). The most frequent physiological parameters measured to assess stress during handling are corticosterone, heart rate, and heterophil/lymphocyte ratio. These and other physiological parameters, like respiration rate, lactate, and creatine kinase, are discussed below.

When animals are exposed to a stressor, the first hormones released into the blood are often adrenaline and noradrenaline, but the rapid breakdown of these substances in the blood, the difficulty in sampling, and the complex methods of analysis make it difficult to measure this response (Knowles and Broom, 1990 ; Nicol and Scott, 1990). The initial response is followed by the release of glucocorticoids from the adrenal cortex. Glucocorticoids are easier to measure than adrenaline and noradrenaline and they breakdown more slowly. There are two ways of measuring corticosterone in fowl: either through faecal samples or by blood sampling. Blood sampling involves handling while as faecal sampling do not.

In studies on catching and crating, in which the concentration of corticosterone is measured in the blood, the birds are caught and blood is sampled immediately to record the basal level. Then the bird is placed in a crate, and blood is sampled within 5 to 30 minutes after catching. In such conditions, the blood should be taken from the animal as soon as possible to minimize errors due to handling. Littin and Cockrem (2001) sampled blood from laying hens at zero minutes, after 15 minutes (during which time period birds were handled every two minutes), and then again after 40 minutes (during which time period they were not disturbed). In such conditions, they found that there was a rise in concentrations of corticosterone in fifteen minute samples, which decreased to the basal level after 40 minutes. Nijdam et al. (2005) collected blood samples from thirty randomly chosen broiler chickens before catching started, fifteen randomly chosen birds after catching started, and fifteen randomly chosen birds when bled at slaughter. They found higher concentrations of corticosterone after thirty minutes of catching and at the slaughterhouse, compared to the beginning of catching. Hemsworth et al. (1994a) repeatedly handled broiler chickens from day one of age (2.5 minutes of close contact and 7.5 minutes visual exposure, twice daily) and measured corticosterone levels at six weeks of age at different time periods during the day. They compared these concentration levels of corticosterone with those of birds that were not handled and found lower levels of corticosterone in the repeated handling group than those not handled. However, if the repeated handling was done for shorter duration (five minutes of staying near the chickens and few seconds of handling them), there was no significant effect of repeated handling (Kannan and Mench, 1996). These experiments suggest that in order for repeated handling to be effective it should be done for longer periods of time, which may not be feasible in modern chicken production.

In a commercial situation, broiler chickens are handled mainly in an inverted manner, as opposed to upright. Kannan et al. (1997) subjected broiler chickens to repeated handling in an inverted manner, multiple birds in an inverted manner, and upright handling, and then measured corticosterone concentrations 0, 1, 2, 3, and 4 hours after the handling. They found that birds handled in an inverted manner had higher concentrations of corticosterone than birds handled in an upright manner. Broom et al. (1986) also compared corticosterone concentrations of birds handled either in an inverted manner or in an upright manner at 0, 5, and 30 minutes after handling. They discovered a marked difference between them after five minutes, with higher concentrations of corticosterone for birds handled in an inverted manner, as compared to birds handled in an upright manner. These marked differences continued even after thirty minutes.

When animals are frightened, both respiration and heart rates increase. Heart rate can be measured through radio telemetric devices (Duncan and Filshie, 1980), and provides a useful measure for short-term stressors like handling. Another indicator of cardiac stimulation due to stress, recently introduced, is Heart Rate Variability (HRV) (von Borell et al. 2007). HRV is the variability in the time period between consecutive heart beats and shows the balance between sympathetic and parasympathetic branches of the autonomic nervous system (Blache et al. 2011). Although heart rate variability has been used in other studies, no study has used HRV during handling of broiler chickens, to our knowledge.

Duncan et al. (1986) measured heart rates during mechanical and manual catching procedures and found that once the harvesting of broiler chickens started, heart rates started to increase considerably during manual catching. In mechanical catching systems, heart rate increased at the beginning but reached a basal level after some time. Duncan and Kite (1987) measured heart rates in four situations where human handling was involved: approach by humans, approach plus restraint, restraint by unseen humans, and approach then held off the ground. In all situations they found that the heart rate increased considerably.

One manifestation of an altered immune system in the blood, due to stress, is a drop in the number of circulating lymphocytes and an increase in the number of heterophils. Increased corticosterone in the blood has been shown to increase the heterophil/lymphocyte ratio (Gross et al. 1980), and short term stressors like handling can also lead to an increase in the heterophil/lymphocyte ratio (Gross and Siegel, 1983).

Campo et al. (2005) exposed laying hens to different noises (trucks and aircraft) and found the treated group had a higher heterophil/lymphocyte ratio than those not exposed to the noise stress. The control group was exposed to the sound of chickens and fans. Gross (1990) found that the heterophil/lymphocyte ratio began to increase, reaching a maximum value at 20 hours after exposure. During handling and transportation, the chickens may experience noise and these studies show that such noise can be a potent stressor to the birds.

Repeated handling with pleasant rewards during handling like stroking them, and showing regular pleasant handling to other chickens, has been shown to lower the heterophil/lymphocyte ratio in chickens (Zulkifli et al. 2000; Zulkifli et al. 2002; Zulkifli and Azah, 2004). No difference in the heterophil/lymphocyte ratio was found between the treatment groups of gentle upright handling and rough inverted handling (Duncan, 1989; Zulkiflie et al. 2000). However, that result should be interpreted cautiously as a bird's reaction to gentle and rough handling may be due to variation in duration of capture, genetic background, and previous experiences.

Creatine kinase is released into the blood when there has been muscle damage: for instance, if bruising occurs during handling or through rigorous exertion (Broom, 2007). Lactate and creatine kinase are indicators of whether the birds have been metabolically exhausted or not. Sandercock et al. (2001) exposed broiler chickens, at 35 and 63 days of age, to heat stress by placing them in containers at either 21 or 32 degrees centigrade. They found significant increases in creatine kinase activity after exposing them to such heat stress. Similar heat stress can happen during transportation of chickens during summer. Nijdam et al. (2005) recorded lactate levels 30 minutes before catching, 30 minutes after the beginning of catching, 30 minutes before the end of catching, and at exsanguination of broiler chickens in slaughter plants. They found that lactate levels increased substantially after the catching process started and continued to increase until the end of transportation.

1.5 Types of injuries during handling

Injuries in broiler chickens can reduce their capacity to tolerate the stress of transportation and can lead to death. The types of injuries can be determined by doing pathological analysis of DOA broiler chickens or through quantifying injuries in carcasses in the shackle line. Studies that have looked at DOA broiler chickens have done the autopsy either immediately at unloading, on day of slaughter, or some hours after the dead bodies were collected. Because of the financial loss due to condemnation and death, the studies on injuries on DOA birds are important to the producers, and most of the studies are done in this category. However, injuries that do not lead to death, for instance wing injuries, may also have implications in terms of animal welfare. Table 1.1 shows studies that have looked at DOA broiler chickens and the percentage of major injuries that occur. Table 1.2 shows studies and their results on manual handling-related injuries recorded before the chickens were processed.

Table 1.1 Studies of injuries in dead on arrival (DOA) birds

Study	Type of catching procedure	No. of flocks examined	Percentage of birds in the load that were DOA	No. of DOA examined	Percentage of DOA birds that died due to trauma/serious injuries	Percentage of DOA birds that died due to ruptured liver	Percentage of DOA birds that died due to hip dislocation	Percentage of DOA birds that died due to head injuries
Bayliss and Hinton (1990)	Manual	1	Not Recorded	Not Recorded	35 % (recorded as catching and transportation injuries)	Not Recorded	Not Recorded	Not Recorded
Gregory and Austin (1992)	Manual	1	0.19 %	1324	35 %	11%	76 %	8%
Nijdam et al. (2004)	Mechanical	21	0.59 %	302	30%	13.5%	9.27%	2.98%
Ritz et al. (2005)	Manual	Not Recorded	0.68 %	328	45%	25%	-	13.5%
Whiting et al. (2007)	Manual	198	0.34%	2451	30%	1.74%	4.4%	10.5%
Lund et al. (2013)	Mechanical	12	0.3%	295	10.2%	14.6%	0.7%	5.8%

Studies of DOA chickens have found that the percentage of birds that died from trauma range from 10 to 45 (Bayliss and Hinton, 1990; Gregory and Austin, 1992; Ritz et al. 2005; Nijdam et al. 2006; Whiting et al. 2007; Lund et al. 2013). The major injuries that lead to death of broiler chickens are hip dislocation, ruptured liver, and head trauma. However, due to inconsistent definition of diagnostic criteria, marked differences in prevalence of diagnostic reports, and terminology used, it is difficult to reach any useful conclusions about the reasons behind the injuries. Table 1 shows that in studies in which manual catching systems were used, the most predominate injuries are hip dislocation and ruptured liver.

Hip dislocation is one of the major injuries that occurs in broiler chickens during catching. It is not only a welfare problem but also a production problem because the discoloration around the hip joint, as a result of hemorrhages, may downgrade the carcass. Hip dislocation has been found to be the result of avulsion of femoral cartilage tissue from the bone (Mitchell, 1986). In the process of catching, overextension of the coxo-femoral joint occurs and the weakest link in the chain, which is the junction between the femoral head and its articular cartilage, gives way. Hip dislocation mainly occurs when the birds are carried by one leg; lifting the birds by two legs reduces the problem (Gregory and Austin, 1992). Another type of injury that occurs, especially in countries like Canada, where modular systems are used, is head injury (Whiting et al. 2007). Head injuries mainly occur when the bird has not been inserted properly inside the drawer of the module. Ruptured liver is another frequent type of injury that occurs when the birds are being caught, and is due to the pressure of one bird on another while they are placed in the crate.

