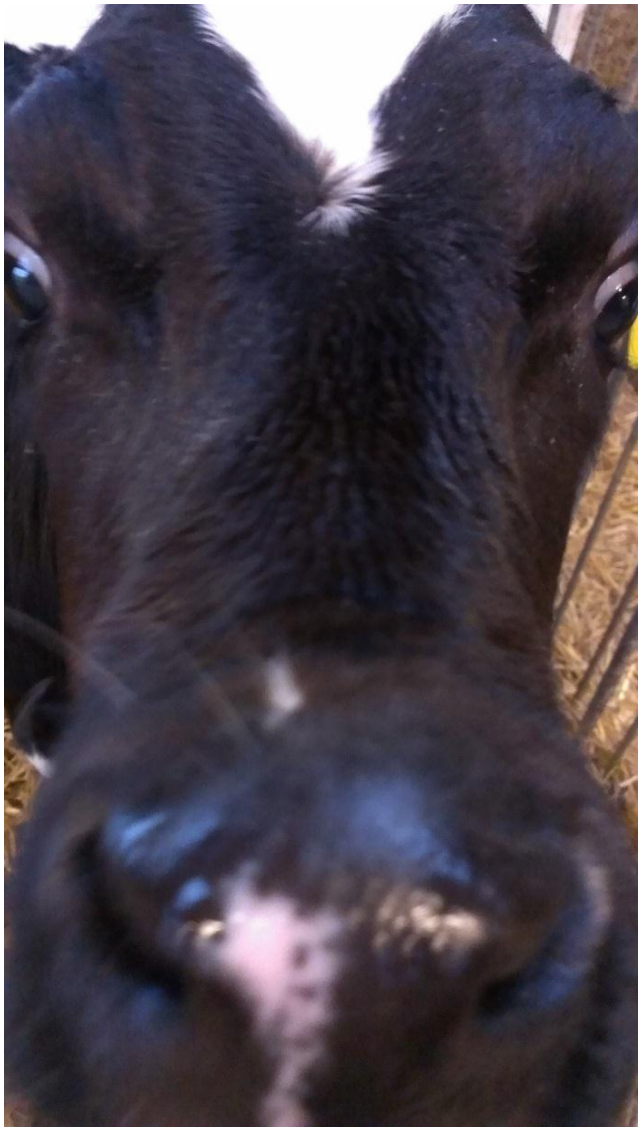
FACULTY OF HEALTH AND MEDICAL SCIENCES
UNIVERSITY OF COPENHAGEN

Comparison of social behaviour and risk of transmission of pathogens between different dairy calf housing systems

Master's thesis

Anne-Marie Østergaard
cjm858



Academic advisor
Liza Rosenbaum Nielsen

Co-adviser
Nina Dam Otten

Submitted: January 2014

Preface

This veterinary thesis was completed in relation to the project: "The schism between animal welfare concerns and disease control in cattle farms" by the "Knowledge centre of Animal Welfare" (ViD).

I thank everybody who read this thesis and helped me in any way during the process.

I would like to thank Stig Jessen from Danish Veterinary Animal and Food Administration (FVST), who helped with an understanding of how the FVST do control on dairy farms and how the FVST interpret EU- and Danish legislations. I thank the farmers, who willingly let me visit their farm and film their calves, without their help, this thesis would not have been possibly. Furthermore I thank the referring veterinarians who put me in contact with the farmers.

For printing this thesis, I thank Mogens Jakobsen and Mogens Lüstrup at Boehringer Ingelheim.

I thank co-advisor Nina Dam Otten, for helping with the planning and the design of the study. Furthermore, thank you for the reading and correction of this thesis.

I would like to thank Liza Rosenbaum Nielsen who has been an amazing and professional adviser. She inspired me constantly, and was helpful and inspirational during the whole process.

Frederiksberg, January 17th 2014

Anne-Marie Østergaard

cjm858

Index

Summary

The welfare of calves is an important aspect in modern dairy production. Calves can be housed in huts, in pens made from wood or in other housing systems, as long as the system complies with the current legislation. §4. Stk. 2 about housing and protection of calves, state that single pens cannot have solid walls, but have to be equipped with walls with openings, where the calves can see and touch other calves (BEK No. 1075 of 22/12/1997). The design of the pens and furthermore the openings in the walls can also have different designs.

The calves' behaviour has been used as an indicator for the presence of welfare. Calves performing play behaviour and jumping around in the housing system are indicators of good welfare and the absence of play behaviour and locomotor activity might be indicators of compromised welfare.

Calves housed in different housing systems have different availability of transmission of pathogens, depending on the allowed contact between the calves. Some housing systems allow the calf to see and touch the neighbour calf via bars in the front yard, which might give them more possibility to transmit pathogens to the neighbour, compared to calves housed in more restricted housing systems.

This thesis involves two studies based on the aim to see if there was a difference between different housing systems and the risk of transmission of pathogens and the behaviour of calves in individual housing systems. The first study was based on two different housing systems and the second study was based on four different housing systems.

Both studies showed no effect of the housing systems on the calves' behaviour. Furthermore, regardless of the housing system, no differences were seen in the contact at the front of the housing systems, thus the risk of transmission of pathogens might be the same for all housing systems. Calves housed in a hut with an open front yard had more contact via the sidewall, compared to a housing system with limited access via the sidewall. Also calves housed unable to make contact at the front had more contact via the sidewall, compared to calves housed in the other observed housing systems.

Sammendrag

Kalves velfærd er et vigtigt aspekt i den moderne mælkeproduktion. Kalve kan opstaldes i hytter, i bokse lavet af træ eller i andre opstaldningssystemer, så længe systemet overholder den gældende lovgivning. §4. Stk. 2 omkring opstaldning og beskyttelse af kalve, skriver at enkeltbokse ikke må have faste vægge, men skal have vægge med åbninger, hvor kalvene kan se og røre andre kalve (BEK No. 1075 of 22/12/1997). Udformningen af boksene og ydermere åbningerne i væggene, kan også være udformet forskelligt.

Kalvenes adfærd har været brugt som en indikator for tilstedeværelse af velfærd. Når kalve har legeadfærd og løber rundt i opstaldningssystemet, så er der indikatorer på god velfærd og manglende legeadfærd og locomotor aktivitet kan være et tegn på kompromitteret velfærd.

Kalve som opstaldes i forskellige opstaldningssystemer har forskellig mulighed for transmission af patogener, afhængig af den tilladte kontakt mellem kalvene. Nogle opstaldningssystemer lader kalven se og røre nabokalven via gitteret i forgården, som muligvis giver dem mere mulighed for transmission af patogener til naboen, sammenlignet med kalve opstaldet i et mere begrænset opstaldningssystem.

Dette speciale indeholder to studier, med målet at se om der er en forskel mellem forskellige opstaldningssystemer og risikoen for transmission af patogener og adfærden hos kalve opstaldet enkeltvis. Det første studie var baseret på to forskellige opstaldningssystemer og det andet studie var baseret på fire forskellige opstaldningssystemer.

Begge studier viste ingen effekt af opstaldningssystemerne på kalvenes adfærd. Ydermere, uanset hvilket opstaldningssystem, var der ingen forskel på kontakten forrest i opstaldningssystemerne, derfor er risikoen for transmission af patogener måske den samme for alle opstaldningssystemer. Kalve som er opstaldet i hytter med en åben forgård havde mere kontakt via sidevæggen. Kalve opstaldet uden mulighed for at lave kontakt forrest, havde mere kontakt via sidevæggen, sammenlignet med kalve opstaldet i de andre observerede opstaldningssystemer.

Introduction

There is an on-going discussion about housing of dairy calves and what is important in relation to this. Being a farmer means balancing the health, welfare and practical matters of the calves, the risk of transmission of pathogens and what works on daily basis. The EU council has made a directive, laying down minimum standards for the protection of calves, for every member country to follow and the Danish government has implemented this directive as legislative orders concerning housing of calves. A lot of the young calves at dairy farms in Denmark are housed in single pens of various types. This is to prevent spread of pathogens as having calves housed separately has been shown to decrease the risk of transmittable diseases from calf to calf (Munksgaard and Søndergaard, 2006).

Housing calves in individual housing systems can have a negative effect on the calves' behaviour. A study showed that combined with a raise in heart rate, it took longer for calves housed in individual pens with solid walls, to seek out an unknown calf, than calves housed in groups (Jensen, et al., 1997; Jensen, et al., 1999). Furthermore, when calves are housed in small pens they do not have the possibility to jump around, so when introduced to a bigger area the calves housed in small pens would tend to be more active and more inclined to perform some kind of locomotion (Jensen, et al., 1999).

Play behaviour might be used as an indicator for good welfare, but when calves are housed in single pens they do not move around as much as calves housed in group pens, this might mean that calves need sufficient space to be able to express play behaviour (Jensen, et al., 1998). This shows that housing calves in individual pens can lead to a negative impact on their behaviour and since behaviour, especially play behaviour, is an indicator for good welfare, individual housing of calves gives rise to the question whether the calves have good welfare or not. Furthermore the Danish Animal Welfare Act §1 states that "*Animals should be treated properly and have the best possible protection from pain, suffering, fear, lasting harm and substantial disadvantage*" (LBK. No. 252 of 08/03/2013), which might conflict with the fear the calves experience when moving them from individual housing to group housing.

When choosing a housing system there are a lot of aspects to consider, the welfare aspects need to correlate with the type of housing and the management. The Danish Animal Welfare Act states the basics of animal welfare such as; the animals need to be free of pain and must be fed etc. (LBK. No.

252 of 08/03/2013). To obtain good welfare these legislations must be fulfilled and furthermore achieved in a way that is practical for the farmer.

Before 1997 it was allowed to house calves in single pens without the possibility of contact to another calf, but this was banned with the EU-directive 2008/119/EF of December 18th 2008. Today the EU-directive and the Danish law state that calves housed individually must have pens with perforated walls and be able to see and touch other calves (BEK No. 999 of 14/12/1993; BEK No. 1075 of 22/12/1997; EU-directive 2008/119/EF). This meant that farmers had to buy or create new solutions for the housing of their calves. Farmers, who had their calves in huts, bought front yards to the huts or made holes in the sidewalls of the plastic huts. Other farmers, who had pens made from wood with solid walls, had to make holes in the sidewalls so the calves could have contact.

One problem for the farmers, the veterinarians and the controlling authority is that the lack of guidelines for the sizes or the shape of the holes in the walls. This gives reason for a discussion whether the calves in fact use the holes or they find other ways to make contact with the neighbour calf e.g. at the front of the pens or over the pen walls. It also raises the question whether there is a difference in the calves' behaviour in the different housing systems and whether there is a difference between the housing systems with regard to the risk of transmission of pathogens between the calves.

Aim

The overall aim of the studies were to see if there was an effect of different housing systems on the risk of transmission of pathogens and the behaviour of 1-7 weeks old calves in Danish dairy farms.

Outline

The following thesis consists of two parts: a pilot study and a standardized study formed as a paper. The standardized study is a further development of the pilot study, thus differences between the farms in the pilot study were sought to be equalized in the standardized study. Repetitions might occur in the paper due to the design of the studies being alike. Followed by the paper is an overall conclusion; making a summary of the two studies. The hypotheses investigated in the studies were:

- H_0 = There is not a difference between the housing systems and the calves' behaviour and the risk of transmission of pathogens.
- H_1 = There is a difference between the housing systems and the calves' behaviour and the risk of transmission of pathogens.

Background

EU-directive

An EU-directive is a subcategory of an EU-law which every member country of EU has to follow, however the individual countries are free to decide how to reach the end result written in the directive (European Commision, 2012). The EU-directive 2008/119/EF of 18 December 2008; laying down minimum standards for the protection of calves, states:

- *"Calves, both group-housed and individually penned, should have sufficient space for exercise, for contact with other cattle and for normal movements when standing up or lying down".*
- *"The width of any individual pen for a calf shall be at least equal to the height of the calf at the withers, measured in the standing position, and the length shall be at least equal to the body length of the calf, measured from the tip of the nose to the caudal edge of the tuber ischii (pinbone), multiplied by 1.1".*
- *"Individual pens for calves (except those for isolating sick animals) must not have solid walls, but perforated walls which allow the calves to have direct visual and tactile contact"* (EU-directive 2008/119/EF).

Further information about how the perforated holes in the sidewalls should look like is not available. This lack of guidelines makes it possible for every EU member state to make their own interpretation of the above legislations, which inevitably will make the housing and the welfare of calves unlike in the various countries.

Danish laws

Derived from the EU-directive, the Danish government has made several laws concerning housing and protection of calves;

- *"§4. When the calves are placed in single pens, the pens must have a width of minimum 0.80 times the shoulder height of the calves"* (BEK No. 999 of 14/12/1993).
- *"§11. Stk. 2. Every calf must be able to see other calves…."* (BEK No. 999 of 14/12/1993).
- *"§2a. Calves over eight weeks cannot be housed in individual pens, unless a veterinarian has certified, that their health or behaviour demands that they are kept isolated to be treated"* (BEK No. 1075 of 22/12/1997).

- *"§4. When a calf under 8 weeks is housed in a single pen, the pen must be minimum 100 cm wide and 120 cm long for calves up to 60 kg and minimum 100 cm wide and 140 cm long for calves over 60 kg".*
  Stk.2. Single pens cannot be equipped with solid walls, but have to be equipped with separating walls with openings, which gives the calves the opportunity to see and touch other calves" (BEK No. 1075 of 22/12/1997).

The above mentioned paragraphs are what the Danish government has decided concerning the housing of calves.

§4. Stk. 2 states that the single pens cannot have solid walls, but have to be equipped with walls with openings where the calves can see and touch other calves (BEK No. 1075 of 22/12/1997). The Danish Veterinary Animal and Food Administration (FVST) interpret this paragraph by saying that it is not enough, when the calves only can see and touch each other through the front of the housing system (Stig Jessen, 2013).

The Danish Animal Welfare Act (LBK. No. 252 of 08/03/2013) is the overall legislation concerning animal welfare;

- *"§1. Animals should be treated properly and have the best possible protection from pain, suffering, fear, lasting harm and substantial disadvantage.*"
- *"§2. Anyone who keeps animals must ensure that they are treated compassionately, including being housed, fed, watered and cared for, and taking into account their physiological, behavioural and health needs in accordance with appropriate practical and scientific knowledge.*
- *"§3. Rooms or areas where animals are kept should be designed in such a way that the animal's needs are met, in accordance with § 2 It must be ensured that the animal has adequate freedom of movement also during ingestion of feed and water and at rest.*

The legislations are made to ensure that the basic needs of the animals are met. Furthermore, the purpose of the welfare legislation is to improve animal welfare and to require a minimum level of permitted conditions (Forkman, 2010).

Instruction for welfare control in dairy cattle farms

The veterinary control team performs ordinary controls and welfare controls of cattle farms. The veterinary control team is a region under FVST from whom they take orders. FVST has made an instruction for the control of welfare in cattle farms in Denmark so the inspectors can be as uniform as possible. This instruction shows how the inspectors are supposed to determine, whether a housing method can be approved or not, but it does not precisely tell what the pens are supposed to look like (FVST, 2011). This is up to the individual inspector to interpret. When the inspectors perform welfare control on a farm, they can inform the farmer what the legislations say and how they are supposed to interpret them, but they cannot advise the farmer how to e.g. house the animals in a way so they will fulfil the laws (Stig Jessen, 2013). The welfare control in the farms seeks to ensure that there is compliance between the legislations and the housing of the calves.

Welfare

When assessing welfare the above legislations must be fulfilled and furthermore it must be a matter of course, to ensure proper welfare for animals. The "Five Freedoms" has been characterised as a golden standard concerning animal welfare.

The Five Freedoms (Farm Animal Welfare Council, 2011):

- Freedom from thirst, hunger and malnutrition.
- Freedom from discomfort.
- Freedom from pain, injury and disease.
- Freedom to express normal behaviour.
- Freedom from fear and distress.

The above Five Freedoms is the basis for recommendations worldwide. The "World Organisation for Animal Health, OIE" has made recommendations for animal welfare and has implemented the "Five Freedoms" as guidance in assessing welfare (OIE Code Commission, 2013).

The assessment of welfare on farm level has led to a project called the "Welfare Quality®" project with the aim of providing a scientifically based tool to assess animal welfare (Welfare Quality®, 2009). There are four basic principles of welfare according to "Welfare Quality®": Good health, good housing, good feeding and appropriate behaviour (Welfare Quality®, 2009). Both the "Five

Freedoms" and "Welfare Quality®" focus on normal and appropriate behaviour. According to "Welfare Quality®" assessing appropriate behaviour involves the following points:

- Expression of social behaviours e.g. grooming and social licking.
- Expression of other behaviours e.g. running or jumping in the pen.
- Good human-animal relationship, e.g. assessor able to eye contact or touch calf without the calf withdraws.
- Absence of fearfulness e.g. negative emotions such as fear, distress, frustration or apathy should be avoided whereas positive emotions such as security or contentment should be promoted.

The above are evaluated and an assessment of the calves' welfare is made from the basis of the evaluation of the calves' health, housing, feeding and behaviour all together.

The Welfare Quality® (2009) was made for veal calves, but the principles of the assessment can be transferred to dairy calves.

Pilot study

Theory

Behaviour

When calves are housed in an isolated environment and then put together with other calves they show more fear than calves that have had contact with other calves from their birth. Furthermore, when calves are housed in individual pens with solid walls, it takes longer for them to seek out an unknown calf than calves housed in groups, and combined with this the calves' heart rate rises (Jensen, et al., 1997; Jensen, et al., 1999). This means that housing calves without any contact to other calves will make them more afraid and be more reluctant to make contact with other calves when grouped at a later stage. Furthermore if the calves could choose, they would prefer the opportunity for full contact than contact through or over bars/walls (Holm, et al., 2002), but inevitable, it comes down to the fact that the calves' behaviour is influenced both by management by the farmer and the housing facilities (Bøe and Færevik, 2003).