Table 1.2: Studies of injuries in manually handled broiler carcasses

Study	Total number of flocks examined	Country where the study was done	Average number of birds examined per flock	Standard for recording bruising	Percentage of birds in the shackle line that were bruised	Percentage of birds that had wing bruising	Percentage of birds on the shackle line that had breast bruising	Percentage of birds on the shackle line that had leg bruising	Percentage of birds on the shackle line that had dislocations	Percentage of birds on the shackle line that had fractures
Ekstrand (1998)	129	Sweden	10100	Swedish National Food Standards	0.022	Not Recorded	Not Recorded	Not Recorded	Not Recorded	0.021
Knierem and Gocke (2003)	1	Germany	87916	The researcher themselves ascertained the bruising	Not Recorded	1.27	0.30	1.20	0.61	0.87
Nijdam et al. (2004)	1907	Netherlands	20433	Dutch Product Board for Livestock, Meat and Eggs. Corrected bruising percentage was calculated.	2.20	Not Recorded	Not Recorded	Not Recorded	Not Recorded	Not Recorded

Studies of carcasses on the shackle line have found that the major type of injury that occurs during handling is bruising. Bruising is usually caused when birds impact something without breakage of the skin, and it provides an indication of the number and severity of physical insults sustained during catching and transportation (Knowles and Broom, 1990). The bruised skin changes colour as it ages and such phenomena can be used for estimating the time period when the bruising occurred (Hamdy et al. 1960). The percentage of chickens that pass through a shackle line that are bruised can range from 0.022 to 25 percent (Griffiths and Nairn, 1984; Ekstrand, 1998; Knierem and Gocke, 2003; Nijdam et al. 2004). These percentages were calculated either in one processing plant or in multiple processing plants. This wide variation in percentage is mainly due to the differences in methods used to categorize bruising in different studies (Nijdam et al. 2004; Nijdam et al. 2005). After analyzing the data on bruising that occurs in broiler chickens in a processing plant, Nijdam et al. (2004) found that season, ambient temperature either at the farm or at nearby meteorological center (more in temperature lower than 5 degree centigrade and less between 20 and 25 degree centigrade), and time of the day of transportation had effects on the percentage of bruised birds that passed through a processing plant. In addition, previous studies have found that sex and average weight of the flock had significant effects on the percentage of bruised birds that passed through the processing plant (Griffiths and Nairn, 1984). We should be careful interpreting these results, however, because these studies mainly looked at types of bruising that are of economic significance rather than a range of bruising that could have welfare significance.

1.6 Mortality and handling

Death, or, mortality of broilers during transportation is measurable and is reported as percentage or counts of birds found dead among the transported birds at slaughter plants, before they are slaughtered. The percentage of broiler chickens that die during transportation can be ascertained from the records of different companies. The death of only a few birds can provide an indication that there are welfare issues for many other birds as well (Nicol and Scott, 1990). Death during transportation may be due to severe physical injury or trauma, thermal stress, or poor health status before transportation (Nicol and Scott, 1990).

More recent studies, conducted after the 1990s, in different countries, show the mean percentage of DOA to be between 0.1 and 1.6 (Gregory and Austin, 1992; Warriss et al. 1992; Alshawabkeh and Tabbaa, 1997; Hunter et al. 2001; Nijdam et al. 2004; Warriss et al. 2005; Petracci et al. 2006; Vecerek et al. 2006; Voslarova et al. 2007; Whiting et al. 2007; Haslam et al. 2008; Chauvin et al. 2011; Prado-Rebolledo et al. 2012). The concern for the welfare of chickens during transportation has resulted in the European Union targeting a percentage of DOA less than 0.5 percent (Anonymous, 2005). In a study done in Canada, less than 0.5 percent DOA was met by 85 percent of the loads, suggesting that the European target can also be reached in a North American setting (Whiting et al. 2007).

Several studies have investigated factors that led to the death of chickens during transportation. There are two types of studies, with overlap between them. Some looked at physical factors like temperature, density in the crates, and transport duration. These studies found an association between percentage of DOA birds and mortality during rearing, transport duration, ambient temperature, catching method, space allowance in crates, weather conditions, lairage duration, time of the day during catching, sex of the chickens, and average weight of the chickens (Warriss et al. 1992; Warriss et al. 2005; Nijdam et al. 2004; Whiting et al. 2007; Chauvin et al. 2011).

Other studies have looked at pathological causes of mortality after observing carcasses at slaughter plants, and found that the cause of death differs according to whether they are caught manually or mechanically. If caught with a manual system, the cause of death also differs depending on whether loose crates or modular systems were used. In a study done in the U.K., where they have used a manual catching system with multiple types of crates and modular systems, the main cause of death was heart failure, followed by trauma, mainly hip dislocations/fractures and crushed skulls (Gregory and Austin, 1992). The results suggest that the cardiovascular system of broiler chickens is not strong enough to cope with the stress of catching and transportation, let alone physical trauma. A Canadian study found that the deaths of chickens due to trauma were mainly from trauma to the head (Whiting et al. 2007). The main reason that those chickens died from head trauma may be because of the use of drawer type modular systems in Canada. In a study done in Denmark, where they use mostly mechanical systems for catching chickens, they have found that very few birds die from hip dislocation, suggesting that hip dislocation occurs mostly in manual catching systems (Lund et al. 2013).

In a study done in the Netherlands, there were significant differences in percentage DOA between different catching companies (Nijdam et al. 2004), but the study did not identify the critical differences between the catching companies, such as how long they have to travel to reach work and so on. More studies need to be done to look at factors during the employment of catchers that can lead to bird mortality during transportation.

The time of day when the chickens were caught was also found to be a risk factor for DOA with those caught during the daytime being more at risk than those caught during the night (Nijdam et al. 2004). Exposure to light has been shown to lead to more avoidance of humans (Newberry et al. 1986) and more fearful behavior (Duncan and Kite, 1987). Most chickens are caught during dark hours and the results of these studies support this practice.

In France, the presence of the farmer during catching had a significant effect on the DOA rate, with the farms that were supervised by the farmer during catching having less risk of mortality (Chauvin et al. 2011). Catching chickens is a physically demanding task and the catchers may do it carelessly after they have been catching the chickens for some time. Good supervision may help keep them focused and avoid carelessness. In the same study, it was found that catching duration was a significant factor affecting the percentage of DOA, with longer catching duration associated with a higher risk of mortality. However, the study does not control for the numbers of chickens per unit time, which might be an important factor to consider.

1.7 Handling and meat quality

Poultry is the second most widely eaten meat product in the world after pork (FAO, 2014), accounting for 33 percent of the world meat intake worldwide (FAO, 2014). Poultry has become a highly desired product and it seems to attract consumers mainly because of low risk of disease, low price, and taste (Kennedy et al. 2004). The appearance of the meat has an effect on the way consumers choose their meat products (Kuttapan et al. 2012). The product’s tenderness, water holding capacity, lightness values, juiciness, cooking loss, and pH value at different time points after slaughter are some of the factors to look at while analyzing the quality of meat. Study have shown that lower stress during handling leads to good meat quality (Belk et al. 2012), while increased activity, such as wing flapping, struggling, and flightiness induced by handling, leads to lower meat quality, for instance by causing deep pectoral myopathy (DPM) (Petracci and Cavani, 2012). In addition, there is potential for high muscle temperature due to flapping, struggling, and stress in the lead up to slaughter, making the breast muscle difficult to chill post mortem (Barbut et al. 2008). All these factors can have an effect on consumer acceptance.

Kannan et al. (1997) measured initial pH for thigh and breast meat of broilers crated for 4 hours after 3 hours of transportation and those slaughtered immediately after transportation. They found that crated birds had higher pH in thigh meat than non-crated ones, but a significant difference in the pH of breast meat was not found. Debut et al. (2003) found that after 2 hours of transport, meat quality (pH at 15 minutes and 24 hours after slaughter, lightness values, and cooking yield) was different in thigh muscles of birds not transported, but such difference was not found in breast muscles. These studies show that the process that chickens undergo during transportation can have an effect on meat quality.

McKee et al. (2009) subjected broiler chickens to repeated handling by their wings, repeated handling by legs, or no handling at all, and measured the fillet weight, fillet dimensions, cooking loss, and tenderness of the meat after slaughter. They found no significant differences between handling treatment and meat quality. However, in this study, there was no variation in handling treatments and there were no other stressors except lighting and handling. More studies need to be done on the effect of different handling treatments (rough or gentle) and with the addition of other stressors on the meat quality of broiler chickens.

Studies have looked at environmental factors and suggested that heat stress before transportation is one of the major factors leading to pale, soft, and exudative (PSE) poultry meat (Petracci et al. 2004; Petracci et al. 2012). Sandercock et al. (2001, 2006) found that rapidly growing birds may be more susceptible to thermal stress before transportation than slow growing birds, which ultimately leads to muscle damage, pH disturbances, and reduced meat quality. Heat stress has also been shown to lead to a decline in water holding capacity and an increase in lightness values (Holm and Fetcher, 1997; Petracci et al. 2004). In a similar manner, cold stress has been found to lead to an increase in pH, high water holding capacity, and darker colouration than chickens that were not cold stressed (Holm and Fletcher, 1997). These studies reinforce the point that the heat and cold stress that broilers can experience during catching may have an effect on meat quality.

Debut et al. (2003) tried to find a relationship between fearfulness of the birds and meat quality. They measured the tonic immobility of the birds and then measured meat quality (pH decline, colour, drip loss, and cooking yield) after slaughter, but did not find any relationship between higher durations of tonic immobility and reduced meat quality.

1.8 Thermal environment during handling

Chickens are homeothermic animals, maintaining a body temperature of 41-42 degrees centigrade (Nicol and Scott, 1990). Within the upper and lower critical temperatures (thermoneutral zone) their normal behaviour is enough to regulate heat loss. If heat production becomes greater than ‘maximum heat loss’ then there can be a welfare problem. Chickens have an upper critical temperature of around 45-47°C and a lower critical temperature of 19-22°C (reported in Nicol and Scott, 1990). Chickens can experience thermal stress before and during transportation. Although many studies have been done on the effect of temperature during the transport stage (for example, Kettlewell et al. 1993; Webster et al. 1993; Kettlewell et al. 2000) there have been fewer studies done on the effects of temperature during the catching phase. It is important to note that temperature control during the catching phase can have a significant impact on the incidence of mortality (Mitchell and Kettlewell, 1998; Mitchell and Kettlewell, 2009).