Even though there is such a big difference in the calves' behaviour, the effect is not irreversible. Several studies have shown that after a few weeks of being grouped with unknown calves, there is no difference between the calves from one housing system to the other (Veissier, et al., 1994; Jensen, et al., 1997). Even though the effect of individual housing is not irreversible, it can still have a negative effect on production economy and animal welfare because the calves show fear and anticipation when being grouped with unknown calves (Bøe and Færevik, 2003).

Single vs. group housing

One of the most used reasoning about housing calves individually, is the lower risk of transmission of diseases between the calves. However, a study showed that there is no difference in the risk of getting respiratory tract infections and diarrhoea when the calves are housed individually compared to small groups of 3-8 calves (Svensson, et al., 2003). The study also showed that the risk of respiratory tract infections was bigger when the calves were housed in big groups (> 8) than being housed individually, but in general, the reduction in group size will lead to a reduced risk of respiratory infections (Svensson, et al., 2003; Svensson and Liberg, 2006).

Even though studies have shown that there is no difference in the occurrence of getting respiratory tract infections when housing calves individually or in small groups, it is very important to keep in mind that these groups need to be stable. When there is a replacement of calves in a group, also known as regrouping, the group dynamic and age diversity keeps changing which has a negative impact on the calves' behaviour instead of the positive impact they would get from a stable group (Bøe and Færevik, 2003; Munksgaard and Søndergaard, 2006).

Furthermore, when calves are housed in stable groups they gain more weight and have a lower incidence of diseases compared to calves housed in changing groups (Pedersen, et al., 2009). Additionally, a study showed that the weight the calves housed in groups gain, needs to correlate with the space allowance for the calves and the feeding method as well (Phillips, 2004; Babu, et al., 2004).

Another very important aspect is the mortality of the calves. A study showed that the mortality was higher when housing calves in groups of over 7 calves, compared to individually housed calves (Losinger and Heinrichs, 1997). The reason for this might be the higher risk of transmission of diseases when housed in a group and the risk of one calf not getting sufficient feed, because of "survival of the fittest", e.g. because of age difference. Even though the mortality rate is higher in group housed calves, group housing takes the calves' development of social behaviour and interaction with other calves into account and furthermore allows the calves to play and exercise (Bøe and Færevik, 2003; Stull and Reynolds, 2008).

Activity

Single housed calves are less active when compared to calves housed in groups, which might be because of the increased space allowance from housing calves together (Jensen, et al., 1998; Chua, et al., 2002). When calves have sufficient space allowance they are able to run or jump around, characterised as play behaviour, which might be used as an indicator for good welfare (Jensen, et al., 1998). Furthermore, when calves are housed in loose housing such as group housing or huts with front yard, they have the opportunity to exercise and to perform normal social behaviour, namely locomotion (Bøe and Færevik, 2003), which they might not be able to when housed in individual pens. Calves housed in small individual pens seem to build-up motivation for locomotor activity and will have more motivation to express this behaviour when placed in a bigger area (Jensen, et al., 1999; Jensen, 2001).

Transmission of diseases

There are several ways of pathogens can be transmitted from one calf to another e.g. direct contact, indirect faecal-to-oral routes and by aerosols. Infectious diseases, such as diarrhoea and respiratory tract infections, are a big problem in rearing of calves and the transmission from one calf to another is a challenge in management systems (Sivula, et al., 1996; Svensson, et al., 2003). Individual housing is supposed to reduce the transmission of pathogens between the calves (Rushen, et al., 2008), but it depends on configuration of the housing system (Stull and Reynolds, 2008). Housing systems, such as huts with a front yard, which have bars all the way to the ground, make it easier for one calf to infect the neighbour calf. When calves are housed in pens with solid walls, which have been perforated for the calves to see and touch each other according to the law, the risk of transmission of pathogens is lower because of the smaller area via which the calves can touch and infect each other. Furthermore, a study about management routines and prevention of *Salmonella* Dublin showed, that housing calves with solid walls, i.e. separating walls, would result in an increased successful control of *Salmonella* Dublin compared to calves housed with bars or partly bars as separation (Nielsen, et al., 2012).

When calves are fed milk, they are stimulated to suck on another calf's ears, muzzle or other body parts also characterised as cross-sucking (Lidfors, 1993). Furthermore, it stimulates sucking for up to 10-15 min after feeding and cross-sucking is most frequent after feeding (de Passillé, et al., 1992; Lidfors, 1993). Cross-sucking is characterised as an abnormal behaviour and detrimental for the health of calves (de Passillé, et al., 1992), thus is cross-sucking a problem in particular group housing, because the calves get very easy access to another calf's body parts which can lead to an infection e.g. in the navel area. However, when calves are weaned there is significant decrease in cross-sucking behaviour, which might be related to the positive feedback mechanism the calves get from being fed milk (Lidfors, 1993).

Materials & Methods

Farms, calves & housing

The study consisted of 3 farms; 1 Holstein, 1 RDM and 1 Jersey which housed calves in huts with a front yard. Six calves from each farm were selected i.e. one breed from each farm. They were milk fed and had an age interval of 5-41 days on the observation days.

The 6 calves were divided into two groups and housed in huts referred to as "open housing" and "restricted housing".

Open housing: 3 calves were observed in their regular huts with front yards.

Restricted housing: 3 calves were housed in huts with a front yard which consisted of plastic being put on the sidewalls, only allowing a window of 40x40 cm to the neighbour calf.

Figure 1: Open housing

Figure 2: Restricted housing

The calves were housed next to each other and were filmed during February and March 2013, two or three times with an interval of one week (n=41).

Filming

A camera was placed in front of the 6 calves. The camera was placed and left without the presence of unfamiliar people, i.e. the observer.

The camera filmed for half an hour before and after milk feeding, giving a total of approximately one hour material. The film material was used to observe and record behaviour for 15 min before milk feeding, no observation during eating, and 15 min after stop of eating. The filming was

performed around the time of feeding because calves generally are more active around feeding time, so this would provide a better data foundation for statistical comparisons (Jensen, et al., 1998).

Analysis

The analysis was based on the calves' behaviour which was divided into positive and negative behaviour and time spent on lying and standing. It was also analysed how much time the calves spent on contact where there was a risk of transmission of pathogens, this will be referred to as risk contact. No further analysis was performed for breed due to effect of the farms being too big to do any reasonable analysis.

Positive behaviour

The positive behaviour was characterised by self-grooming, playing with or without the neighbour and touching muzzle with the neighbour. Self-grooming was when the calf licked itself in a non-stereotypical way. Playing behaviour was when the calf ran back and forth in the pin and jumped in the air with or without seeking out the neighbour, as described by Jensen et al. (1998). When the calves were budding muzzles it could be via the grid in the front yard or at the front of the pens and it was defined as touching muzzle, not sucking or licking.

Negative behaviour

The negative behaviour was characterised by licking or sucking on fixtures and cross-sucking (Munksgaard and Søndergaard, 2006). This can be on the grids to the neighbour, the grids in the front of the pin or the front yard or just the connectors on the sides where the grid was connected to the hut or the pen. The cross-sucking was characterised as the calf licking or sucking on another calf. The calf can be sucking on e.g. the muzzle, the ear or the neck of the neighbour calf. The cross-sucking was via the grid of the pen or the front.

Waste time

Due to snow on the lens and bad angle of the camera, some of the calves' behaviour was unable to be observed, this was referred to as "waste time". The waste time was subtracted from the total observed time.

Lying

Lying was characterised as the calves lying down in the pen or hut. They could be doing other things while lying down e.g. sleeping, self-grooming or just looking around.

Standing

Standing was characterised as the time the calves spent on standing and looking around. When waste and lying time, positive and negative behaviour were subtracted from the observed time, the time referred to as "Standing" was left.

Risk contact

The risk contact was characterised by every direct contact between the calves where transmission of pathogens is possible. This can be contact by touching muzzles or other parts of the body of when the calves are cross-sucking. This contact was characterised as either general contact, contact at the front of the housing system or via the sidewall.

Outcome

The outcome of interest is in percentage of the given behaviour out of the total observed time. The total observed time was 1800 seconds for each calf. The duration of behaviour was calculated with the example of the two calves below:

	Positive behaviour	Negative behaviour	Lying	Standing	Waste time	Observed time
Calf1	61 s	15 s	960 s	584 s	90 s	1710 s
Calf2	0 s	102 s	60 s	1638 s	0 s	1800 s

All observations were calculated in duration in seconds.

The percentage of observed time was calculated as follows (calf1): 61 s/1710 s= 0.036*100= 3.6 %. This means that calf1 used 3.6 % of the observed time on positive behaviour. Calf1 used most of the observed time on lying (56.1 %). On the contrary calf2 used most of the observed time on standing.

Statistical methods

To compare the observed proportion of time the calves spent on the respective behaviours, the data from the two housing systems was all log-transformed, except "standing" where the original data was used to further analysis due to a better normal distribution. The data was t-tested to compare the systems.

The median, 5 % and 95 % percentiles were used due to data not being normally distributed. The percentiles will be referred to as "perc".

Results

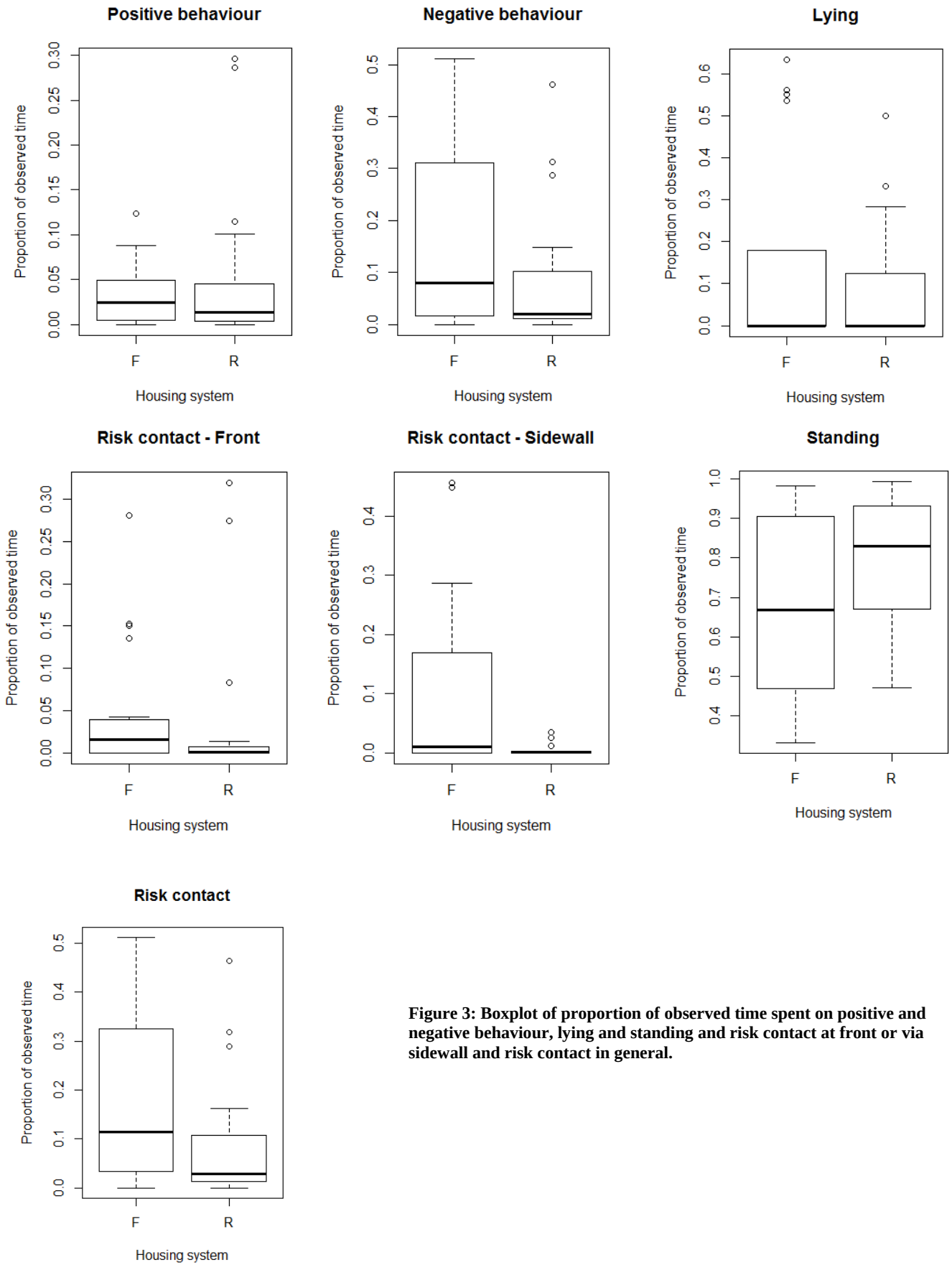


Figure 3: Boxplot of proportion of observed time spent on positive and negative behaviour, lying and standing and risk contact at front or via sidewall and risk contact in general.

Behaviour

In the study data it was found that calves overall spent most of the observed time on standing with a median of 0.71 (5-95 % perc: 0.52-0.98). There was no statistical significant difference (t=-1.21, p=0.23) between the proportion of observed time spent on standing in the two housing systems.

The second most frequent behaviour of the observed time was spent on negative behaviour with a median of 0.05 (5-95 % perc: 0.00-0.44), and there was no significant difference (t=1.41, p=0.17) between the two housing systems. During the study it was observed that when the calves performed negative behaviour of sucking or licking on inventory it was especially on metal fixtures in the pen.

The positive behaviour with a median of 0.02 (5-95 % perc: 0.00-0.12) showed no significant difference (t=-0.15, p=0.88) between the proportion of observed time spent on positive behaviour in the two housing systems.

The time spent on lying with a median of 0.00 (5-95 % perc: 0.00-0.55) was the behaviour done the least and showed no significant difference (t=0.82, p=0.42) between the two housing systems.

Risk contact

The median of the risk contact in general 0.05 (5-95 % perc: 0.00-0.45) showed no statistical significant difference between the housing systems (t=1.83, p=0.08). However, the calves housed in open housing had a median of 0.12 and calves housed restricted had a median of 0.03.

The observed time the calves spent on risk contact via the sidewall had a median of 0.002 (5-95 % perc: 0.00-0.29) and a significant difference (t=2.97, p=0.006) between two housing systems. The calves housed with open housing had a median on 0.011 and had more contact via the sidewall, compared to the calves housed restricted with a median of 0.001.

The risk contact at the front of the housing system with a median of 0.001 (5-95 % perc: 0.00-0.27) showed, on the contrary no significant difference (t=1.31, p=0.20) between the proportion of observed time spent on risk contact.

The minimum, median, mean and maximum values for the respective observations can be found in "Appendix 1".

For standing, lying, positive and negative behaviour and risk contact at the front, we cannot reject H_0 because the p-values were higher than 0.05. Based on this, there was no difference between the

two housing systems and the observed time spent on standing, lying, positive and negative behaviour and risk contact at the front.
For the risk contact via the sidewall, we can reject H_0 because the p-value was lower than 0.05. This means that there is a difference between the two housing systems and the observed time spent on risk contact via the sidewall.

Making a summary; overall, the calves used most of the observed time on standing and second most on negative behaviour. The calves housed restricted spent more time on standing than calves housed in open housing. Furthermore, when only looking at the risk contact of transmission of pathogens, the calves housed with open housing, used more of the observed time on contact via the sidewall, compared to calves housed restricted.

Discussion

The farmers need to ensure good welfare for the calves; this means e.g. that the calves need to be free of thirst, hunger, diseases and injuries (LBK. No. 252 of 08/03/2013). Combined with the welfare aspect the farmer needs to follow the laws by housing the calves so they can see and touch each other (BEK No. 1075 of 22/12/1997). Especially the housing of the calves has caused trouble for some farmers, because the legislations are not very clear about how the pens or huts should look.

The calves housed in open housing spent more of the observed time on risk contact in general and furthermore on risk contact via the sidewall, compared to calves housed restricted. The calves housed in open housing had a front yard with metal bars as the separating wall between the calves. The reason why these calves had more risk contact via the sidewall than the calves housed restricted might have been because the calves housed with open housing had greater possibility of contact than the calves housed restricted. Hence, the calves housed restricted, only had a window of 40x40 cm's to make contact through and the calves had to be close to the window to see the neighbour calf. Also, the calves housed restricted might have preferred to make contact at the front because they did not notice the calf through the window in the sidewall. The calves housed with open housing had full possibility to make contact with the neighbour, compared to the calves housed restricted. Additionally, some of the calves housed restricted, might not have had time to get used to the plastic on the sidewalls, hence some of the calves had already been housed in the hut for some time, compared to other calves who got taken from the dam and put into a hut already equipped with plastic. This might have had an impact on the lower amount of observed time spent on contact via the sidewall and the reason for the significant difference between the two housing systems.

Negative behaviour was characterised as sucking on fixtures and cross-sucking. During the observations it was found that the calves sucked mostly on the neighbour calf's muzzle and ears in accordance to Lidfors' (1993) findings. The negative behaviour might correspond from being milk fed which stimulates sucking and cross-sucking (Lidfors, 1993). In particular the muzzle of the calves got smeared with milk; this might have led to further cross-sucking between the calves. However, the study did not show any difference between the time spent on negative behaviour and the housing system.

When housing calves without any contact to other calves it will make them more afraid and more reluctant to make contact with other calves when grouped at a later stage (Jensen, et al., 1997; Jensen, et al., 1999). One of the owners of the farms visited in this project has experienced the same thing. He had previously housed calves in huts with no front yard but after the law demanded that the calves have to be able to see and touch other calves, he bought front yards to the huts. The farmer observed that when he grouped the calves after being housed individually, the calves' behaviour changed from being much attached to the farmer who fed them, and afraid of the other calves, to being more outgoing and interested in the other calves in the pen. The farmer sees this change in behaviour as a good thing, because the calves seem more lively and less stressed (Anonymous, 2013). Undoubtedly, others farmers have experienced the same thing, and the observations by the farmer should stand as an example for others farmers awareness and care for the calves.

In this study, there were no significant differences between the calves' behaviour in the two housing systems. The only observed difference between the housing systems was the time spent on risk contact.

The breeds in the present study were Holstein, RDM and Jersey and there were one farm per breed. However, further studies of the breeds were not performed due to the large effect of the farms on the breeds. This might mean that there was in fact a difference between the breeds, but there was no statistical background for an analysis. Boxplots and histograms can be found in "Appendix 1".

Some of the calves were observed with diarrhoea and pneumonia and under treatment. The calves could have been dehydrated or in other ways weakened, thus, the results might be influenced by this fact. No multivariable analysis was made with sick or not as influence due to few data observations.

A higher density, number of calves, would probably have made the study more accurate. In addition to the density, the weather might have had an influence. On some of the observed days the weather was very cold and windy with snow, which might have made the calves stay more in the huts, just standing.

The data material analysed in this study was not sufficient to be used in a proper analysis, thus a more standardized study with less bias was needed.

Conclusion

There were no significant differences between the calves' behaviour in the two housing systems. The only observed difference between the housing systems was the time spent on risk contact; hence the calves housed with open housing had more contact via the sidewall.

Paper

Effect of dairy calf housing systems on social behaviour and contact patterns.

Abstract

Housing of dairy calves can be designed in many ways; such as group housing or individual housing in different ways, as long as the welfare of the calves is taken into account. When assessing welfare the calves' behaviour is, among others things, observed and evaluated based on positive or negative behaviour. Positive behaviour can be characterised as jumping around in the pen and performing play behaviour and negative behaviour as cross-sucking or sucking on fixtures. Calves tend to have more positive behaviour and more locomotor activity when housed in groups, compared to individual housed calves (Jensen, et al., 1998; Bøe and Færevik, 2003). However, from a "protection against infections" point of view, individual housing is preferable due to the lower risk of contact and thereby less transmission of pathogens.

The aim of this study was to see if there was a difference between different housing systems and the risk of transmission of pathogens and the behaviour of calves in individual housing systems. The study was based on four different housing systems, with different designs and availability of contact between the calves.

The study showed no differences between the calves' behaviour and the housing systems. Also, regardless of the housing system, no differences were seen in the contact at the front of the housing systems, thus the risk of transmission of pathogens was the same for all housing systems. However, when regrouping the calves based on the ability to make contact at the front or not, the calves housed with no ability of making contact at the front, had the most risk contact via the sidewall.

Introduction

From a welfare perspective, housing calves in groups is often preferable compared to individual housing (Svensson and Liberg, 2006) and if the calves could choose they would value full contact more than contact through bars (Holm, et al., 2002). Additionally, play behaviour has been proven to be a good indicator of welfare, and calves in groups have more play behaviour than calves housed individually (Jensen, et al., 1998; Chua, et al., 2002). When housing calves it might work best for some farmers to house the calves in groups, while it might be best for others with individual housing. Inevitably, it comes down to that the calves' behaviour is influenced both by management by the farmer and the housing facilities (Bøe and Færevik, 2003),

Individual housing is supposed to reduce the transmission of pathogens between the calves (Rushen, et al., 2008), but it might depend on the design of the individual housing system. Some housing systems give the calves great opportunity to touch another calf and thereby might transmit pathogens, while other housing systems make transmission harder by only allowing a window in the sidewall of the pen to make contact. The Danish legislation about "Housing and protection of calves", state that single pens have to be equipped with openings in the sidewalls which gives the calves the opportunity to see and touch other calves (BEK No. 1075 of 22/12/1997). These criteria can be interpreted in many ways and the design of these housing systems can be very varying in size and shape.

Svensson et al., 2003 found that the disease incidence was the highest during the calves second week of life, this might support the reasoning behind keeping the calves housed as individually as possible. Studies have shown that individual housing could have an effect on production economy and animal welfare (Bøe and Færevik, 2003), but after a few weeks of being grouped with unknown calves, there is no difference in the behaviour between the calves from one housing system to the other (Veissier, et al., 1994; Jensen, et al., 1997). The calves housed individually do not achieve as much social stimulus and locomotor play as calves house in groups; this might be due to the smaller space allowance individually housed calves are given compared to group housed calves (Jensen, et al., 1998; Bøe and Færevik, 2003).

The design of the housing system might have influence on the calves' behaviour, such as how much they are able to perform play behaviour or unwanted behaviour. Furthermore the design of the housing system has different benefits and challenges, such as how easy it is to clean and especially

how much contact and consequently how much the risk of transmitting pathogens between the calves in the respective housing system is. It might not be possibly to say that one is better than the other.

The aim of this study was to see if there was a difference between 4 different housing systems and the risk of transmission of pathogens and the behaviour, of 8-49 days old calves in 11 Danish dairy farms.

Materials & Methods

Farms, calves & housing

The study consisted of 11 dairy farms: 1 RDM, 3 Holstein/RDM and 7 Holstein. The farms housed calves in either huts with a front yard (6 farms) or pens with homemade holes in the sidewalls (5 farms), all with straw bedding. The chosen calves were milk fed in bowls twice a day and had an age interval of 8-49 days. A number of 2-4 calves per farm were filmed in February 2013 (n=6) and November 2013 (n=33).

The calves were divided into 4 different groups:

Figure 4: Group A: Huts with front yard and the possibility of contact at the front of the front yard (3 farms)

Figure 5: Group B: Homemade holes in the sidewalls and the possibility of contact at the front (4 farms)

Figure 6: Group C: Huts with front yard and <u>without</u> the possibility of contact at the front of the front yard (3 farms)

Figure 7: Group D: Homemade holes in the sidewall and <u>without</u> the possibility of contact at the front (1 farm)

Recordings

A camera was placed in front of the 4 calves and left without the presence of unfamiliar people, i.e the observer.

The camera filmed for half an hour before and after milk feeding, giving a total of approximately one hour material. The film material was used to observe and record behaviour for 15 min before milk feeding, no observation during eating, and 15 min after stop of eating. The filming was performed around the time of feeding because calves generally are more active around feeding time (Jensen, et al., 1998), so this would provide a better data foundation for statistical comparisons.

Behaviour

The analysis was based on the calves' behaviour which was divided into positive and negative behaviour and time spent on lying and standing. It was also analysed how much time the calves spent on contact where there was a risk of transmission of pathogens, this will be referred to as risk contact.

The positive behaviour was characterised by self-grooming, playing with or without the neighbour and touching noses with the neighbour. The negative behaviour was characterised by licking or sucking on fixtures and cross-sucking, meaning sucking on a neighbour calf (Munksgaard and Søndergaard, 2006). The lying was when the calves were lying down in the pen or hut. Standing was characterised as the time the calves spent on standing and looking around. The risk contact was characterised by every contact between the calves e.g. touching noses or other parts of the body or when the calves were cross-sucking either at the front of the housing system or via the sidewall and contact in general.

Outcome

The outcome of interest was the percentage of the observed time of a given behaviour out of the total time observed. The total observed time was 1800 seconds for each calf. Due to snow on the lens and bad angle of the camera, some of the calves' behaviour was unable to be observed, this was referred to as "waste time". The waste time was subtracted from the total observed time. When waste time, lying time, positive and negative behaviour was subtracted from the observed time, the time referred to as "standing" was left.

The duration of behaviour was calculated in following way:

	Positive behaviour	Negative behaviour	Lying	Standing	Waste time	Observed time
Calf1	61 s	15 s	960 s	584 s	90 s	1710 s
Calf2	0 s	102 s	60 s	1638 s	0 s	1800 s

All observations were calculated in duration in seconds.

The percentage of observed time was calculated as follows (Calf1): 60s/1710s = 0.036*100= 3.6 %.

This means that calf1 used 3.6 % of the observed time on positive behaviour. Calf1 used most of the observed time on lying (56.1 %). On the contrary, calf2 used most of the observed time on standing.

Statistical methods

The videos were analysed by looking at the duration of a specific behaviour which was converted into proportion of total time observed. All data was log-transformed to give a better normal distribution, except "standing" due to a better normal distribution in the original data. Analysis of variance was used to compare the groups.

Group D was not included in the further analysis due to lack of data. Furthermore, the observed time spent on lying was not analysed due to lack of observations.

The median, 5 % and 95 % percentiles was used due to the data not being normally distributed. The percentiles will be referred to as "perc".

Results

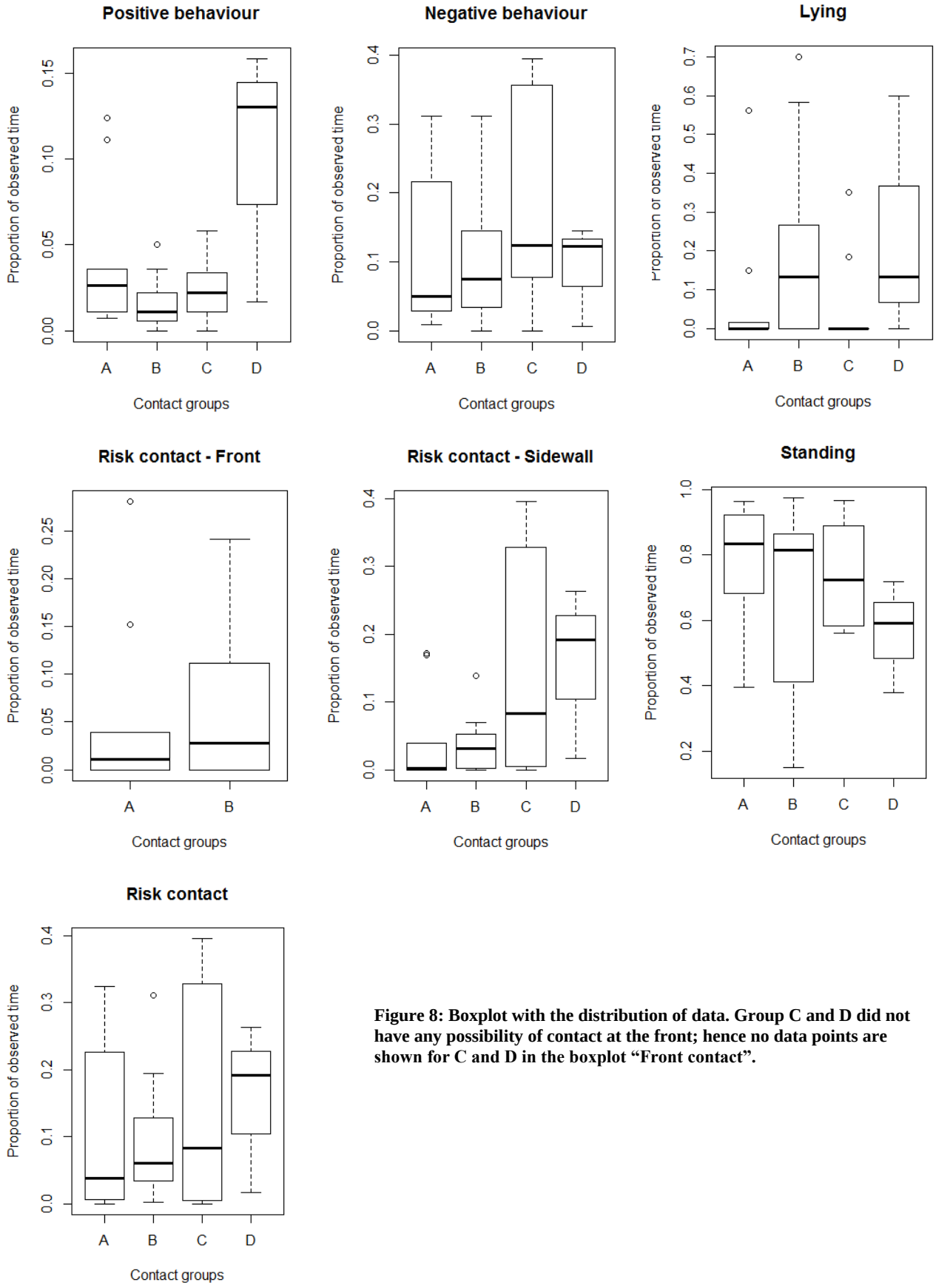


Figure 8: Boxplot with the distribution of data. Group C and D did not have any possibility of contact at the front; hence no data points are shown for C and D in the boxplot "Front contact".

Descriptive data

Behaviour

In the study data, it was found that calves overall spent most of the observed time on standing with a median of 0.81 (5-95 % perc: 0.37-0.97). The second most frequent behaviour of the observed time was spent on negative behaviour with a median of 0.08 (5-95 % perc: 0.01-0.36) and then positive behaviour with a median of 0.02 (5-95 % perc: 0.003-0.13). The behaviour done the least during the observed time was lying with a median of 0.00 (5-95 % perc: 0.00-0.59).

Risk contact

The median of the risk contact in general was 0.05 (5-95 % perc: 0.00-0.34). The proportion of observed time spent on risk contact at the front with a median of 0.02 (5-95 % perc: 0.00-0.23) were only available for group A and B. The risk contact via the sidewall with a median of 0.03 (5-95 % perc: 0.00-0.34) was available for all groups, but the only way of contact for calves housed in group C and D.

Analysis of variance

Group D and the observed time spent on lying, were not included in the further analysis due to lack of data. Group D consisted of one farm with 3 observed calves.

Behaviour

The observed time the calves spent on standing ($p=0.53$) showed no significant difference between the three groups, the same was the case for negative behaviour ($p=0.46$) and positive behaviour ($p=0.21$).

Risk contact

No significant difference between the housing systems and the time spent on risk contact in general ($p=0.65$) was seen. The proportion of observed time spent on risk contact via the sidewall showed no significant difference ($p=0.11$) between the housing systems and likewise for the proportion of observed time spent on risk contact at the front of the housing system ($p=0.44$).

Group A and B were put into one group and compared to group C. The proportion of observed time spent on risk contact via the sidewall showed no statistical significant difference between the two groups ($p=0.057$), however, the calves housed in group C had more risk contact via the side wall with a median of 0.08 compared to calves housed in group A+B with a median of 0.006.

Summary

A summary of the results tells us that the housing system had no significant influence on the observed time the calves spent on standing, positive and negative behaviour. Furthermore, no significant difference was found between the housing systems and the time spent on risk contact in general, at the front and trough the sidewall. However, when regrouping group A and B together and comparing them with group C; group C had more risk contact via the sidewall.

The minimum, median, mean and maximum values can be found in "Appendix 2".

Discussion

The calves spent 81 % of the observed time on standing, often looking at things happening at the farm. The calves performed negative behaviour such as cross-sucking or sucking on fixtures in 8 % of the observed time. Cross-sucking is characterised as an abnormal behaviour and detrimental for the health of calves (de Passillé, et al., 1992). In this study, cross-sucking was limited to the ears and muzzle, as in the study by Lidfors (1993). The housing systems observed in this study made it hard for the calves to cross-suck other places than the ears and muzzle, also it has been found that cross-sucking might often be limited to the head and muzzle due to frequently being smeared with milk (Jensen and Budde, 2006), this might correlate with the present study.

Regardless of the housing system, no statistical significant differences were found in the observed time spent on either positive or negative behaviour. Several studies have shown that calves need space to be able to perform positive behaviour such as running back and forth in the pen and jumping in the air with or without seeking out the neighbour (Jensen, et al., 1998), but in the present study no significant differences were found on space allowance and observed time spent on positive or negative behaviour. However, it could be argued that a longer duration of observed time could give other results, such as the calves housed with a hut and a front yard have twice as much space allowance and are therefore able to perform more play behaviour and locomotor activity, but this was not the case in the present study.

The calves housed in group C spent 8.3 % of the observed time on risk contact trough the sidewall compared to the calves in group A+B who spent 0.6 %. Group C's only possibility of contact with the neighbour calves was via the sidewall, while group A+B only spent 2.2 % of the observed time

on risk contact at the front. This result might mean that calves housed without the possibility of contact through the front, will have more risk contact in general; hence the calves in group C spent 8.3 % of the observed time on risk contact in general, compared to 3.7 % in group A and 6.1 % in group B.

The disease status, if any, was in this study unknown. Some of the calves in the study were observed with diarrhoea, which might have had an effect on the calves behaviour and willingness to perform any kind of behaviour and contact. In a perfect study the disease status would be taken into account in a multivariable analysis, but this was not possibly in the present study due to lack of data.

To observe more behaviour the calves should be observed for a longer duration than 1800 seconds. This might give a better estimate of the calves' behaviour and if there is a true risk of transmission of pathogens or not.

Despite trying to select farms within the parameters wanted, it was not possible to observe farms that were completely alike, due to the designs of the housing systems not being as expected on the day of observation.

Conclusion

The study showed that the calves spent most of the observed time on standing. There were no differences between the calves' behaviour and the housing systems. Furthermore, regardless of the housing system, no differences were seen in the contact at the front of the housing systems, thus the risk of transmission of pathogens might be the same for all housing systems. However, when regrouping the calves based on the ability to make front contact or not, the calves housed in group C, with no ability of making contact at the front, had the most risk contact via the sidewall.

Housing calves in different systems did not have a statistical significant effect on the calves' behaviour or the risk contact of transmitting pathogens.

Overall conclusion

Both studies showed no statistical significant differences between the calves behaviour and the housing the systems. Furthermore, regardless of the housing system, no differences were seen in the contact at the front of the housing systems. However, calves housed in a hut with an open front yard had more contact via the sidewall, compared to calves housed in a hut with a window in the sidewall of the front yard. Also calves housed unable to make contact at the front had more contact via the sidewall, compared to calves housed in the other housing systems.

The studies show that calves might have more contact with a risk of transmission of pathogens, when housed in a hut with a front yard with metal bars.

Perspectives

To observe more behaviour the calves should be observed for a longer duration than 1800 seconds. In the above studies the calves were only observed around feeding time. Studies have shown that calves have a high level of play behaviour and locomotor activity around the spreading of straw (Jensen, et al., 1998), which might give another outcome than the present studies.