Yalcin et al. (2004) measured the rectal temperature of broilers at three stages: immediately after catching, 1 hour after crating, and after 1 hour of transportation, at different ages and during both fall and summer, in Turkey. They found, in most cases, as the crating duration increased, rectal temperature increased too (except in fall and when the chickens were 35 days of age). Ritz et al. (2005) recorded the temperature of the environment of broiler chickens while they were being caught, transported, and post-transported in the humid sub-tropical climate of southeastern USA. They found that the transport phase had a lower environmental temperature than pre and post transport phases. They found that once the door of the farm was opened to start the catching process, the barn temperature rose from ~ 28°C to ~ 35°C. They also found that more heat developed in the back of the barn than the front, and suggested that catching delays and piling up of the chickens should be avoided to reduce the thermal stress experienced by the chickens. They also suggested that ventilation should be provided at the back of the barn. However, we should note that this study was done in summer in a sub-tropical climate. More studies are needed on the temperatures experienced by chickens during the catching phase in winter and other climatic conditions.

The addition of potassium and sodium salts in drinking water, and feed withdrawal before acute heat stress, have been suggested to help birds cope with heat stress (Soutyrine et al. 1998; Ahmad et al. 2008; Sayed and Downing, 2011). However, those studies were done during rearing phases only. More studies need to be done to find out if such supplementation helps birds cope with heat stress during catching.

1.9 Fitness for transport

It is necessary to determine the fitness of the birds before they are transported. If the bird is unfit for transportation, it should be culled immediately by an authorized person. Transporting unfit birds is not only detrimental to their welfare but may also lead to financial losses when they are condemned for consumption. The birds may become unfit during their rearing stage in the farm but go unnoticed, or they may be unfit due to injuries occurring during the catching process. The person who handles birds before transportation should follow guidelines from industries, governments, and other similar organizations to recognize unfit birds and treat them appropriately.

There is increasing evidence that lameness is the most severe welfare problem in modern broiler production (Webster, 1994). The response of chickens to analgesic drugs demonstrates that lameness is painful to birds (Danbury et al. 1997, 1999). Usually researchers categorize lameness on a scale from no lameness to severe. Activity decreases as lameness goes from normal to severe (Weeks, 2000). Standing and moving for severely lame birds may cause pain and such birds may not survive the stress of catching and transportation.

During catching and transportation there are increasing demands for oxygen. Generally, the birds' cardiovascular system can fulfill the demand for oxygen when the heart pushes the blood to the lungs, where oxygen exchange takes place. However, when there is increased demand for oxygen during the catching phase, and if the chickens have a condition like ascites when the abdomen is filled with fluids, the heart failure may worsen and lead to death of the chickens. Birds with ascites have been found to exhibit a significant stress response, as shown by corticosterone measurement (Luger et al. 2003). Fluctuating temperature has been found to lead to an ascites-like condition in broiler chickens (McGovern et al. 2000). Signs of heart malfunction, are related to the imbalance between oxygen supply and requirements. In broiler chickens, if the ratio between development of energy-supplying organs (heart and lungs) and energy-consuming organs does not change appropriately, oxygen becomes a limiting factor (Scheele, 1997). Increased thermal demand, for instance, during handling and transportation may also have an effect on the heart, as more oxygen needs to be rapidly supplied to the organs in such situations. If the chickens with conditions like ascites are allowed to undergo the stress of catching and transportation, then they may have to breathe heavily, their lungs may become congested, liver function may be affected, and all these factors may lead to death.

Scientists and staff working for universities, industries, and governments in Canada have produced a booklet entitled ‘Should this bird be loaded’ to recognize the fitness of the bird for transportation (Thomson et al. 2012). According to the booklet, weak birds, emaciated birds, birds that are unable to walk, birds with swollen heads, birds with discoloured combs, birds with discharge from eyes and nostrils, and birds with dislocated and exposed bones must not be loaded for transportation. Such recommendations can be useful, as they give guidelines for stockpersons working for poultry companies to reduce animal welfare problems during handling and transportation.

1.10 Attitude of stockperson during handling

Attitudes are generally held with respect to some aspect of the individual's world, such as another person, a physical object, a behaviour, or policy. It is important to realize that attitude cannot be observed directly; it can be only observed through a person's behaviour. Attitude has to be assessed properly if it is to be used to predict behaviour. A variety of different types of behavioural attitudes need to be observed to accurately predict a stockperson's attitude toward their job (Hemsworth and Coleman, 2011).

In order to better understand why attitude is important in modern chicken production, we need to understand the psychology of attitude development. A major theory in understanding attitude in humans comes from Fishbein and Ajzen's Theory of Reasoned Action (Ajzen and Fishbein, 1977, 1980), which holds that a person's beliefs, when combined with their evaluation of their beliefs, leads to the formation of attitudes. That is, a person's beliefs about the object, emotional response to the object, and behavioural tendency towards the object could be used to measure the attitude of a person. The theory holds that a person's attitude is formed with their subjective norm, which is the extent to which the person believes other people would approve of his/her behaviour and the extent to which the person is willing to comply with other people's expectations. That means other people's expectation and how far the person is willing to comply with other people expectation forms a person attitude. This theory, and its most recent development, theory of planned behaviour (Ajzen, 1985), could be used to create a questionnaire to assess stockpersons' attitudes.

Studies with farm animals indicate that the behaviour of animals towards humans develops as a consequence of associations between the stockperson and the rewarding and aversive elements of handling events (Hemsworth and Coleman, 2011). The animal response to the interaction with humans is determined by how they are handled during rearing. Cransberg et al. (2000) performed different behavioural tests to assess the correlation between stockpersons' behaviours and broiler chickens' behaviours. They found that there was a correlation from 0.02 to 0.44 between different stockpersons' and chickens' behaviours. They also found that the speed of movement of a stockperson was related tochickens' active response to humans (like running away). They, unexpectedly, found that negative behaviours shown by stockpersons were related to the increased number of chickens orienting towards humans in later tests. They suggested that such results may be due to birds' habituation to negative handling.

The attitude of a stockperson toward animals has been shown to be related to the behaviour that the person has towards a animals in the pig and dairy industries (Hemsworth et al. 1994b; Breuer et al. 2003). However, a study conducted in several broiler farms in Australia did not find any relationship between the attitude and behaviour of stockpersons (Cransberg et al. 2000). Since there is not much physical contact between chickens and humans in broiler farms, the behaviour of the stockpersons the study measured consisted of such items as speed of movements and waving arms, and not direct interaction with chickens, which may have an effect on the results. A study done in several broiler farms in Brazil found that four factors involving attitude had significant effects on broiler mortality (Alencar et al. 2006). The four factors were the relationship between company and worker, affective viewpoint towards animals, positive attitude towards training, and critical evaluation of oneself. However, the study conducted a questionnaire only and did not measure the behaviour of stockpersons.

There are very few studies done on the attitudes and behaviours of stockpersons who handle animals before slaughter. In a pig abattoir in Australia, Coleman et al. (2003) used a questionnaire to study the relationship between attitudes and behaviours of the stockpersons. They found that whether the stockperson switched the electric prod 'on' or 'off' was related to attitude. In general, there was a significant association between a stockperson with a positive attitude, such as believing that pigs have feelings, and the use of an electric prod switched to 'off,' and a significant association between persons with a negative attitude, such as believing that pigs are greedy, and the use of an electric prod switched to 'on.' No research has been identified on the relationship between the attitude of catchers and their behaviour while handling chickens before slaughter.

One of the recent techniques used to change a stockperson's attitude towards animals is cognitive behavioral intervention. This is a technique used in clinical psychology, where the intervention program is targeted to change both the attitude and behavior of the person. It is mainly used to treat behavioural pathologies, such as the fear of snakes. Modification treatment programs, using cognitive behavioural intervention techniques, have been shown to be very effective in inducing positive interactions between humans and animals in the dairy cow and pig industries (Hemsworth et al. 1994a; Hemsworth et al. 2002). Such an intervention program is lacking in the poultry industry. Moreover, we need to see if such a modification training program will be useful in changing behaviours of catchers.

There may be several factors that have an effect on the worker's performance during catching. Using an artificial neural modelling technique, Jaiswal et al. (2005) found that in mechanical catching systems, the size and shape of the poultry barn was influential in reducing the time required to catch the chickens. They found that making the poultry barn narrower but longer made the time required for movement longer and increased the harvest time. They found that some combinations of width and length caused a decrease in harvesting time and some other combinations increased the time required to catch the chickens. This study may have implications for manual catching as well, as the time required to catch the chickens may be related to fatigue experienced by the catchers.

Catching chickens is a laborious task that requires constant input for it to be productive. In a study done in a strawberry farm in California, it was found that giving workers picking strawberries 5 minutes of rest every hour, in addition to their legal requirements for rest, considerably increased their productivity and decreased fatigue (Faucett et al. 2007). Workers in the catching industry usually work at night and the role of sleepiness in the occurrence of accidents in truck drivers, train drivers, and airline pilots has been supported by several studies (Akersted, 1995). In a study done in a gas utility plant, significant reductions in sleep were found in the workers working a twelve hour night shift, which ultimately reduced their alertness while working (Rosa and Bonnet, 1993). Moreover, long working hours may lead to fatigue, which may lead to more errors in the performance of the workers (Dinges, 1995; Rosa, 1995; Lilly et al. 2007).

Alencar et al. (2006) found that back pain was the most frequent problem reported by people working in the broiler industry in Brazil. However, not many studies are done on problems faced by catchers that can affect their productivity. More questionnaire type studies should be done to determine the kinds of problems catchers face, and in order to find solutions for reduced performance during catching.