When calves are housed in small groups < 8 they have a lower risk of transmission of diarrhoea and respiratory tract infection (Svensson, et al., 2003) and stable groups gain more weight and have a lower incidence of diseases compared to calves housed in changing groups (Pedersen, et al., 2009). Furthermore, group housing gives the calves opportunity to perform social behaviour and locomotor activity (Bøe and Færevik, 2003; Stull and Reynolds, 2008). Group housing might be a good alternative to individual housing due to the above findings and might take the calves' behaviour into account. Additionally, when housing calves in a group from birth, it is possible to isolate the groups from each other. Also, Svensson et al. (2003) found that the disease incidence was highest during the calves second week of life, and by housing the calves in groups from their birth it is possible to keep the risk of transmission within the group.

When improving a farm's disease status an alternate option instead of individual housing or group housing, could be housing in pairs, hence the calves housed in pairs will have more social behaviour than calves housed individually (Duve and Jensen, 2012). Housing calves in pairs might reduce the spread of pathogens to all calves and improve the calves' social behaviour which is an important aspect in the assessment of welfare. Furthermore, the thesis showed that the calves will tend to have contact via the sidewall, when housed in a hut with front yard. Chua et al. (2002) found no difference in weight gain and health compared to calves housed in single pens. Therefore it might be argued that it is beneficial to house calves in pairs, due to the increased space allowance, improved social contact and no difference in health and weight gain.

During both studies it was observed that the calves got a varying amount of milk distributed, this might give the calves different terms to cope with and might give the calves an uneven weight gain. Furthermore, it was observed that when the calves needed help drinking milk, the helper did not switch gloves between the calves. This means that even though the farmer might house the calves with the minimum risk of transmission of pathogens, the helper might transmit pathogens from one calf to another, by putting the same gloved fingers in the mouth of different calves. So regardless of

the housing system, it comes down to management as Bøe & Færevik (2003) also noted in their study.

By talking to farmers visited in the standardized study, there was a general concern and frustration regarding the design of the calves housing systems. The farmers were frustrated about the lack of instructions concerning the holes in the sidewall. It seems there is a need for accurate instructions for the farmers as well as for the controlling authority to avoid confusion and frustration from both sides. The holes in the sidewalls are meant to ensure good welfare for the calves, thus it might be rewarding for the calves to agree about how the design should look like.

This thesis showed no differences in the calves' behaviour, regardless of the housing system. In a new study it might be relevant to have a bigger sample size and only two different housing systems to compare, as in the pilot study. This might limit the bias to a minimum. One breed might also be preferable; hence the effect of the breeds in this thesis is unknown.

References

Anonymous (2013): Interview with dairy cattle farmer.

Babu, L.K., Pandey, H.N. & Sahoo, A. (2004): Effect of individual versus group rearing on ethological and physiological responses of crossbred calves. *Applied Animal Behaviour Science.* Vol. 87:3–4, pp. 177-191.

BEK No. 1075 of 22/12/1997 (1997): Ministry of Justice.

BEK No. 999 of 14/12/1993 (1993): Ministry of Justice.

Bøe, K.E. & Færevik, G. (2003): Grouping and social preferences in calves, heifers and cows. *Applied Animal Behaviour Science.* Vol. 80:3, pp. 175-190.

Chua, B., Coenen, E., van Delen, J. & Weary, D.M. (2002): Effects of Pair Versus Individual Housing on the Behavior and Performance of Dairy Calves. *Journal of Dairy Science.* Vol. 85:2, pp. 360-364.

de Passillé, A.M.B., Metz, J.H.M., Mekking, P. & Wiepkema, P.R. (1992): Does drinking milk stimulate sucking in young calves? *Applied Animal Behaviour Science.* Vol. 34:1–2, pp. 23-36.

Duve, L.R. & Jensen, M.B. (2012): Social behavior of young dairy calves housed with limited or full social contact with a peer. *Journal of Dairy Science.* Vol. 95:10, pp. 5936-5945.

EU-directive 2008/119/EF (2009): *Directive of 2008/119/EF of December 18th 2008, laying down minimum standards for the protection of calves
*, Den Europæiske Unions Tidende [cited 01/16]. <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32008L0119:en:NOT>.

European Commision (2012): *What are EU directives*, 2012/06/25, European Commision, [cited 12/05]. <http://ec.europa.eu/eu_law/introduction/what_directive_en.htm>.

Farm Animal Welfare Council (2011): *Report on Priorities for Animal Welfare Research and Development*, [cited 01/15]. <http://www.fawc.org.uk/pdf/old/animal-welfare-priorities-report-may1993.pdf>.

Forkman, B. (2010): *Welfare Assessment and control,* Ministy of Food, Agriculture and Fisheries, Danish Veterinary and Food Administration, Danish Center for Animal Welfare [cited 01/16]. <https://www.foedevarestyrelsen.dk/Publikationer/Alle%20publikationer/2012090.pdf>.

FVST (2011): *Instruction for welfarecontrol in cattlefarms,* [cited 01/16]. <http://www.foedevarestyrelsen.dk/SiteCollectionDocuments/25_PDF_word_filer%20til%20download/05kontor/Dyrevelf%C3%A6rd%20Instrukser%20Tjeklister%202012/Instruks%20kv%C3%A6g%20okt%202011.pdf>.

Holm, L., Jensen, M.B. & Jeppesen, L.L. (2002): Calves' motivation for access to two different types of social contact measured by operant conditioning. *Applied Animal Behaviour Science.* Vol. 79:3, pp. 175-194.

Jensen, M.B. & Budde, M. (2006): The Effects of Milk Feeding Method and Group Size on Feeding Behavior and Cross-Sucking in Group-Housed Dairy Calves. *Journal of Dairy Science.* Vol. 89:12, pp. 4778-4783.

Jensen, M.B. (2001): A note on the effect of isolation during testing and length of previous confinement on locomotor behaviour during open-field test in dairy calves. *Applied Animal Behaviour Science.* Vol. 70:4, pp. 309-315.

Jensen, M.B., Munksgaard, L., Mogensen, L. & Krohn, C.C. (1999): Effects of Housing in Different Social Environments on Open-field and Social Responses of Female Dairy Calves. *Acta Agriculturae Scandinavica: Section A, Animal Science.* Vol. 49:2, pp. 113-120.

Jensen, M.B., Vestergaard, K.S. & Krohn, C.C. (1998): Play behaviour in dairy calves kept in pens: the effect of social contact and space allowance. *Applied Animal Behaviour Science.* Vol. 56:2–4, pp. 97-108.

Jensen, M.B., Vestergaard, K.S., Krohn, C.C. & Munksgaard, L. (1997): Effect of single versus group housing and space allowance on responses of calves during open-field tests. *Applied Animal Behaviour Science.* Vol. 54:2–3, pp. 109-121.

LBK. No. 252 of 08/03/2013 (2013): Ministry of Food, Agriculture and Fisheries (FVST).

Lidfors, L.M. (1993): Cross-sucking in group-housed dairy calves before and after weaning off milk. *Applied Animal Behaviour Science.* Vol. 38:1, pp. 15-24.

Losinger, W.C. & Heinrichs, A.J. (1997): Management practices associated with high mortality among preweaned dairy heifers. *Journal of Dairy Research.* Vol. 64:01, pp. 1-11.

Munksgaard, L. & Søndergaard, E. (2006): DJF Rapport - Velfærd hos malkekøer og kalve. 74.

Nielsen, T.D., Vesterbæk, I.L., Kudahl, A.B., Borup, K.J. & Nielsen, L.R. (2012): Effect of management on prevention of Salmonella Dublin exposure of calves during a one-year control programme in 84 Danish dairy herds. *Preventive Veterinary Medicine.* Vol. 105:1–2, pp. 101-109.

OIE Code Commission (2013): *Introduction to the recommendations for animal welfare,* [cited 01/15]. <http://www.oie.int/index.php?id=169&L=0&htmfile=chapitre_1.7.1.htm>.

Pedersen, R.E., Sørensen, J.T., Skjøth, F., Hindhede, J. & Nielsen, T.R. (2009): How milk-fed dairy calves perform in stable versus dynamic groups. *Livestock Science.* Vol. 121:2–3, pp. 215-218.

Phillips, C.J.C. (2004): The Effects of Forage Provision and Group Size on the Behavior of Calves. *Journal of Dairy Science.* Vol. 87:5, pp. 1380-1388.

Rushen, J., Passillé, A.M., Keyserlingk, M.A.G. & Weary, D.M. (2008): *The Welfare of Cattle.* Springer, The netherlands.

Sivula, N.J., Ames, T.R., Marsh, W.E. & Werdin, R.E. (1996): Descriptive epidemiology of morbidity and mortality in Minnesota dairy heifer calves. *Preventive Veterinary Medicine.* Vol. 27:3–4, pp. 155-171.

Stig Jessen (2013): Personal telephone Interview, December 15th 2013.

Stull, C. & Reynolds, J. (2008): Calf Welfare. *Veterinary Clinics of North America: Food Animal Practice.* Vol. 24:1, pp. 191-203.

Svensson, C. & Liberg, P. (2006): The effect of group size on health and growth rate of Swedish dairy calves housed in pens with automatic milk-feeders. *Preventive Veterinary Medicine.* Vol. 73:1, pp. 43-53.

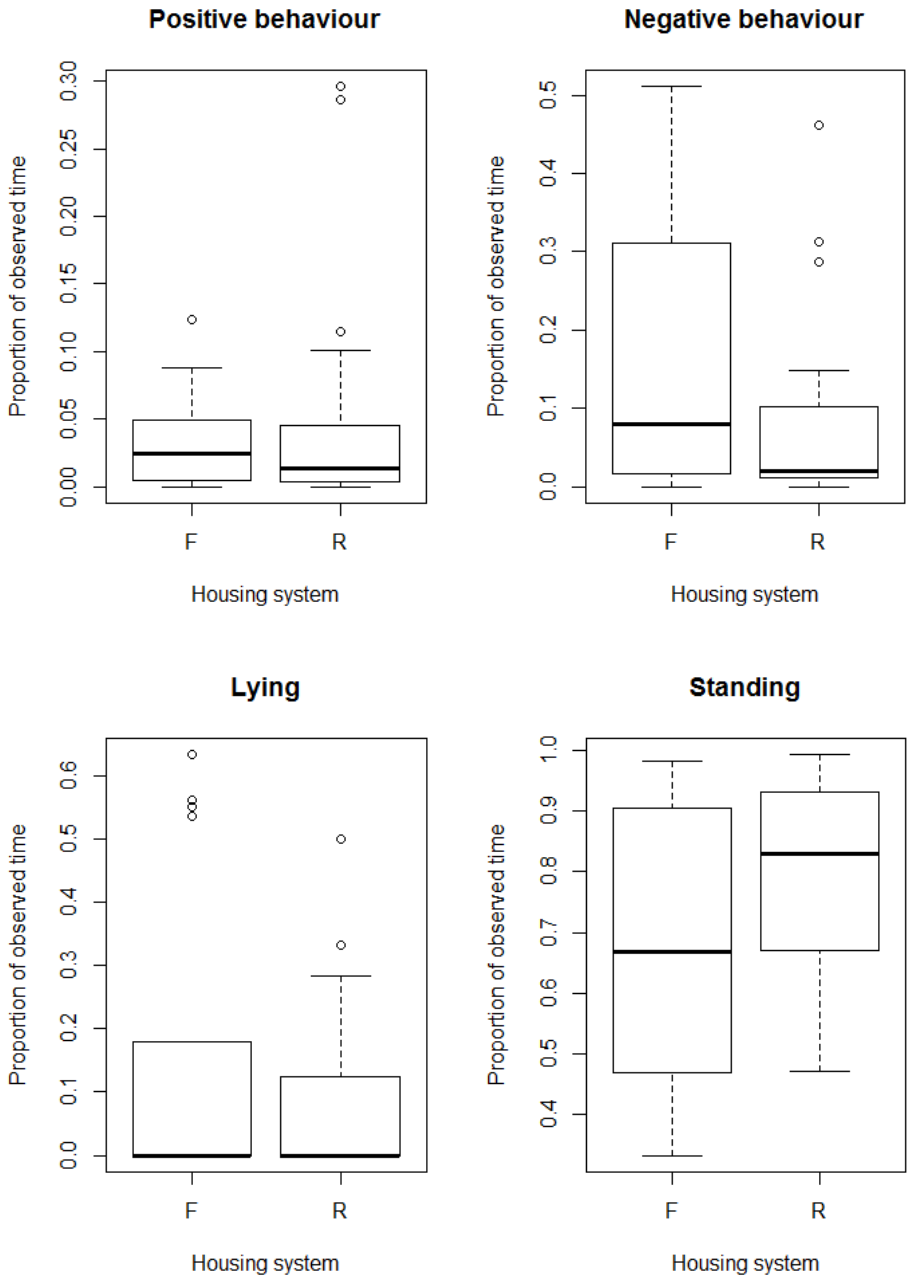
Svensson, C., Lundborg, K., Emanuelson, U. & Olsson, S. (2003): Morbidity in Swedish dairy calves from birth to 90 days of age and individual calf-level risk factors for infectious diseases. *Preventive Veterinary Medicine.* Vol. 58:3–4, pp. 179-197.

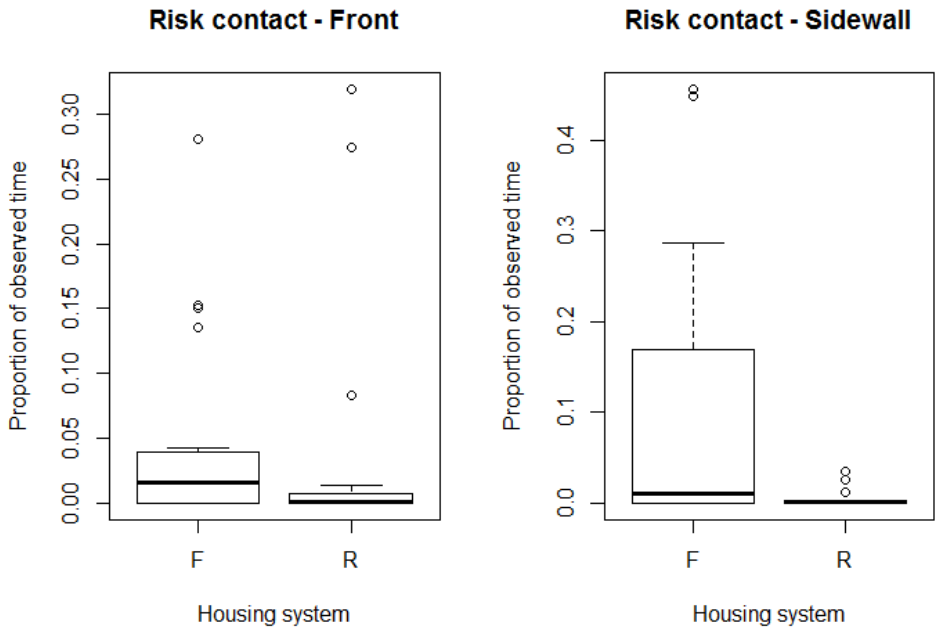
Veissier, I., Gesmier, V., Le Neindre, P., Gautier, J.Y. & Bertrand, G. (1994): The effects of rearing in individual crates on subsequent social behaviour of veal calves. *Applied Animal Behaviour Science.* Vol. 41:3–4, pp. 199-210.

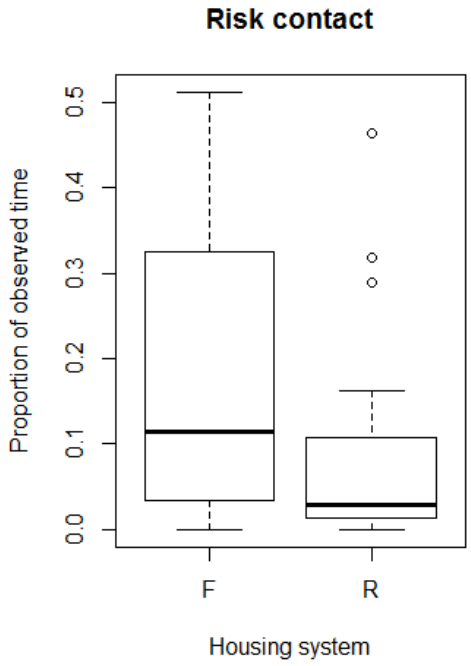
Welfare Quality® (2009): *Assessment protocol for cattle,* Welfare Quality® Consortium, Lelystad, Netherlands [cited 01/16]. <http://www.welfarequalitynetwork.net/network/45848/7/0/40;>.

Appendix 1

Pilot study



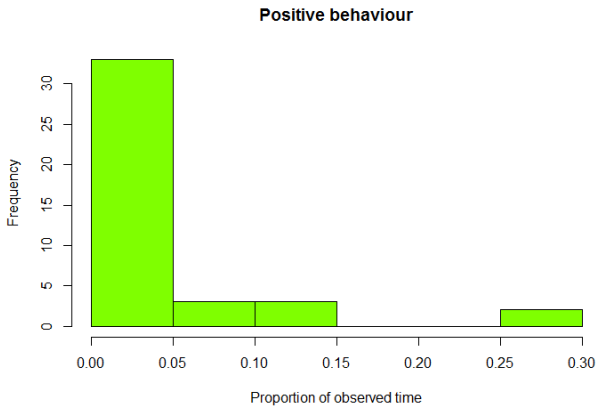

Risk contact - Front
Proportion of observed time
0.00
0.05
0.10
0.15
0.20
0.25
0.30
F
R
Housing system
Risk contact - Sidewall
Proportion of observed time
0.0
0.1
0.2
0.3
0.4
F
R
Housing system

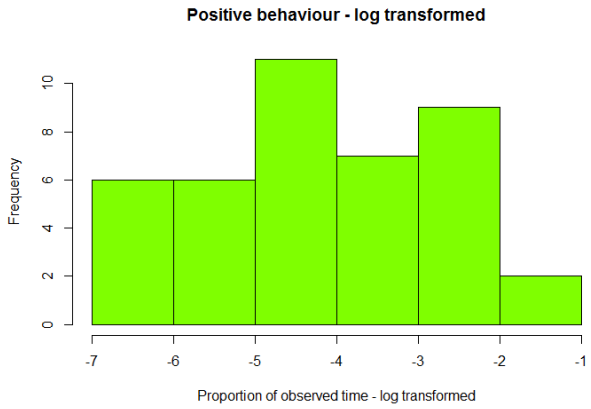

Risk contact
Proportion of observed time
0.0
0.1
0.2
0.3
0.4
0.5
F
R
Housing system

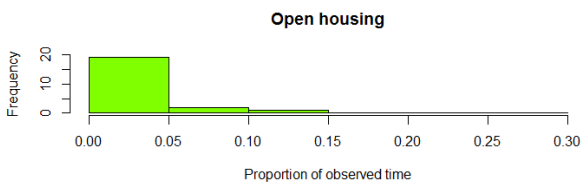
Positive behaviour

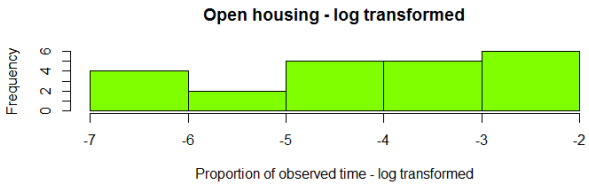
Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD*
0.000	0.000	0.004	0.015	0.040	0.049	0.124	0.296	0.066

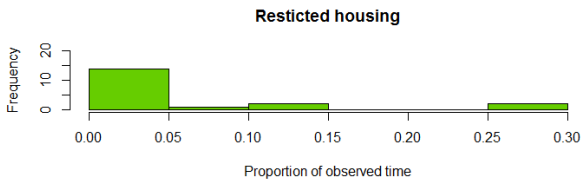
*SD: Standard Deviation

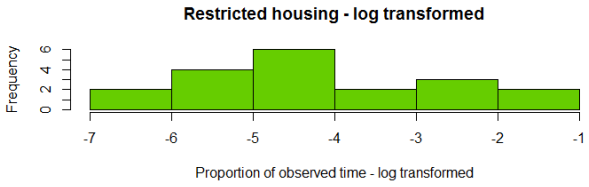












Open housing:

Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.000	0.000	0.006	0.025	0.030	0.047	0.087	0.124	0.032

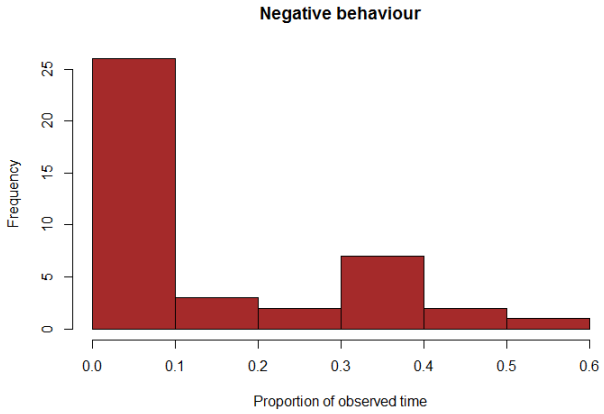
Restricted housing:

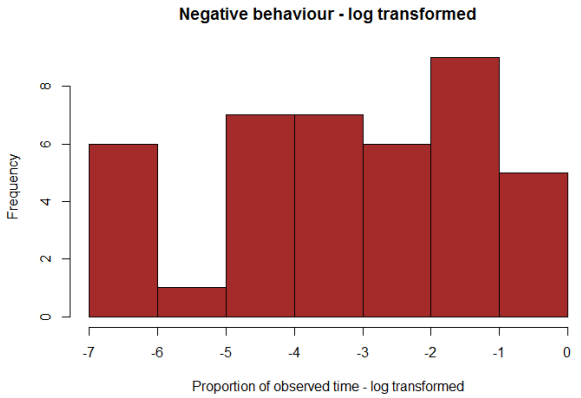
Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.000	0.000	0.004	0.014	0.053	0.046	0.287	0.296	0.090

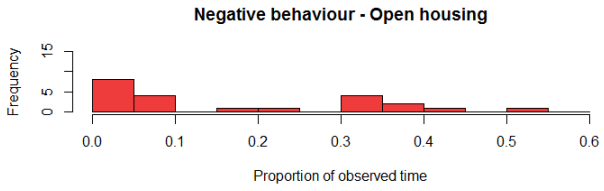
The t-test shows that the p-value was 0.879 (t=-1.153).

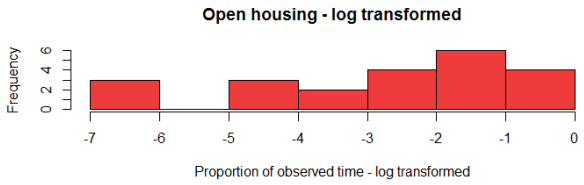
Negative behaviour

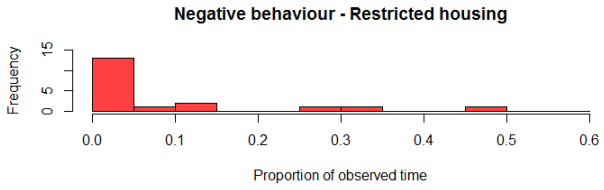
Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.000	0.000	0.015	0.046	0.130	0.287	0.435	0.511	0.156

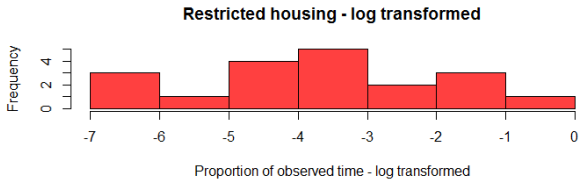












Open housing:

Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.000	0.000	0.020	0.081	0.168	0.311	0.432	0.511	0.169

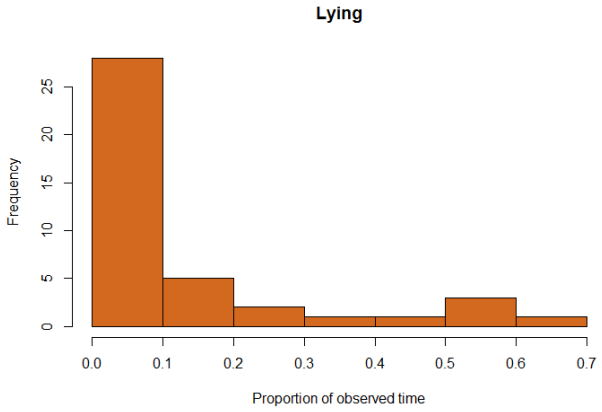
Restricted housing:

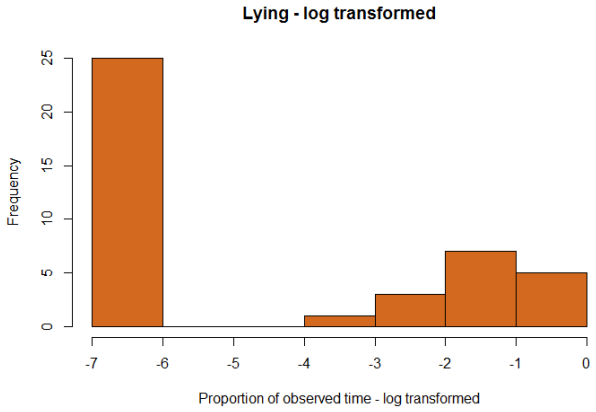
Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.000	0.000	0.012	0.020	0.085	0.102	0.327	0.461	0.130

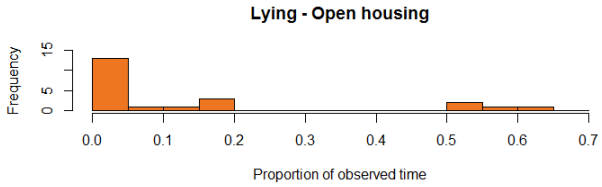
The t-test shows that the p-value was 0.168 (t=1.405).

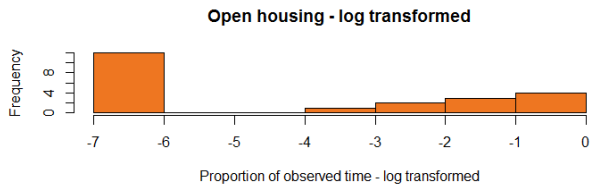
Lying

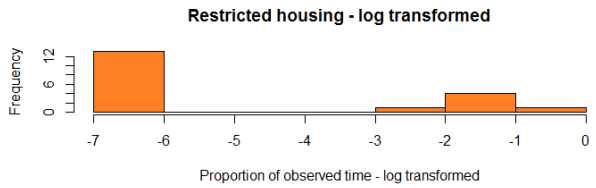
Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.000	0.000	0.000	0.000	0.113	0.167	0.550	0.633	0.188











Open housing:

Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.000	0.000	0.000	0.000	0.139	0.176	0.561	0.633	0.218

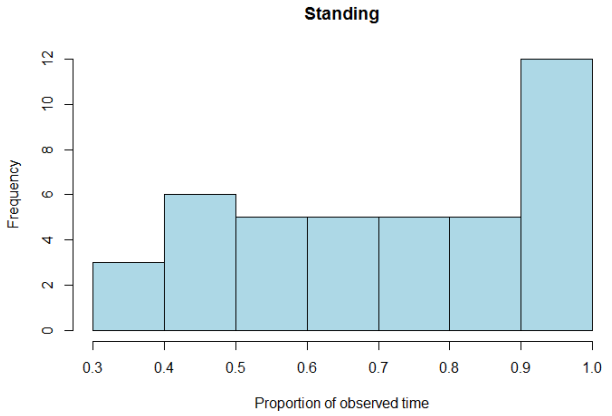
Restricted housing:

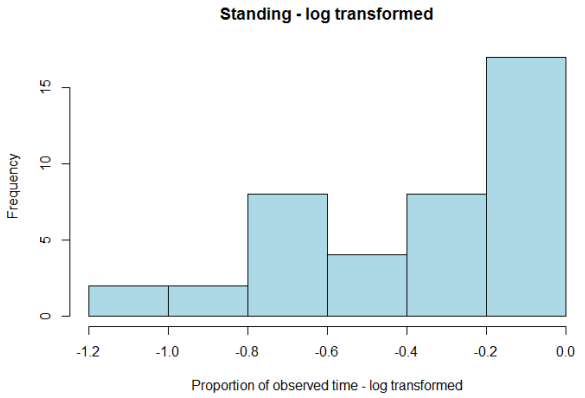
Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.000	0.000	0.000	0.000	0.836	0.125	0.350	0.500	0.147

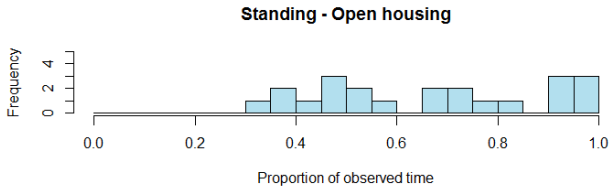
The t-test shows that the p-value was 0.416 (t=0.821).

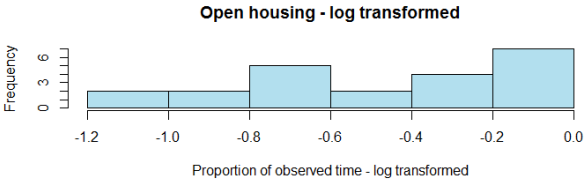
Standing

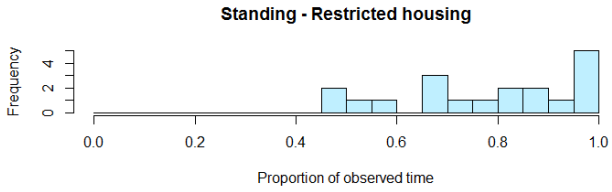
Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.333	0.394	0.515	0.710	0.717	0.906	0.982	0.993	0.206

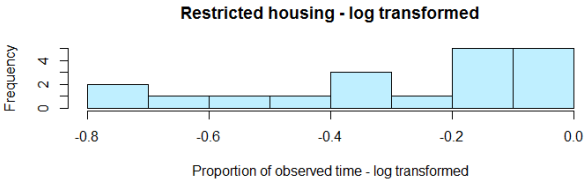












Open housing:

Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.333	0.366	0.474	0.668	0.663	0.887	0.963	0.983	0.219

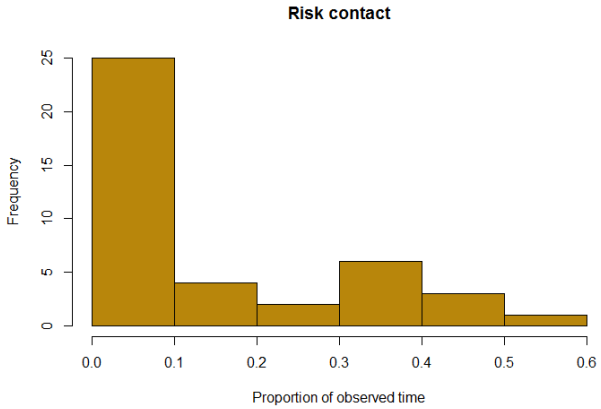
Restricted housing:

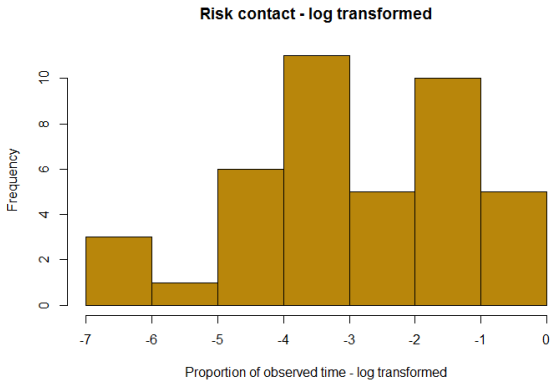
Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.472	0.480	0.671	0.829	0.779	0.931	0.983	0.993	0.177

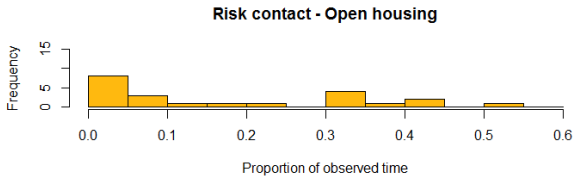
The t-test show that the p-value was 0.233 (t=-1.213).

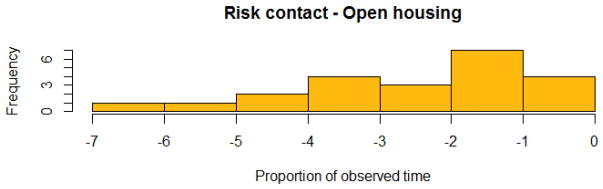
Risk contact

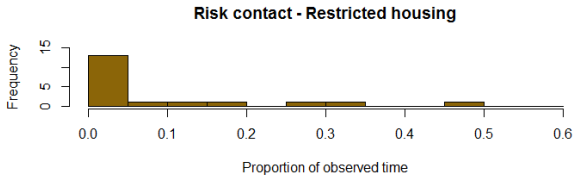
Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.000	0.000	0.020	0.046	0.138	0.290	0.449	0.512	0.156

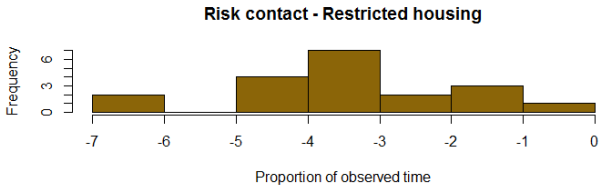












The analysis of variance was done without group D, due to lack of data.

Open housing:

Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.000	0.004	0.034	0.115	0.180	0.323	0.447	0.512	0.168

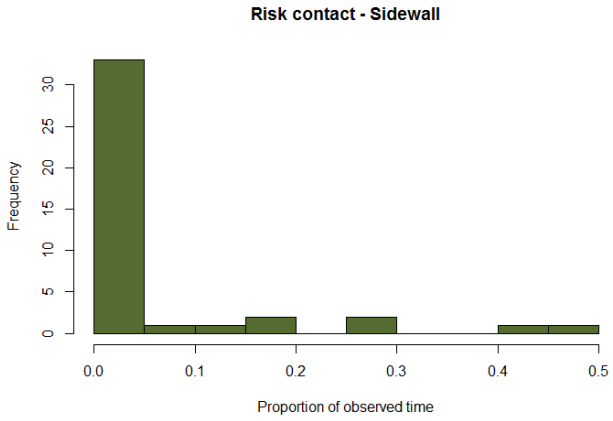
Restricted housing:

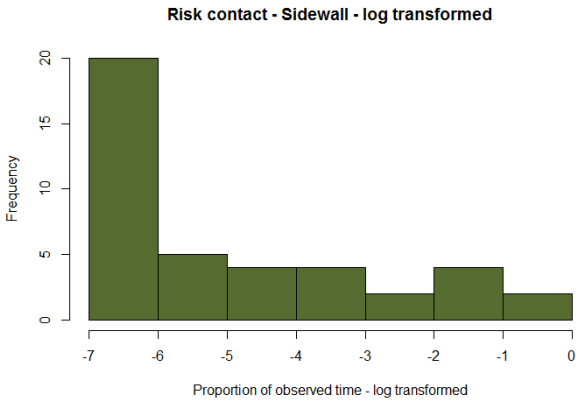
Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.003	0.010	0.014	0.028	0.090	0.108	0.334	0.465	0.130

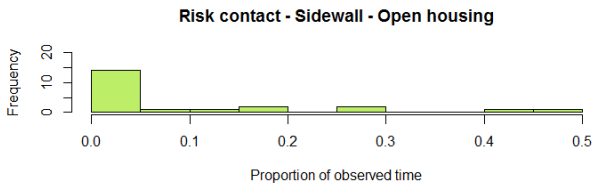
The t-test show that the p-value was 0.075 (t=1.830).