1.11 Objective

The main objective of the study was to identify the risk factors affecting wing injuries in broiler chickens during catching and transportation to a slaughter plant in eastern Canada. The central hypothesis of the study was that the main risk factors for the occurrence of wing injuries occurred during loading and unloading.

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Chapter 2

Risk factors affecting wing injuries of broiler chickens at a slaughter plant in New Brunswick, Canada

2.1 Abstract:

An epidemiological study was conducted on risk factors affecting wing injuries of broiler chickens during catching and transportation to a slaughter plant in New Brunswick, Canada. The slaughter plant provided detailed information about the truck loads of chickens transported to the plant between January 2009 and July 2010. All of the information was collated into a single file. The data were divided into different handling events which are the collection of loads coming from the same producer and from the same handling night. A multilevel model with three levels: producer (86), handling event (1694) and loads (4494) was fitted. The final model included seven variables: weight, sex, season, catching team, time of day during catching, speed of catching and interaction between speed of catching and time of day during catching. An increase in bird weight leads to an increase in the occurrence of wing injuries ($P < 0.001$). The model shows that loads with mixed sex and pullets had higher percentage of wing injuries than loads with cockerels ($P<0.001$). Loading in the fall resulted in significantly decreased wing injuries compared to loading in the winter, spring and summer ($P<0.001$). There was significant difference in percentage of wing injuries between different catching teams.The model showed that the speed of catching (birds per hour) was associated with percentage of wing injuries only during the time period between 7:01-17:00 with speed of catching less than 5000 birds per hour associated with less percentage of wing injuries. When the speed of catching was lower than 5000 then the percentage of wing injuries was lower during the time period between 17:01-11:59 than other time periods. When the speed of catching was higher than 5000 then the percentage of wing injuries was higher during the time between 7:01-17:00 than in other time periods.

2.2 Introduction

Reducing injuries in animals is important for improving animal welfare, as injuries are generally a precursor for pain (Wall, 1979; Rutherford, 2002; Weary et al. 2006; Steeds, 2009). Serious injuries are also thought to be one of the primary causes of death in broiler chickens during transportation to slaughter (Nicol and Scott, 1990; Gregory and Austin, 1992). Identification of risk factors for injuries during handling and transportation of broiler chickens is important, as it may allow identification of management practices that can reduce injuries, and lead to subsequent implementation of strategies to improve the welfare of broiler chickens during transportation.

Broiler chickens are handled by humans when they are loaded for transport to the slaughter plant. After transport they are kept in a holding facility before being sent to slaughter. Several events occur before slaughter that can injure the bird. However, handling of chickens before transportation to slaughter plants has been identified as the most likely source of injuries in broiler chickens (Mitchell and Kettlewell, 1998). Injuries due to the catching of the birds can be observed in carcasses at slaughter plants as bruises (skin discoloration) and fractured or dislocated bones (Barbut, 2001). The types of injuries recorded in slaughter plants can be observed either in 'dead on arrival' chickens (Bayliss and Hinton, 1990; Gregory and Austin, 1992; Ritz et al. 2005, Nijdam et al. 2006; Whiting et al. 2007; Lund et al. 2013) or in carcasses after evisceration (Ekstrand, 1998; Knierim and Gocke, 2003; Nijdam et al. 2004).

Wing injuries are predominate injuries in broiler chickens during catching and transportation to slaughter plants.Several studies have looked at different types of wing injuries during transportation of broiler chickens. Knierim and Gocke (2003) found that in a

German slaughter plant, the percentage of slaughtered birds with fractured and dislocated wings were 0.77 and 0.59, respectively. Ekstrand (1998) analyzed data from a poultry plant in Sweden and found that during manual catching, wing fractures were the only type of fracture recorded, at 0.02%. Gregory et al. (1989) recorded the prevalence of broken bones in broiler chickens at a British slaughter plant just before stunning and found that the prevalence of broken radiuses and ulnas was 0.8%, while none of the chickens had broken humeri before stunning. This wide range in percentage values is difficult to interpret because of the different handling methods and types of injuries recorded. It has been found that red wing tip injury, which leads to trimming of the wing tips, is related to how vigorously the birds flap their wings (Gregory et al. 1989). In manual catching systems, where loose crates are used, birds may be more prone to wing injuries due to the small openings through which the birds are placed into the crates (Kettlewell and Turner, 1985).

During the handling of broiler chickens, several factors influence the occurrence of injuries, such as the weight of the chickens, management of handling, quality of catchers, the activity level of the chickens, the season, the ambient temperature, and the time of day of catching (Kettlewell and Turner, 1985; Bayliss and Hinton, 1990; Gregory and Austin, 1992; Kettlewell and Mitchell, 1994; Ritz et al., 2005; Nijdam et al. 2004). Loose crate handling systems, where the crates are carried from the trailers to the barn, are very labour intensive and the occurrence of injuries in these systems very much depends on the management of the handling process, such as the ability of the catchers to catch chickens in an appropriate manner and rest periods provided (Kettlewell and Turner, 1985; Bayliss and Hinton, 1990).

The processing of broiler chickens by electric stunning usually includes passing the chickens along a shackle line, stunning them by dipping their heads into electrified water with low voltage, cutting the neck after stunning, defeathering, and evisceration. Different factors during processing can also lead to higher occurrences of injuries. It has been found that the frequency of wing flapping by chickens on the shackle line can lead to wing injuries such as red wing tip, bone breakage, and bruising (Gregory et al. 1989; Newberry and Blair (1993); Sparrey and Kettlewell, 1994). If electric stunning is used, the wings may dip into the water before the head, causing wing injuries (Raj, 2003). In a similar manner, high numbers of hemorrhages in the wings were found in chickens where electric stunning was carried out by cardiac arrest (Gregory and Wilkins, 1989). And, if electric stunning is not executed properly, birds may flap their wings vigorously during neck cutting, leading to wing injuries. Injuries can also occur if the defeathering equipment is not functioning properly.

Most studies looking at risk factors for the occurrence of injuries in broiler chickens have looked at individual factors (Hamdy et al. 1961; Schotyssek and Ehinger, 1976; Mayes, 1980; Bingham, 1986). In reality, many different factors can lead to the occurrence of injuries during processing. Using all the potential injury-causing factors during broiler production in a multivariable model, taking into account confounding factors and their interactions, can lead to a more reliable identification of risk factors and estimates of their effects. Nijdam et al. (2004) conducted an epidemiological study looking at risk factors for bruising in a slaughter plant in the Netherlands where they found several risk factors like season, time of transport and ambient temperature. However, no epidemiological studies have been carried out in Canadian settings, looking at factors associated with injuries to broiler chickens slaughtered for consumption.

This study examined risk factors affecting wing injuries in broiler chickens at a slaughter plant in eastern Canada. The central hypothesis of this analysis was that the main risk factors for the occurrence of injuries in broiler chickens at a slaughter plant occur during loading and unloading.

2.3 Material and Methods

2.3.1 Transportation and slaughter

A total of 4944 truck loads of broiler chickens originating from 86 different producers (min=1 load and max=234 loads, per producer) were included in the study. These broiler chickens were raised in either mixed or separate sex flocks (cockerel and pullets), in heated and mechanically ventilated multi-floored barns with automatic provision of food and water on wood shavings litter.

The timing of the slaughter was determined by the slaughter plant, which arranged for one of eleven catching teams to manually catch and load the birds, using a loose crate system. Loading started at various times throughout the day. The median number of birds per truck load was 6,800. The birds were loaded into crates at either ten birds per crate (3946 loads) or more than ten birds per crate (547 loads). After loading was complete and the crates securely stacked on a flat-bed trailer, the driver adjusted the ventilation and transported the birds to the slaughter plant.

On arrival at the slaughter plant, most loads were kept in the crates on the trailer in a holding barn. After a period of 2-6 hours in the holding barn, the birds were subjected to ante-mortem inspection. The vehicle was then driven into the unloading bay, where the crates were unloaded from the vehicle, and the birds were removed from the crates and placed on a shackle line. The birds were electrically stunned in a water bath, exsanguinated, defeathered, and processed.

2.3.2 Data collection, data manipulation and variable description

2.3.2.1 Data collection

The poultry slaughter plant provided detailed information about the loads of chickens transported to the plant between January 2009 and July 2010. All of this information was collated into a single data file. Additional information was also available, mainly from hand-written producer records of flocks, transportation reports from the drivers, and slaughter plant holding barn reports. Some measurements, such as journey duration and number of chickens per crate, were calculated from the raw data. The time of the day when loading began was noted to be in one of three categories: 0:00-7:00, 7:01-17:00, or 17:01-23:59.

2.3.2.2 Variable description

The variables used in the analysis are listed in Table 2.1.

Table 2.1: Different variables used for analysis and the nature of those variables

Variable	Nature
Percentage of Wing Injuries in a Load	Continuous: Outcome
Average weight per event (kg)	Continuous: Predictor
Age of the chickens (days)	Continuous: Predictor
Journey duration (hours)	Continuous : Predictor
Loading duration (hours)	Continuous: Predictor
Percentage of loading period carried out in daylight	Continuous: Predictor
Speed of loading (number of birds per hour)	Categorical: Predictor (<5000, >=5000)
Time of the day when loading took place	Categorical: Predictor (0:00-7:00, 7:01-17:00, 17:01-11:59)
Number of birds per crate	Categorical: Predictor (10 (Standard), > 10)
Season	Categorical: Predictor (Winter, Fall, Spring, Summer)
Sex	Categorical: Predictor (Mix, Pullet, Cockerel)
Catching Team	Categorical: Predictor (A, B , C , D , E , F, G , H , I, J , K)

2.3.2.3 Data manipulation

The outcome was recorded as the percentage of wing injuries per load. However, as multiple loads were often collected from the same producers in one handling event, each load was not considered to be an independent event. To account for such clustering, the load data was nested within different ‘handling events’. A ‘handling event’ consisted of loads slaughtered within a 24 hour period that were collected from the same producer. Loads are trucks loaded with chickens for transport to the slaughter plant. Figure 2.1 shows the multi-level structure of the data and the variables considered at the level of event or load. Although in Figure 2.1, I have put these variables according to load level, they tend to vary according to load only in some events. For example, only 71 events had different ages within the same event, and 165 events had different weights within the same event.