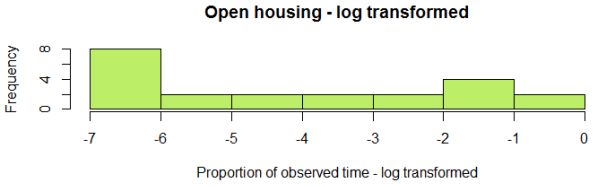
Risk contact – Via Sidewall

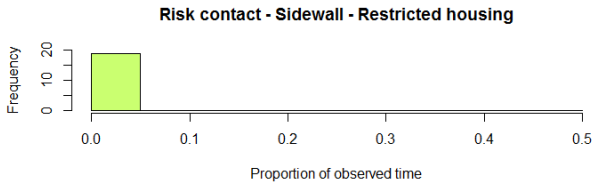
Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.000	0.000	0.000	0.002	0.054	0.033	0.287	0.456	0.115

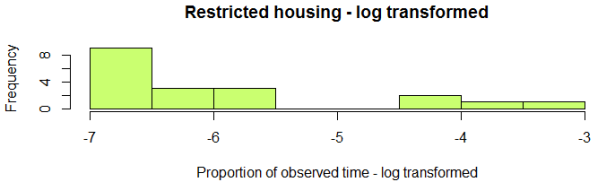












Open housing:

Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.000	0.000	0.000	0.011	0.096	0.156	0.441	0.456	0.145

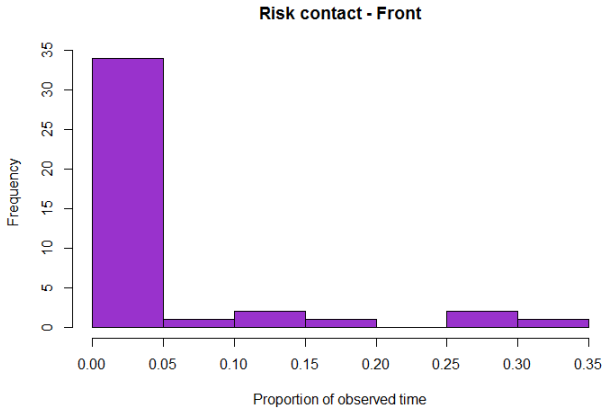
Restricted housing:

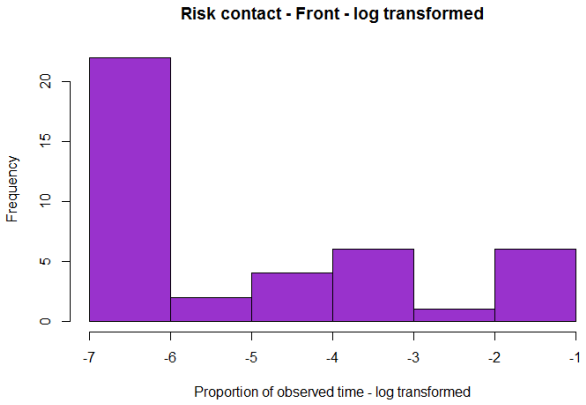
Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.000	0.000	0.000	0.010	0.005	0.003	0.026	0.034	0.009

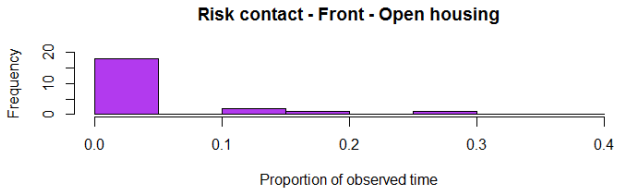
The t-test show that the p-value was 0.006 (t=2.968).

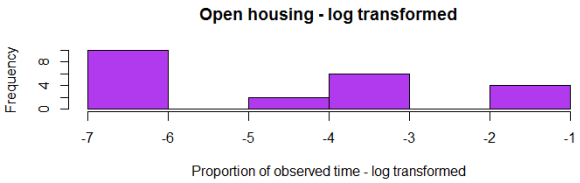
Risk contact – Front

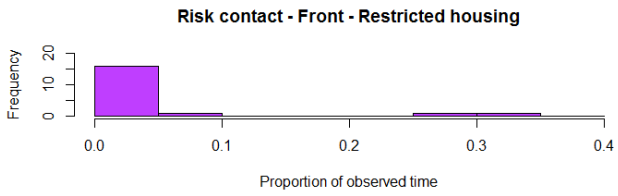
Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.000	0.000	0.000	0.001	0.040	0.033	0.274	0.319	0.082

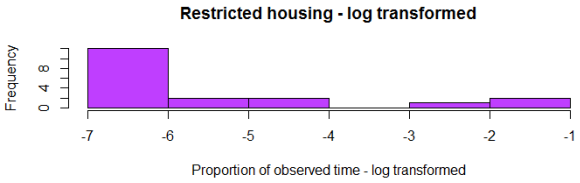












Open housing:

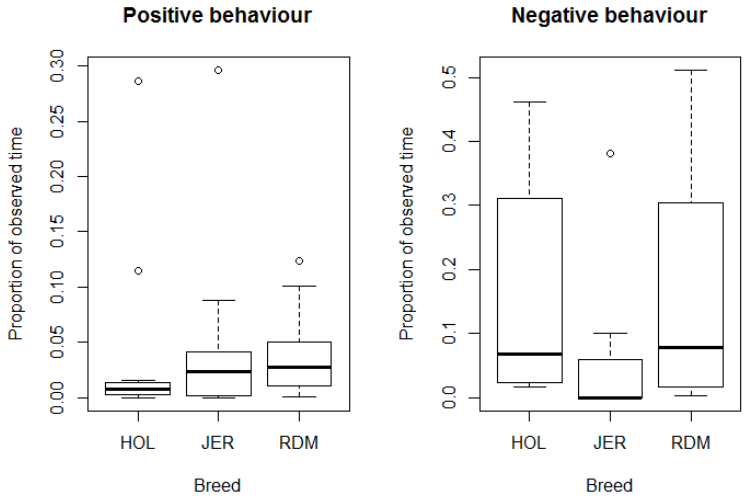
Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.000	0.000	0.000	0.016	0.043	0.038	0.152	0.281	0.072

Restricted housing:

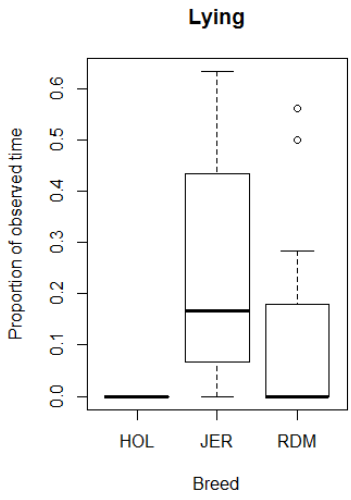
Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.000	0.000	0.000	0.001	0.037	0.008	0.279	0.319	0.094

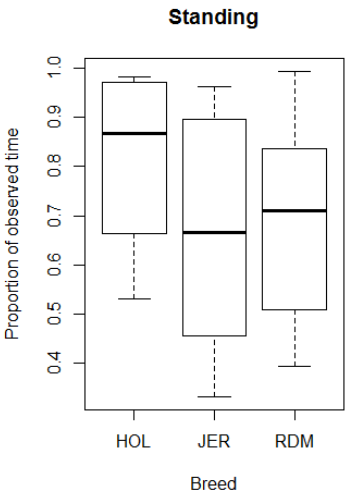
The t-test showed that the p-value was 0.1989 (t=1.307).

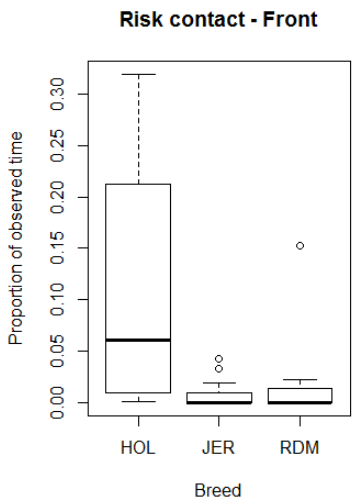
Breed

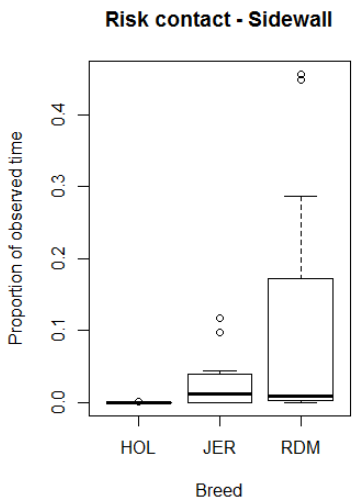

Positive behaviour
Proportion of observed time
0.00
0.05
0.10
0.15
0.20
0.25
0.30
HOL
JER
RDM
Breed

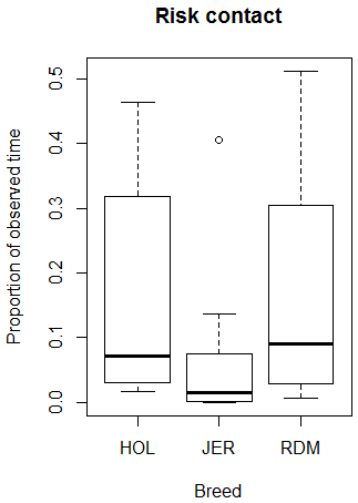
Negative behaviour
Proportion of observed time
0.0
0.1
0.2
0.3
0.4
0.5
HOL
JER
RDM
Breed

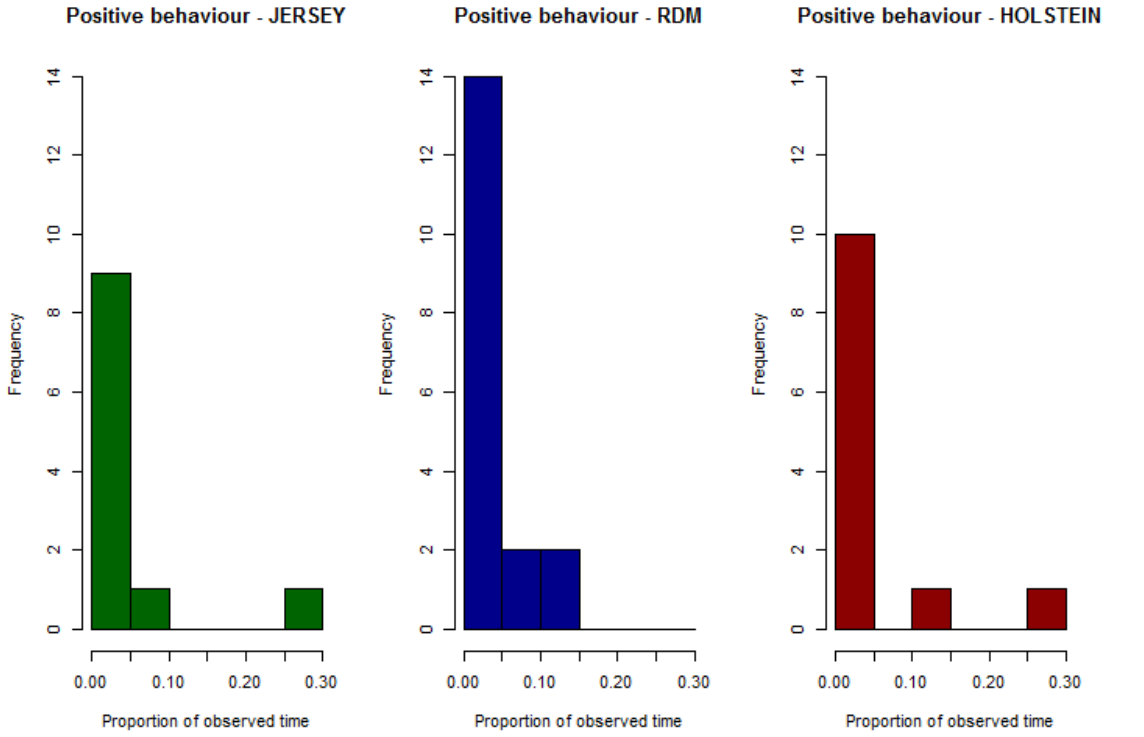

Lying
Proportion of observed time
0.0
0.1
0.2
0.3
0.4
0.5
0.6
HOL
JER
RDM
Breed

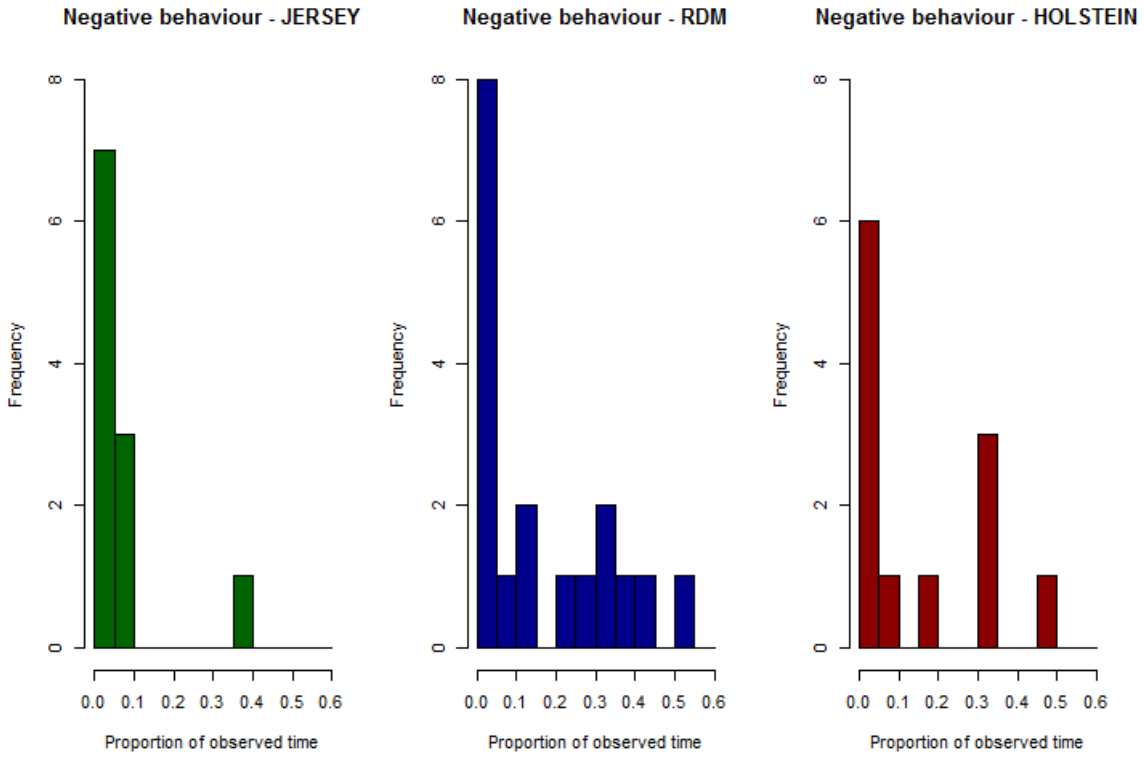

Standing
Proportion of observed time
0.4
0.5
0.6
0.7
0.8
0.9
1.0
HOL
JER
RDM
Breed

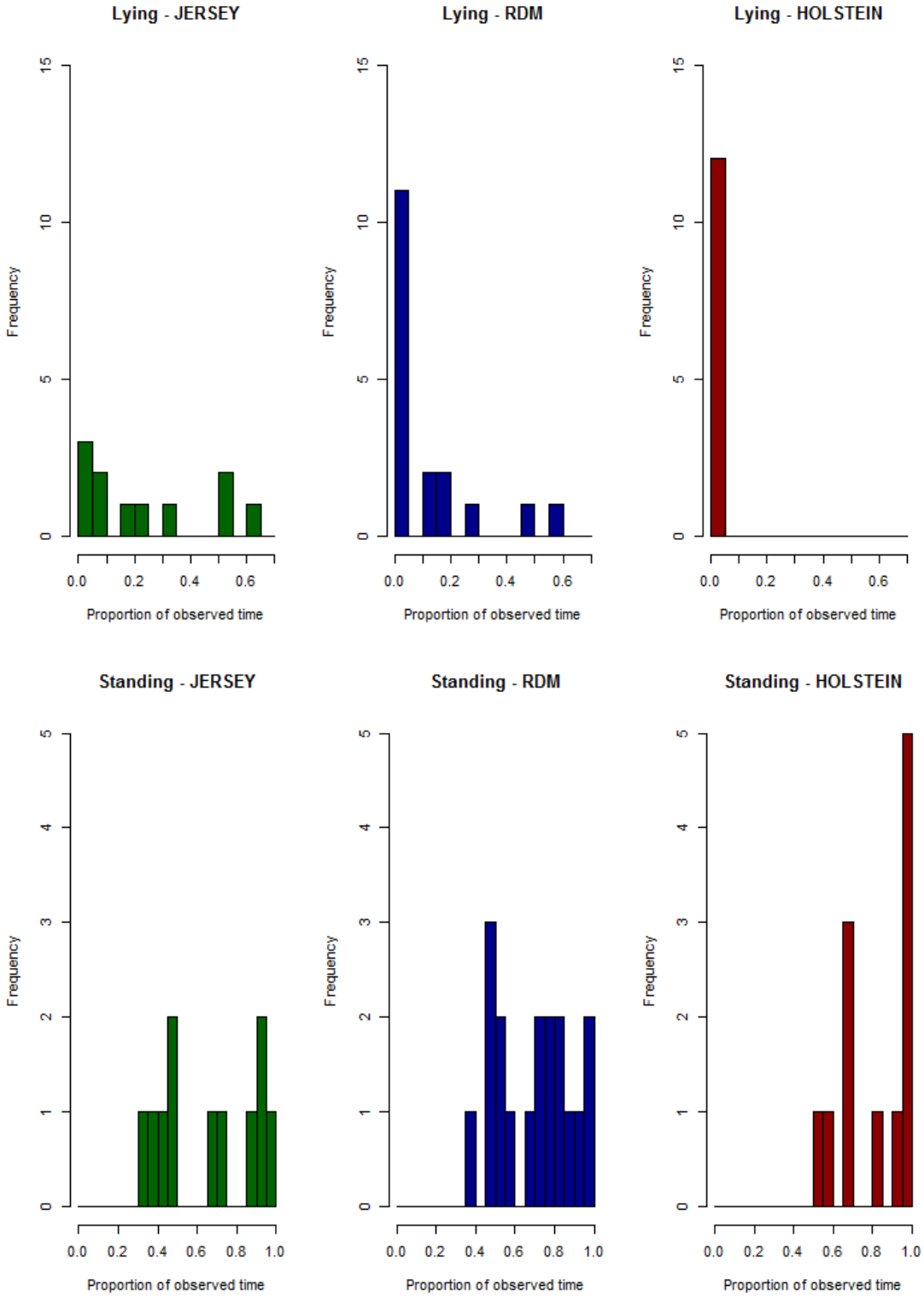

Risk contact - Front
Proportion of observed time
0.00
0.05
0.10
0.15
0.20
0.25
0.30
HOL
JER
RDM
Breed