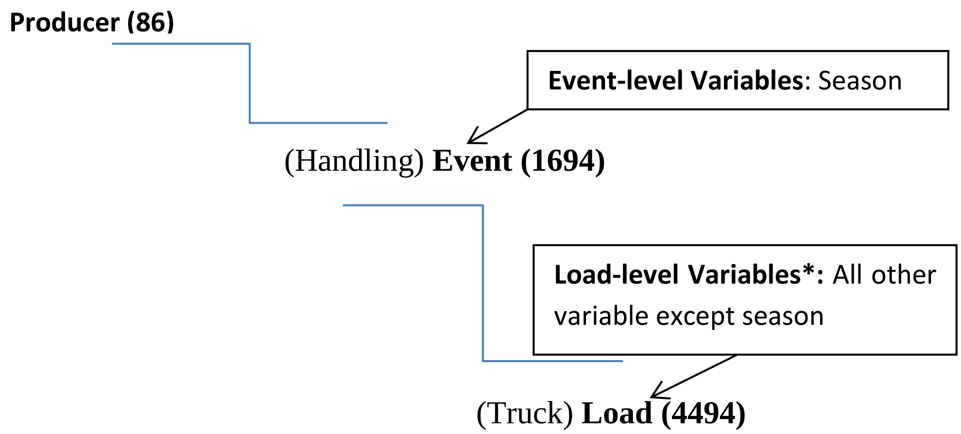

Figure 2.1 Multi-level data structure. Producers are the farms from where the loads come from. There were 4494 loads nested within 1694 events from 86 producers. Season is varied at event level and other variables are varied at load level. The model was built with three levels: producers, events, and loads.

To determine whether the amount of daylight that the chickens experienced during catching had an effect on the occurrence of injuries, the percentage of daylight that likely occurred for each load was calculated. From the website, www.timeanddate.com, we took the times of sunset and sunrise for different handling events. The percentage of daylight was calculated as the total number of daylight minutes for that load divided by total time taken to load multiplied by 100. The percentage of daylight for each load could range from zero (loaded entirely in the dark) to one hundred percent (loaded entirely in light).

There were some potential errors in the original data provided and those were corrected instead of removing them. These were errors that were clearly identified as an error. For example, the extreme value of 36.7% of wing injury was identified as a recording error and corrected to 3.67%. Two weight values and five age values were also corrected in the data. These were identified by comparing age and weight in the same handling event.

2.3.3 Statistical analysis

Descriptive statistics at both the load and handling event levels were generated.

The histogram of percentage wing injuries was bimodal with high number of repetition of values in lower percentage of injuries (Figure 2.2). There appeared to be some evidence that these lower percentages of wing injuries were driving the results when we built the model with all the data in it. So the model was built with data that was greater than 2% wing injuries. A square root transformation was done to the data to meet the assumptions of statistical modelling.

A multilevel linear mixed model, using handling event and producer as random effect, was fitted to the data. For categorical variables, 'dummy' variables were created according to whether the variable was in that particular category, and these were compared to a reference category. First, each predictor was modelled with the outcome variable to ascertain whether there was any unconditional association. Any predictors that did not show an unconditional association at a liberal significance level of $p<0.2$ were removed from the model. Then, a manual backward elimination process was used to build the model, starting with a maximum model using all potential predictors identified by the unconditional associations. The Wald test was used to remove predictors that did not show any significant association. Collinearity between different predictors was also assessed during the model building process. Testing for interactions occurred after the model was built; the following interaction were tested: between season and percentage of daylight, age and weight, sex and weight, time of day of loading and season and between speed of loading and time of day of loading. Linearity between the continuous predictors and the outcome variable was assessed using scatterplots. If the continuous predictor did not have a linear relationship with the outcome variable, then either a polynomial form of the predictor was included in the model or the variable was categorized. Akaike's Information Criteria (AIC) was also used to compare different models. Lower AIC values were ascertained to be better models. Homoscedasticity and normality of residuals for our final models were checked graphically for both random effects and error terms.

Wing injuries greater than 2% were used in the analysis. Out of 4219 loads that had values greater than 2%, initially only 3626 loads could be used in the final model. It was due to missing values of speed of loading and time of day (missing=650) which occur because a substantial number of loads had insufficient information about the start and end times of loading to determine the variables: time of day, percentage of daylight and speed of loading. These observations have been included in the analysis as a separate group identified by the predictor: Missing. Finally the model was built with all the 4219 values that were greater than 2%.

The effect of each factor was reported as a coefficient. Pairwise multiple comparisons were evaluated using the Bonferroni methods for the significant main effects and the interactions. A graph was drawn between the back transformed predicted percentage of wing injuries and different values of variables included in the final model.

Descriptive statistics were also conducted on variables where the wing injuries were less than 2%. A multivariable logistic regression was also conducted between the binary outcome: percentage of wing injuries less than 2% (n=259) and greater than 2% (n=4219).

Random effect of producer and event was also included in the model. The interaction was not tested in this model.

Statistical analysis was performed in Stata, version 13.

2.4 Results

2.4.1 Distribution of wing injuries

Of the 4494 truckloads, 16 loads did not have wing injury data, 4219 loads had injuries greater than 2%, 330 loads had wing injury levels greater than 10%, while 28 loads had wing injuries greater than 15%. Figure 2.2 shows the distribution of percentages of wing injuries, which varied from 0.3% to 20%, with a right skewed distribution. The median percent of wing injuries was 5.7 (Table 2.2).

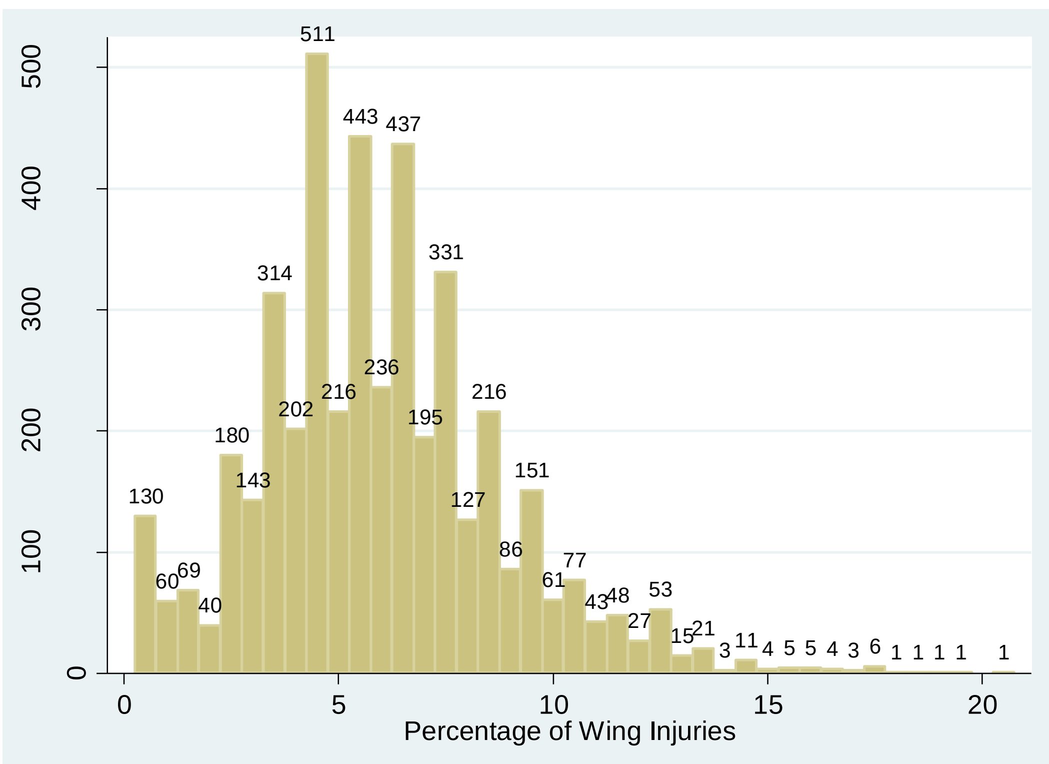

Figure 2.2 Distribution of percentage of wing injury values and frequency of occurrence

2.4.2 Summary statistics of condition of loading and transport

Some of the key variables during loading and transportation are shown in Tables 2.1, 2.2 and 2.3. Table 2.2 provides descriptive statistics for a number of variables used in the model including all the data. Table 2.3 provides descriptive statistics for the same variables for those data where percentage of wing injuries is less than 2%.

Table 2.2: Descriptive Statistics of the major variables including all the data.

Variable	Number of observation	Mean	SD	Median	Q1	Q3
Percentage of Wing Injuries per load (%)	4478	5.97	2.82	5.7	4.0	7.7
Age of the chickens (days)	4494	38.56	1.91	38	37	40
Average weight (kg)	4494	2.25	0.14	2.27	2.20	2.35
Journey duration (hours)	3686	7.37	4.46	9.5	3.67	10.75
Loading duration (hours)	3818	1.70	0.45	1.67	1.42	1.92
Loading period done in daylight (%)	3848	31.44	42.89	0	0	85
Speed of catching (No. of birds loaded per hour)	3846	4190	955	4061	3552	4680

Table 2.3: Descriptive Statistics of key variables where percentage of wing injuries is less than 2%:

Variable	Number of observation	Mean	SD	Median	Q1	Q3
Percentage of Wing Injuries per load (%)	259	0.87	0.47	0.70	0.30	1.30
Age of the chickens (days)	259	38.19	1.85	38.00	37.00	39.00
Average weight (kg)	259	2.21	0.15	2.23	2.15	2.40
Journey duration (hours)	204	7.19	4.53	10.09	5.75	10.92
Loading duration (hours)	204	1.69	0.42	1.67	1.42	1.99
Loading period done in daylight (%)	204	18.08	35.00	0.00	0.00	12.14
Speed of catching (No. of birds loaded per hour)	204	4184	983	4066.	3494	4660

2.4.3 Factor influencing percentage of wing injuries

The unconditional associations between different variables and coefficients with square-root-transformed outcomes with their mean or frequency are shown in Table 2.4. The variables associated with the percentage of wing injuries in a univariate analysis were weight, age, loading duration, percentage of daylight, number of birds in crates, sex,season and catching team. The speed of catching was not significant in the unconditional association but it was significant later when the interaction between speed of catching and time of day was included in the model. It was kept in the final model because the interaction was significant and this interaction could be of some biological significance.

The final model included seven variables (Table 2.5); weight, sex, season, catching team, time of day during catching, speed of catching and interaction between speed of loading and time of day during catching. Age and time of the day when loading were also significant.

However, age and weight were highly correlated (r=0.69). Weight was used as the variable in the model because it represents more precise information (age of chickens vary only between 36 and 41 days). Percentage of daylight was also significant in the model but time of day categories was used because of a better (lower) AIC values.

The final model (Table 2.5) showed an increase in 1 kg of weight leads to an increase in the occurrence of square root transformed wing injuries by 0.32 ($P < 0.001$) (Figure 2.3). The model shows that loads with mixed sex and pullets had higher percentage of wing injuries than loads with cockerels ($P<0.001$) (Figure 2.4). The comparison between mixed and pullets were not significant. Loading in the fall resulted in significantly decreased wing injuries compared to loading in the winter, spring and summer ($P<0.001$) (Figure 2.5). Comparisons between summer and spring, winter and spring and winter and summer were not significant. Catching group I had a lower percentage of wing injuries than other catching groups (Figure 2.6).

The model showed that the speed of catching (birds per hour) was associated with percentage of wing injuries only during the time period between 7:01-17:00(daytime) with speed of catching birds less than 5000 birds per hour associated with less percentage of wing injuries (Table 2.6; Figure 2.7). However the effect of speed of catching was not significant in the time period between 17:01-11:59 (evening) and 00:00-7:00 (morning). When the speed of catching was lower than 5000 then the percentage of wing injuries was lower during daytime than the other time periods (Table 2.6; Figure 2.7). When the speed of catching was higher than 5000 then the percentage of wing injuries was higher during the time between daytime than other time periods (Table 2.6; Figure 2.7)

Table 2.4 Variables that were candidates for inclusion in the full model (based on a p-value >0.2) in the univariate modelling of association with square root transformed percentage of wing injuries that are greater than 2%.

Variables	Number of observations	Frequency (%) or mean (s.d.)	Coefficients	P-value
Average weight per load (in kg)	4219	2.26 (0.14)	0.32	0.001
Age of the chickens (in days)	4219	38.6 (1.92)	0.02	0.001
Loading Duration (hour)	3629	1.70 (0.46)	-0.05	0.046
Percentage of Daylight during catching:	3629	32.29 (43.21)	0.002	<0.001
Stocking density in the crates (in number per crate)				0.006
10 (Standard)	3733	88.48	Ref.*	
Greater than 10	486	11.52	-0.09	
Sex				<0.001
Cockerels	546	12.94	Ref.*	
Mixed	2887	68.43	0.20	
Pullets	786	18.63	0.15	
Season				<0.001
Fall	558	13.23	Ref.*.	
Spring	1398	33.14	0.18	
Summer	1021	24.18	0.19	
Winter	1242	29.44	0.10	
Time of the day of loading*				<0.001
00:00 -7:00(Morning)	953	22.59	Ref.*	
7:01- 17:00 (Daytime)	695	16.47	0.08	
17:01 -11:59 (Evening)	1995	47.29	-0.13	
Missing in time of loading only	576	13.65	-0.14	
Speed of catching (in number of birds caught per load)*				0.41
<5000	2985.	70.75	Ref.*	
>=5000	641	15.19	0.02	
Missing in speed of catching only	593	14.06	-0.08	
Catching Team				<0.001
I	525	12.44	Ref.*	
A	918	21.76	0.50	
B	407	9.65	0.38	
C	97	2.30	0.85	
D	494	11.71	0.37	
E	370	8.77	0.43	
F	410	9.72	0.53	
G	30	0.71	0.45	
H	107	2.54	0.44	
I	861	20.41	0.55	

*Ref=Reference

Table 2.5 Variables and coefficients in the final model of square transformed outcome with 95 percentage confidence interval and P-value.

Variables	Coefficients	95% CI	P-value
Average weight per load (in kg)	0.32	0.14 to 0.50	<0.001
Sex			<0.001
Cockerel	Ref.**		
Mixed	0.17	0.10 to 0.25	<0.001
Pullets	0.18	0.10 to 0.26	<0.001
Season			<0.001
Fall	Ref.**		
Spring	0.19	0.11 to 0.26	<0.001
Summer	0.19	0.11 to 0.26	<0.001
Winter	0.15	0.07 to 0.22	<0.001
Catching Team			<0.001
I	Ref.**		
A	0.42	0.28 to 0.55	<0.001
B	0.36	0.20 to 0.52	<0.001
C	0.69	0.49 to 0.89	<0.001
D	0.22	0.06 to 0.38	0.01
E	0.27	0.11 to 0.43	0.001
F	0.36	0.20 to 0.52	<0.001
G	0.28	-0.01 to 0.56	0.06
H	0.36	0.15 to 0.57	0.001
J	0.43	0.29 to 0.57	<0.001
Speed of catching			
< 5000 birds per hour	Ref.**		
≥ 5000 birds per hour	0.20	0.08 to 0.31	0.001
Time of day during catching*:			<0.001
7:01-17:00	Ref.**		
00:00- 7:00	0.02	-0.05 to 0.09	0.54
17:01-11:59	-0.16	-0.22 to -0.09	<0.001
Interaction between speed of catching and time of catching*			<0.001
7:01-17:00 & < 5000	Ref.*		
00:00-7:00 & ≥ 5000	-0.35	-0.48 to -0.22	<0.001
17:01-11:59 & ≥ 5000	-0.17	-0.31 to -0.03	0.02
Missing**	-0.12	-0.21 to -0.04	0.01
Intercept	0.69	0.25 to 1.12	0.002
Variance: Producer	0.01	0.01 to 0.03	
Variance: Event	0.08	0.07 to 0.10	
Variance: Residuals	0.28	0.26 to 0.29	

*Ref=Reference

**Where both time of day and speed of catching are missing

Table 2.6 Regression coefficients of wing injuries at different categories of time of day and speed of catching.

Time of Day	Speed of Catching	
	< 5000 birds per hour	≥ 5000 birds per hour
00:00- 7:00 (morning)	1.30[C]	1.14[AB]
7:01-17:00 (daytime)	1.28[BC]	1.47[D]
17:01-11:59 (evening)	1.12[A]	1.15[AB]

NB: coefficients sharing a letter in the groups are not significantly different at 0.05 level.

Table 2.7 shows the intra class correlation within different producers and handling event in the final model.

Table 2.7 Intra-class correlations within different producer and handling event.

Level	Intra-class Correlation (ICC)	Standard Error	95 % Confidence Interval
Within Producers	0.04	0.01	0.02-0.07
Within Events	0.26	0.02	0.22-0.30

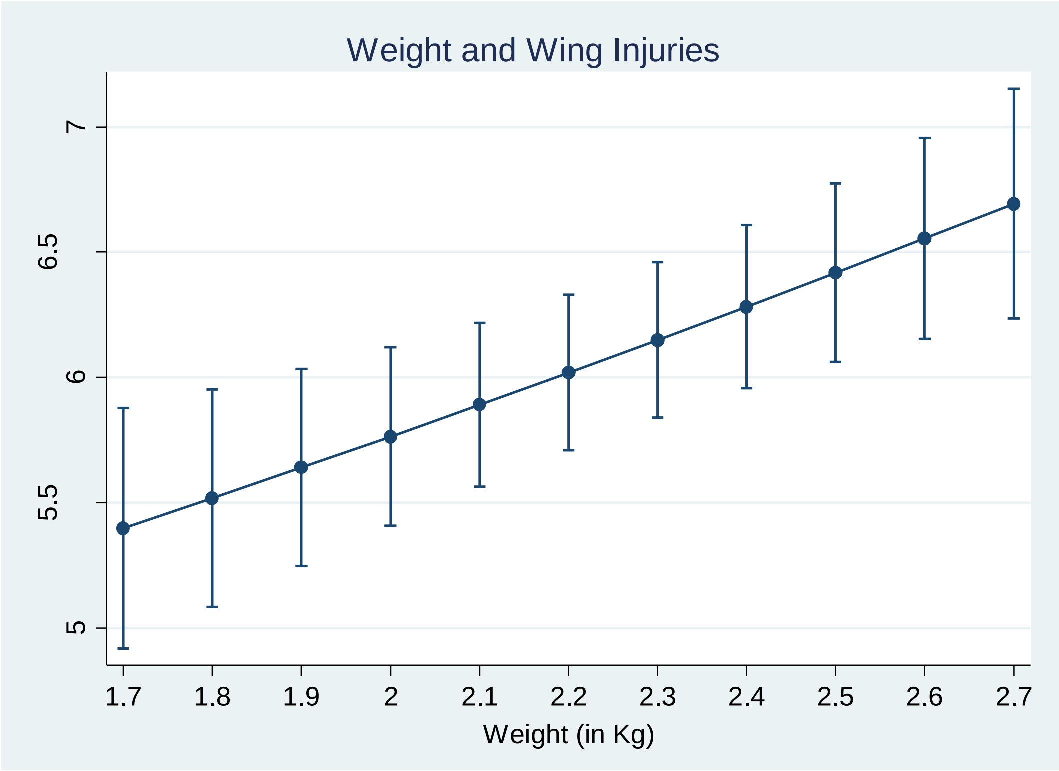

Figure 2.3 Graph of predicted percentage of wing injuries with weight in kilograms. The other predictors were set at following: Catching team = A, Time of day = 7:01-17:00, Speed of catching= <5000 birds/hour, Sex = mixed and Season = spring.