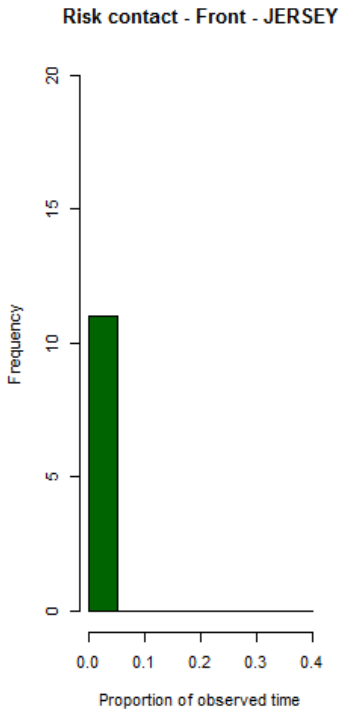

Risk contact - Sidewall
Proportion of observed time
0.0
0.1
0.2
0.3
0.4
HOL
JER
RDM
Breed

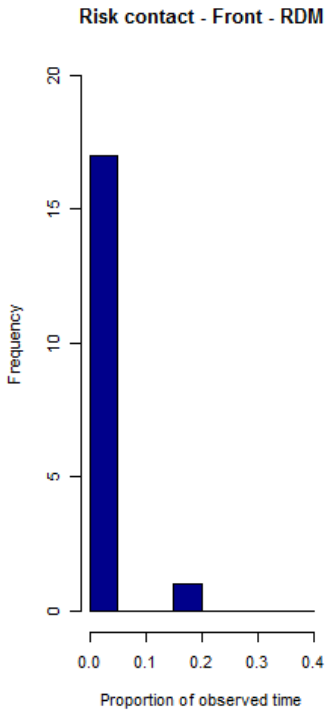

Risk contact
Proportion of observed time
0.0
0.1
0.2
0.3
0.4
0.5
HOL
JER
RDM
Breed

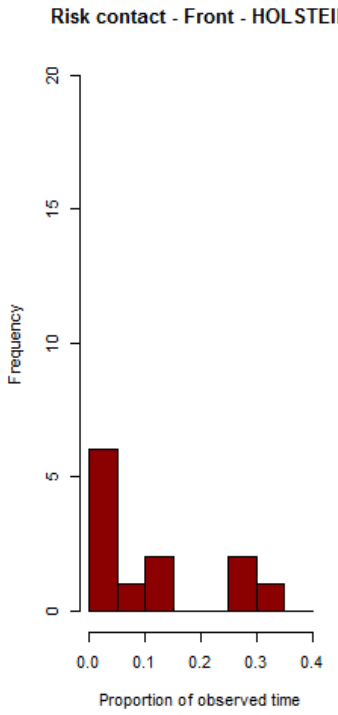

Positive behaviour - JERSEY
Positive behaviour - RDM
Positive behaviour - HOLSTEIN
Frequency
Proportion of observed time
0.00
0.10
0.20
0.30

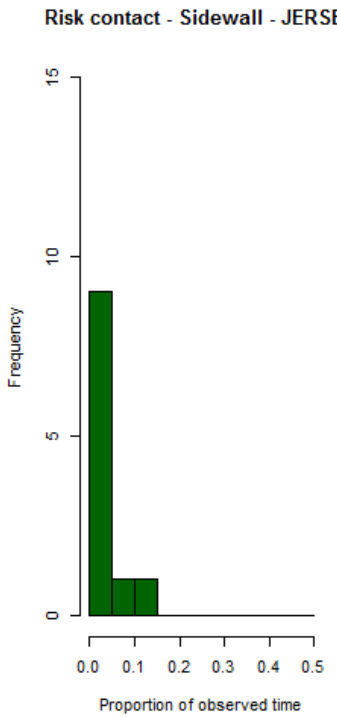

Negative behaviour - JERSEY
Negative behaviour - RDM
Negative behaviour - HOLSTEIN
Frequency
Proportion of observed time
0.0
0.1
0.2
0.3
0.4
0.5
0.6

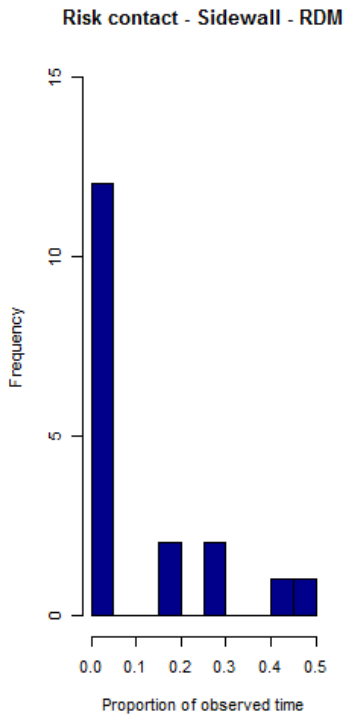

Lying - JERSEY
Lying - RDM
Lying - HOLSTEIN
Standing - JERSEY
Standing - RDM
Standing - HOLSTEIN
Frequency
Proportion of observed time

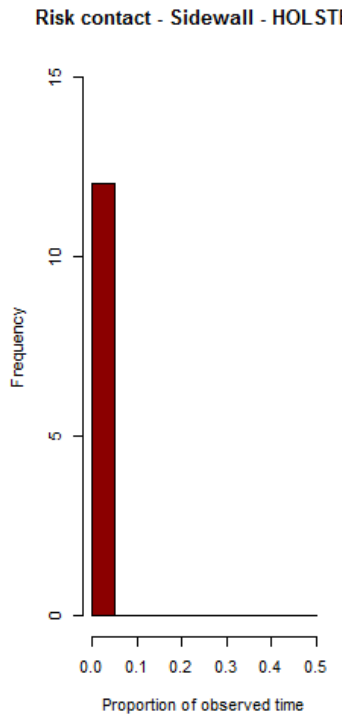

Risk contact - Front - JERSEY
Frequency
0
5
10
15
20
0.0
0.1
0.2
0.3
0.4
Proportion of observed time

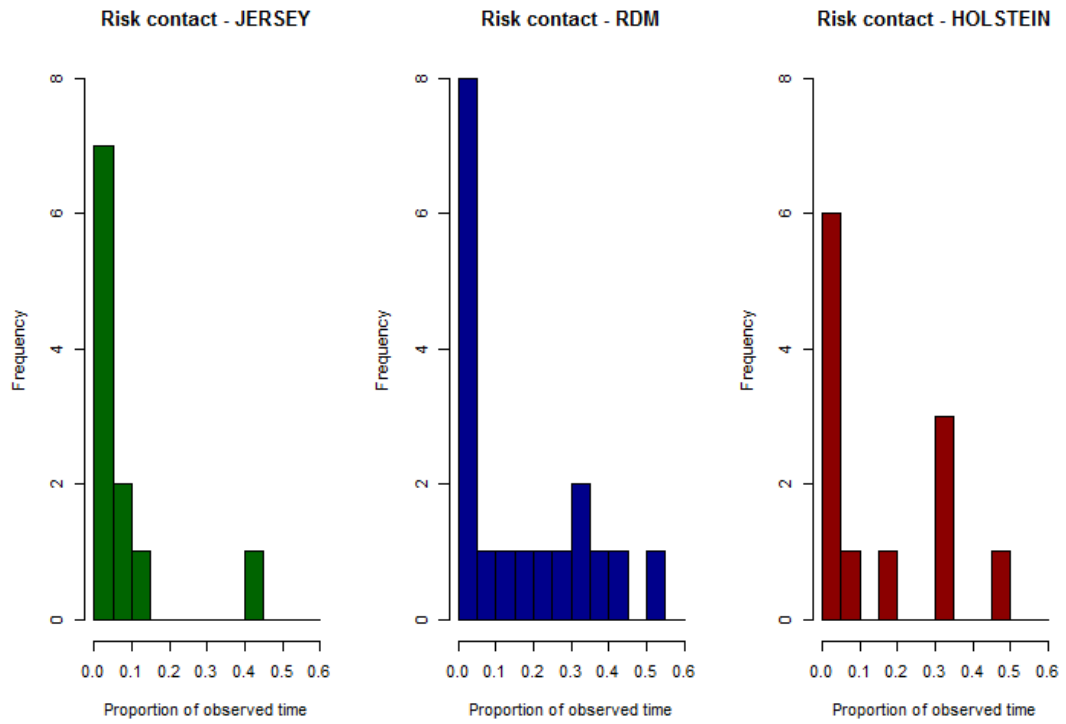

Risk contact - Front - RDM
Frequency
0
5
10
15
20
0.0
0.1
0.2
0.3
0.4
Proportion of observed time


Risk contact - Front - HOLSTEIN
Frequency
0
5
10
15
20
0.0
0.1
0.2
0.3
0.4
Proportion of observed time


Risk contact - Sidewall - JERSEY
Frequency
0
5
10
15
0.0
0.1
0.2
0.3
0.4
0.5
Proportion of observed time

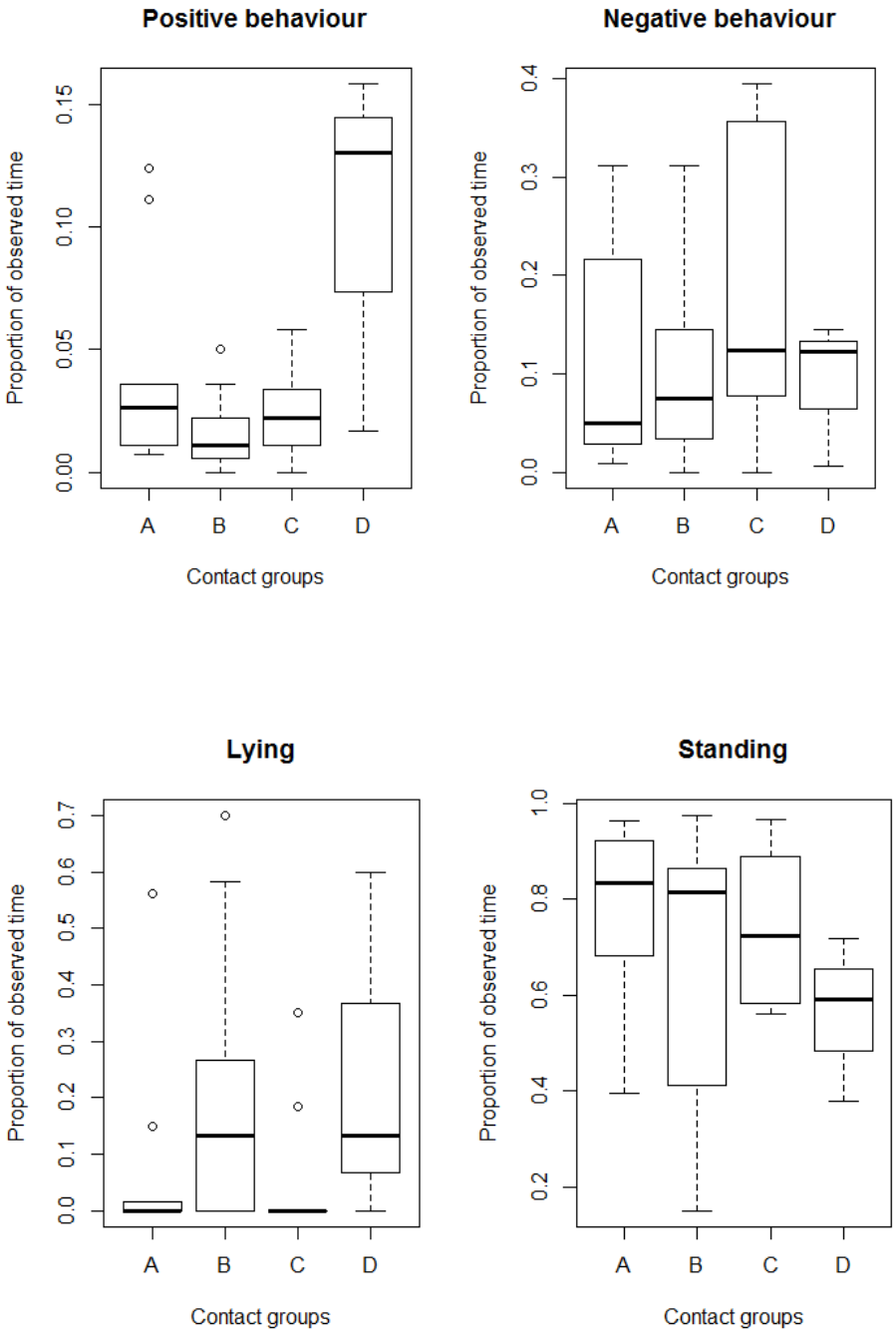

Risk contact - Sidewall - RDM
Frequency
0
5
10
15
0.0
0.1
0.2
0.3
0.4
0.5
Proportion of observed time

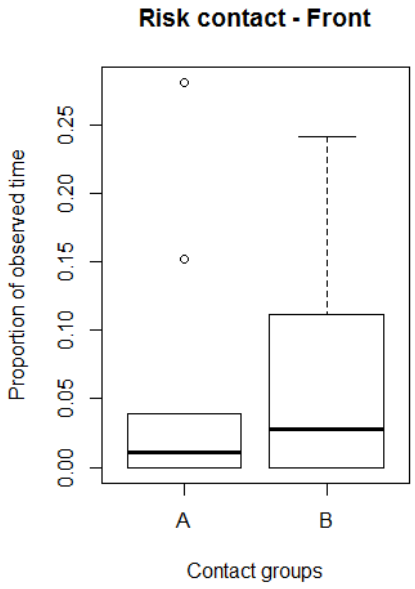

Risk contact - Sidewall - HOLSTEIN
Frequency
0
5
10
15
0.0
0.1
0.2
0.3
0.4
0.5
Proportion of observed time

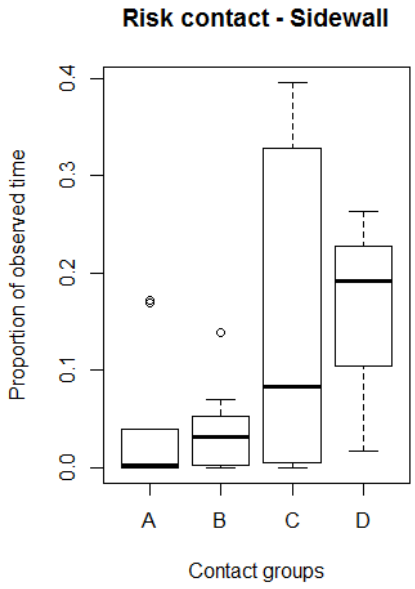

Risk contact - JERSEY
Frequency
0
2
4
6
8
0.0 0.1 0.2 0.3 0.4 0.5 0.6
Proportion of observed time
Risk contact - RDM
Frequency
0
2
4
6
8
0.0 0.1 0.2 0.3 0.4 0.5 0.6
Proportion of observed time
Risk contact - HOLSTEIN
Frequency
0
2
4
6
8
0.0 0.1 0.2 0.3 0.4 0.5 0.6
Proportion of observed time