Figure 2.4 Graph of predicted percentage of wing injuries with sex of broiler chickens (Mixed = Cockerel + Pullet). The other predictors were set at following: Weight=2.6 kg (mean), Catching team = A, Time of day = 7:01-17:00, Speed of catching =<5000 birds/hour and Season = spring.

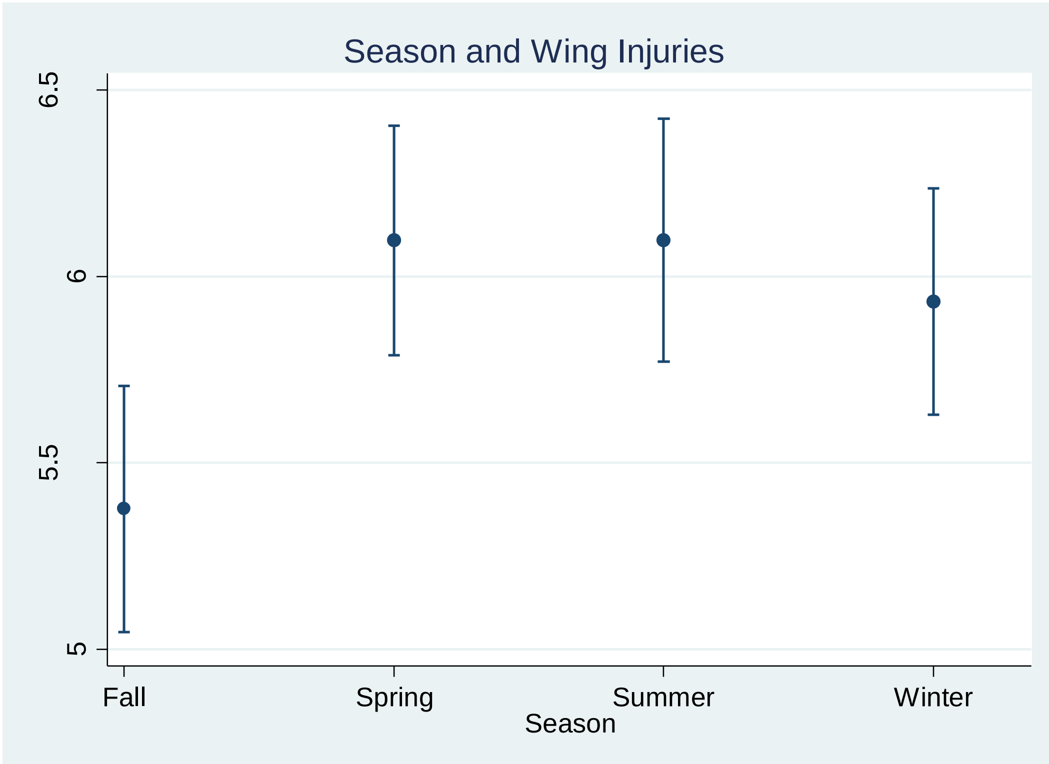

Figure 2.5 Graph of predicted percentage of wing injuries with different season. The other predictors were set at following Weight=2.6 kg(mean), Catching team = A, Time of day=7:01-17:00, Speed of catching= < 5000 birds/hour and Sex = mixed.

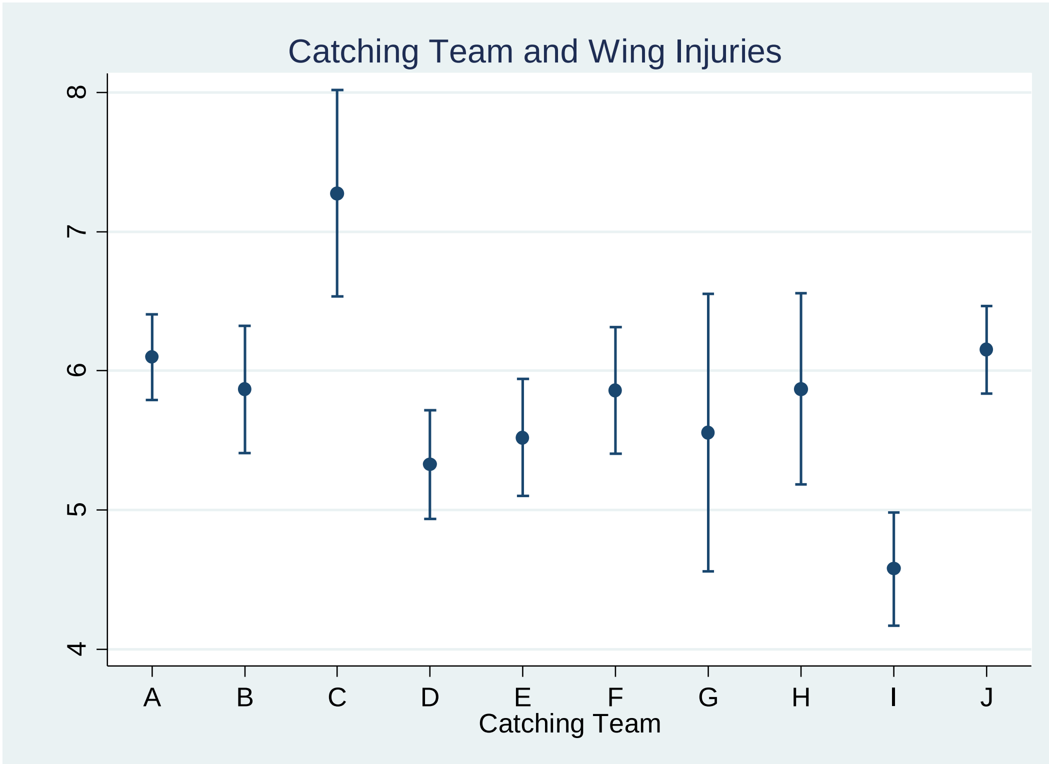

Figure 2.6 Graph between value of transformed percentage of wing injuries and different catching teams. The other predictors were set at following Weight=2.6 kg(mean), Time of day=7:01-17:00, Speed of catching=<5000 birds/hour, Sex=Mixed and Season=Spring.

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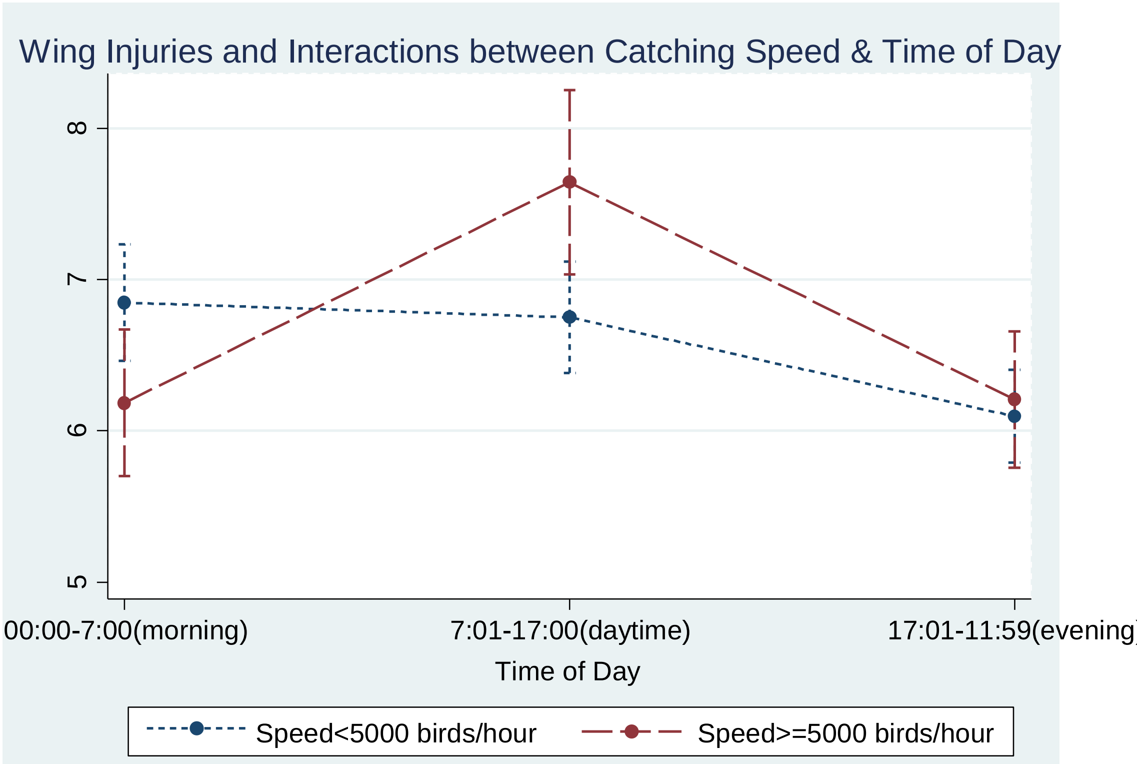

Figure 2.7 Graphs showing percentage of wing injuries at different catching speed and time of day. The other predictors were set at following Weight=2.6 kg(mean), Catching Team=A, Sex=Mixed and Season=Spring. The group of missing values not shown.

Table 2.8 below shows the outcome of a logistic model with categories of percentage of wing injuries (greater than 2% and less than 2%) as the outcome. The coefficient in the table shows the log-odds associated with lower percentage of wing injuries (<2%). Increased weight reduced the log-odds of low percentage of wing injuries by 1.76. Increased percentage of daylight reduced the log odds of low percentage of wing injuries by 0.01. Compared with loads that have standard number of birds per crate (10), those loads that have greater than the standard increased the log odds of low percentage of wing injuries by 0.68. Compared with cockerels, mixed and pullets reduced the log odds of low percentage of wing injuries by 0.91 and 1.24 respectively. Compared with fall, spring and winter increased the log odds of low percentage of wing injuries by 0.95 and 2.16 respectively. The effect whether the group had a low percentage of wing injuries or high percentage of wing injuries also depended on which catching team the chickens were caught by.

Table 2.8 Variables and coefficients that were significant in a final logistic regression model in which the binary outcome was percentage of wing injuries lower than 2%. The coefficients shows the log-odds associated with lower percentage of wing injuries:

Variable	Coefficients	95 % CI	P-value
Weight	-1.76	-3.16 to -0.36	0.02
Percentage of daylight	-0.01	-0.01 to -0.001	<0.001
Stocking density (in number per crate)			
10(Standard)	Ref.*		
Greater than 10	0.68	0.21 to 1.16	0.01
Sex			<0.001
Cockerel	Ref.*		
Mixed	-0.91	-1.42 to -0.41	<0.001
Pullets	-1.24	-1.85 to -0.63	<0.001
Season			<0.001
Fall	Ref.*		
Spring	0.95	0.15 to 1.76	0.02
Summer	0.30	-0.57 to 1.18	0.50
Winter	2.16	1.38 to 2.94	<0.001
Catching Team			0.008
I	Ref.*		
A	0.84	0.21 to 1.46	0.01
B	0.20	-0.58 to 0.97	0.62
C	0.70	-0.80 to 2.20	0.36
D	-0.18	-0.99 to 0.63	0.66
E	0.45	-0.36 to 1.25	0.28
F	1.11	0.35 to 1.87	0.004
G	0.23	-1.76 to 2.21	0.82
H	-1.91	-4.11 to 0.28	0.09
J	0.54	-0.15 to 1.23	0.13
Missing**	0.36	-0.17 to 0.89	0.18
Intercept	-0.51	-3.75 to 2.73	0.76
Variance:Producer	0.03	0.00001 to 59.70	
Variance:Event	1.54	0.90 to 2.63	

*Ref.=Reference **Missing in percentage of daylight

2.5 Discussion

In this study, we investigated different risk factors affecting wing injuries of broiler chickens during catching and transportation. The final model included seven variables weight, sex, season, catching team, time of day during catching, speed of catching and interaction between speed of loading and time of day during catching.

The median percentage of wing injuries per load was 5.7, which is quite high compared to previous studies (Gregory et al. 1989; Ekstrand, 1998; Knierim and Gocke, 2003; Grandin, 2009). However, the percentage of wing injuries in a load depends on a variety of factors, such as type of loading procedure, method of recording injuries, and so on. The high percentage of wing injuries in our study could be due to the fact that a loose crate system was used and that electric rather than gas stunning was the protocol adopted. Gas stunning may have a lower percentage of wing injuries because in the gas stunning processing systems, the birds will already immobilizedstunned when they enter the processing line.

Weight may have an effect on wing injuries because the catchers invert the chickens to place them in crates, so heavier birds may experience more discomfort and flap their wings more. The study by Nijdam et al. (2004) did not find any significant association between bird weight and bruising. However, it should be noted that Nijdam et al. (2004) used different contributions from breasts, legs, and wings for the calculation of percentage of bruising, with wing bruising contributing least to the total. In addition, Nijdam et al. (2004) used modular systems for catching, and show only mean values in their summary statistics, making it difficult to compare our data with theirs.

In our study, season had a significant effect on wing injuries. Loading done during the fall resulted in less wing injuries compared to the other seasons. A similar effect was wasreported by Nijdam et al. (2004). They also found that injuries in fall were lower than in summer and spring. It should be noted that there was less loading occurring in fall than in other seasons. Approximately 568 loads were transported in the fall compared to approximately 1044, 1458 and 1425 in the summer, spring and winter respectively. Cooler temperatures resulting in active birds in the fall may be a contributing factor to less wing injuries. .

In the group where the speed of catching was lower than 5000 per hour, the percentage of wing injuries was always lower during evening than other time periods (Table 2.6; Figure 2.7). Similarly, where the speed of catching was higher than 5000, then the percentage of wing injuries was higher during daytime than other time periods (Table 2.6; Figure 2.7). This could be attributed to lower amount of daylight between 17:01-11:59(evening) and higher amount of daylight between 7:01-17:00(daytime). Percentage of daylight was not used in the model because the effect was explained by the time of the day. A similar result, in terms of time of day, was also found by Nijdam et al. (2004), where catching and transportation at night was associated with less bruising. Decreased weight of the wing of chickens has been found for birds raised in higher light intensity (Downs et al. 2006; Lien et al. 2007; Lien et al. 2008; Deep et al. 2010). Rearing chickens in lower light intensity has been found to be detrimental to welfare because of increased leg, footpad, and eye injuries (Blatchford et al. 2009; Deep et al. 2010). Light has an effect on the behavior of the chickens, and it has been shown that giving broiler chickens more light leads to more fearful behavior, and the chickens become more active after exposure to light (Kristensen et al. 2006; Schwean-

Lardner et al., 2013). Sudden exposure to light during handling may lead to more wing injuries due to high activity levels. However other factors during night time like cool temperature and less noise could also have an effect.

The final model showed that during daytime (7:01-17:00), the speed of catching birds' less than 5000 birds per hour was associated with less percentage of wing injuries (Table 2.6; Figure 2.7). Such effect was not shown in other categories of time of day.

There could be several reasons why catching birds quickly during daytime could lead to more injuries. It could be good to keep the speed of birds lower during daytime than other time periods because the culmination of higher speed of catching and higher percentage of daylight and temperature could lead to more stress and activity to the birds thus causing more wing injuries.

Our study found that pullets had more wing injuries than cockerels. Similar result was reported by Mayes (1980). This study showed that there was greater prevalence of bruising in females than males while our study found that females were more prone to wing injuries than males. The feather covering of the birds is likely to vary between sex (females with more feathers) and this could affect the ability of the birds to respond to thermal extremes. The birds who could not respond to thermal stress more appropriately could be more prone to wing injuries.

Another factor affecting the percentage of wing injuries was the catching team, which is consistent with the findings of Nijdam et al. (2004). Catching teams may be employed by a private company or by the processors themselves. The workers generally came from the same province where the farms were located, and catchers may be added to a team if required, based on the amount of work at hand (Gittins et al., 2006). In our study, it was not possible to identify specific characteristics related to the different catching teams which may have been associated with increased wing injuries.

The significant factor in the multilevel multivariable logistic model was weight, number of birds in the crate (crate stocking density), percentage of daylight, sex, season and catching team (Table 2.6). Similar variables were significant when we used only the higher percentage of injuries (greater than 2%) in our model. Furthermore these studies have higher median percentage of injuries than any other study. Those 259 loads with lower percentage of injuries should be loads where the handling was done more appropriately.

In our unconditional associated model and in logistic model the number of birds per crate was a significant factor with lower number of birds per crate having higher percentage of wing injuries. It could be because higher number of birds per crate reduces the movement of the birds inside the crates thus making them less prone to injuries in the wing.

Limitations: One of the major limitations in our study was that we did not have sufficient data to support an analysis of the effects of temperature and humidity on the occurrence of wing injuries. Ambient temperature and humidity during catching, transportation, and lairage may have an effect on the occurrence of wing injuries as shown by the study by Nijdam et al. 2004.

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3. Summary and Conclusions:

There appears to be several welfare issues associated with manual catching, carrying and loading for transportation of broiler chickens to slaughter plants. Depopulation of broiler chickens occurs at midnight and is a primary cause of injuries and death of chickens. To assess animal welfare during handling we can look at injuries, percentage of mortality and fearfulness of the chickens. Procedures to reduce fear in chickens before handling could include: environmental enrichment during growing phases, genetic selection, conditioning the birds to fear and feeding with ascorbic acid (Vitamin C). We can also assess animal welfare during handling by measuring physiological responses which could include heart rate, corticosterone levels, and respiration rate. Types of injuries during handling depend on whether the handling is done by a mechanical or manual system. Studies have reported two types of causes of death of broiler chickens during handling; physical factors like thermal temperature, and pathological causes like heart failure. The meat quality of the chickens also depends on the types of handling the chickens are exposed to. It is very important to improve conditions during handling in such a way that the chickens are less exposed to thermal stress. The fitness of the chickens should be assessed by carefully followed industry guidelines to assess the risk of transportation.

Data from a slaughter plant in New Brunswick identified risk factors for injuries during handling and transportation of broiler chickens. Wing injuries was used as the outcome variable. The loads were divided into different 'handling events' to account for clustering of the data. A multilevel linear mixed model using producer and 'handling events' as random factors and percentage of wing injuries as outcome was used.The median percentage of wing injuries 5.7%.The average weight of the chickens, sex of the chickens, season, catching team, time of day during catching, speed of catching and interaction between time of day during catching and speed of catching were the primary risk factors responsible for the occurrence of wing injuries.An increase in bird weight led to an increase in the occurrence wing injuries ($P < 0.001$). The model shows that loads with mixed sex and pullets had higher percentage of wing injuries than loads with cockerels ($P<0.001$). Loading in the fall resulted in significantly decreased wing injuries compared to loading in the winter, spring and summer ($P<0.001$). There was significant difference in percentage of wing injuries between different catching teams. The effect of time of day was dependent on the speed of catching. Higher percentage of injuries was found in time period between 7:00 and 17:00if the speed of catching was higher.

An additional descriptive and analytical epidemiological study was conducted in Nova Scotia slaughter plants to estimate the extent of dead on arrival (DOA) birds and leg injuries, and identify associated risk factors. Data was collected on the day of loading and further data on each load was provided by the slaughter plant. The data collected during loading included environmental recordings, litter bedding collection to determine moisture content, and behaviour of handlers and chickens. Other farm level and load level variables were available from the data provided by the slaughter plant. Frequencies of different behaviours were made and recorded as a percentage of the behaviours. A multilevel model with handling event as a random factor was created. The results showed higher percentage of wing injuries in the current study than the Nova Scotia dataset which could be due to different procedure of slaughter (Nova Scotia data used gas stunning). This study will be presented to be published in a journal.