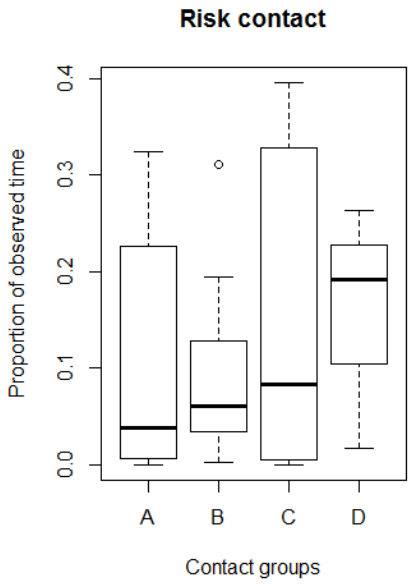
Appendix 2

Standardized study



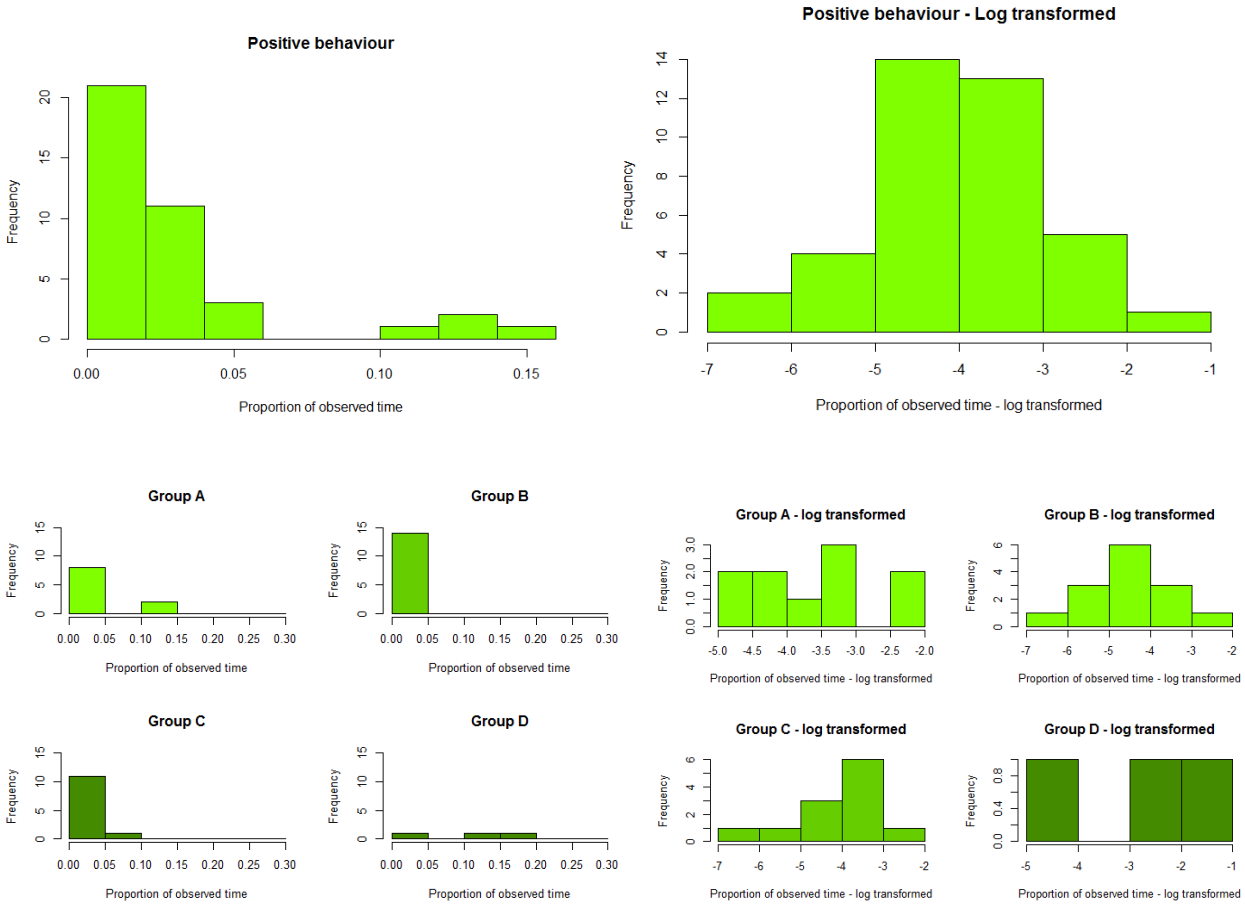

Risk contact - Front
Proportion of observed time
0.00
0.05
0.10
0.15
0.20
0.25
A
B
Contact groups


Risk contact - Sidewall
Proportion of observed time
0.0
0.1
0.2
0.3
0.4
A
B
C
D
Contact groups


Risk contact
Proportion of observed time
0.0
0.1
0.2
0.3
0.4
A
B
C
D
Contact groups

Positive behaviour

Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.000	0.003	0.011	0.017	0.031	0.034	0.125	0.158	0.037



The analysis of variance was done without group D, due to lack of data.

Group A:

Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.007	0.007	0.011	0.026	0.039	0.035	0.118	0.124	0.043

Group B:

Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.000	0.004	0.006	0.011	0.016	0.020	0.041	0.050	0.014

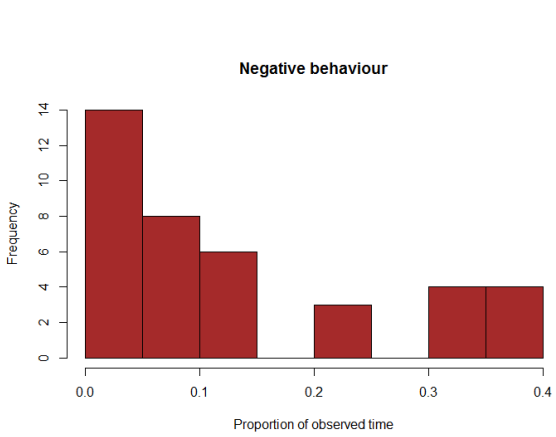
Group C:

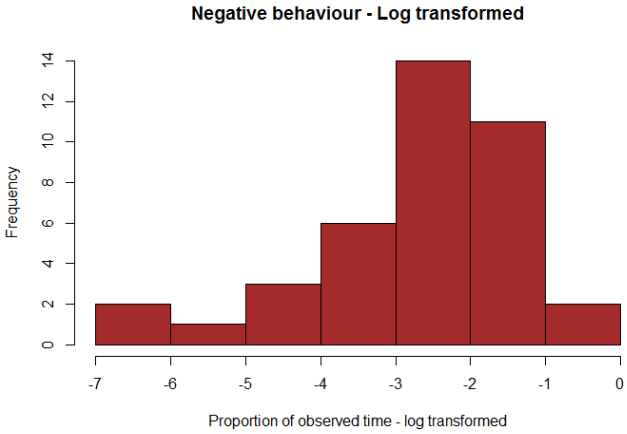
Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.000	0.002	0.011	0.022	0.023	0.034	0.052	0.058	0.018

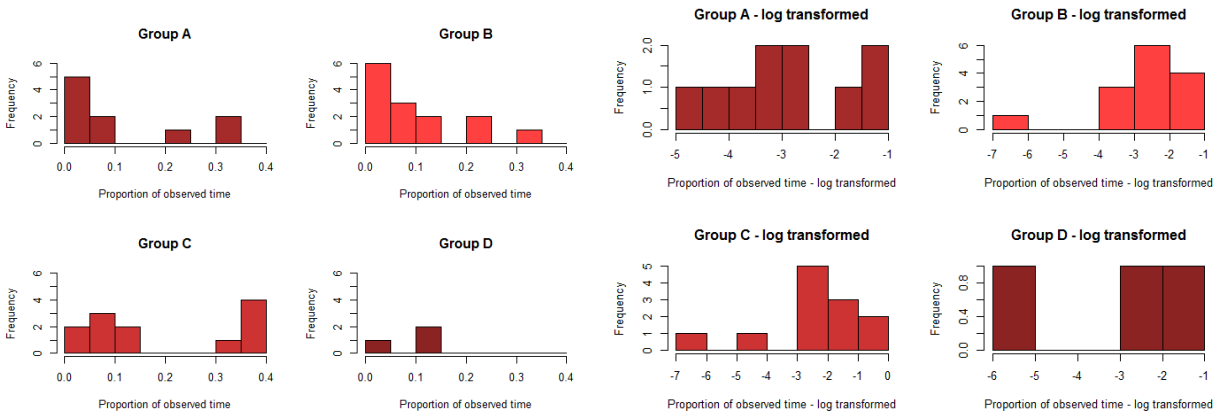
The analysis of variance showed p=0.220.

Negative behaviour

Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.000	0.005	0.035	0.078	0.132	0.208	0.364	0.394	0.124







The analysis of variance was done without group D, due to lack of data.

Group A:

Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.009	0.012	0.031	0.050	0.109	0.179	0.310	0.311	0.121

Group B:

Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.000	0.018	0.038	0.075	0.103	0.13	0.246	0.311	0.088

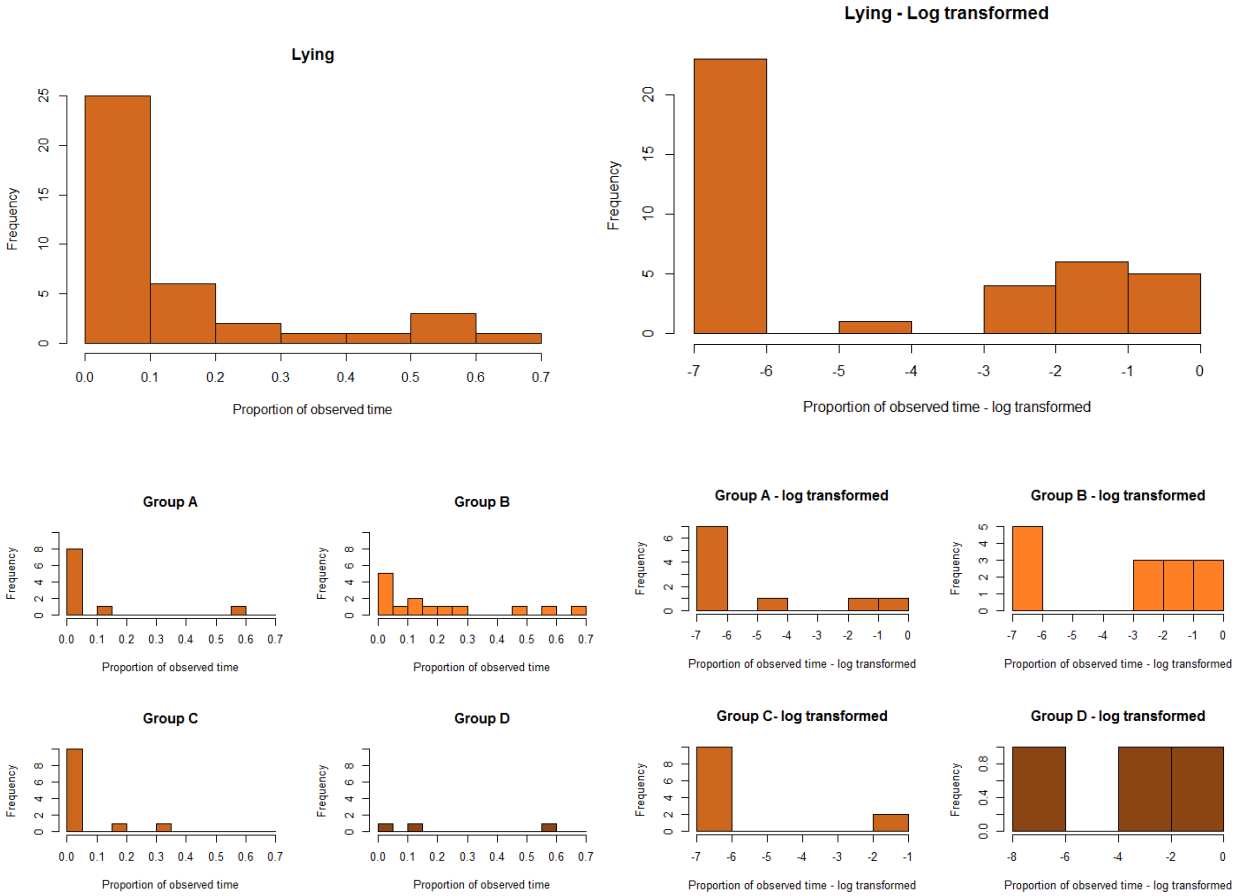
Group C:

Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.000	0.006	0.078	0.124	0.194	0.355	0.393	0.394	0.157

The analysis of variance showed p=0.703.

Lying

Min.	5 %	1st Quartile	Median	Mean	3rd Quartile	95 %	Max.	SD
0.000	0.000	0.000	0.000	0.123	0.167	0.585	0.700	0.201



The analysis of variance was done without group D, due to lack of data.

Group A:

Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.000	0.000	0.000	0.000	0.073	0.013	0.376	0.561	0.178

Group B:

Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.000	0.000	0.000	0.133	0.201	0.261	0.624	0.700	0.231

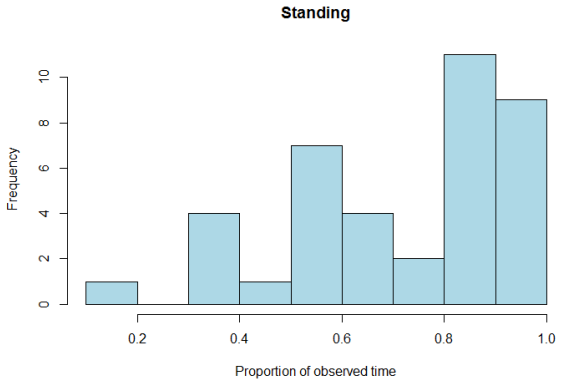
Group C:

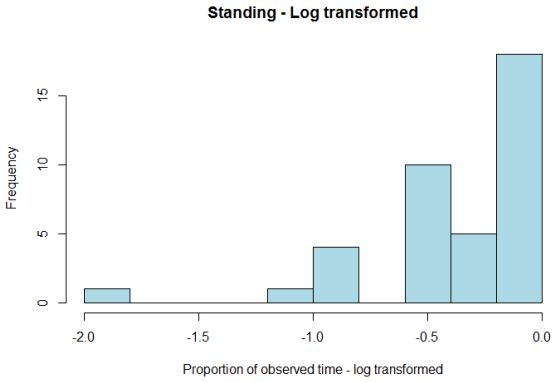
Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.000	0.000	0.000	0.000	0.044	0.000	0.258	0.350	0.110

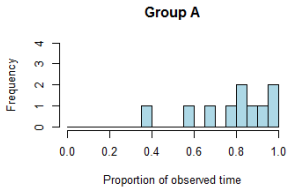
Lying was not further analysed due to lack of observations.

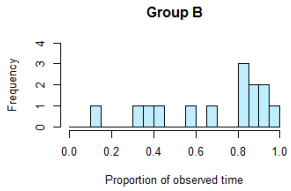
Standing

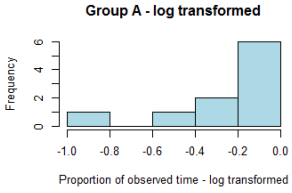
Min.	5 %	1st Quartile	Median	Mean	3rd Quartile	95 %	Max.	SD
0.150	0.373	0.579	0.811	0.715	0.875	0.965	0.975	0.211

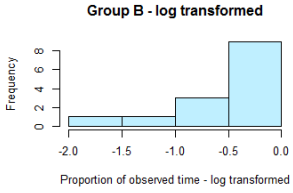


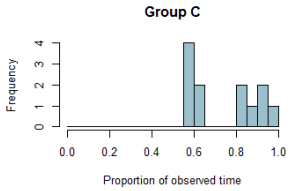


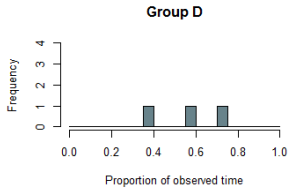


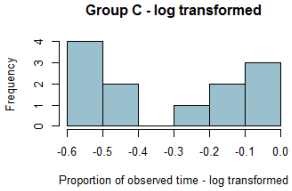


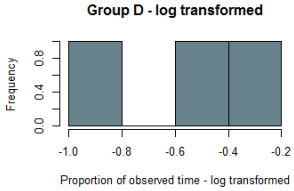












Group A:

Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.394	0.471	0.700	0.835	0.778	0.913	0.958	0.964	0.184

Group B:

Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.150	0.266	0.453	0.815	0.681	0.862	0.955	0.975	0.265

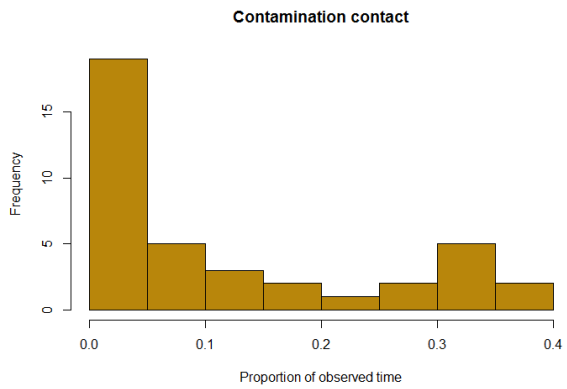
Group C:

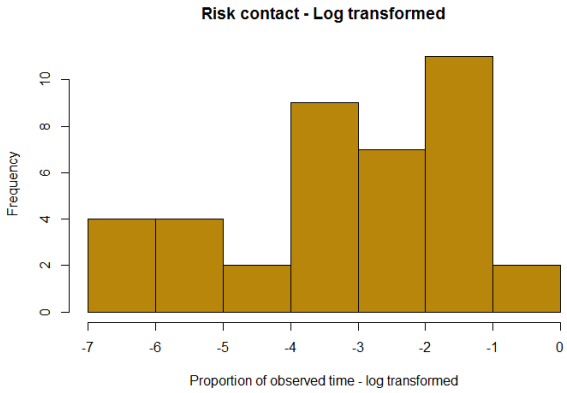
Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.561	0.567	0.584	0.725	0.739	0.878	0.937	0.968	0.159

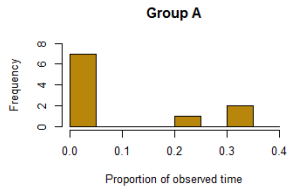
The analysis of variance showed p=0.534.

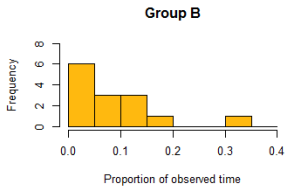
Risk contact

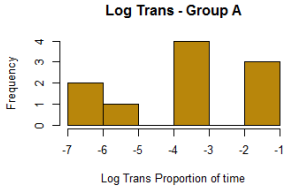
Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.000	0.000	0.024	0.053	0.120	0.211	0.339	0.396	0.129

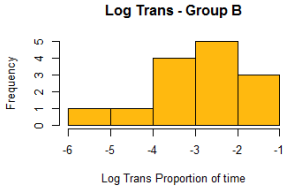


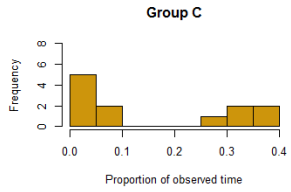


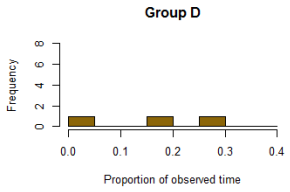


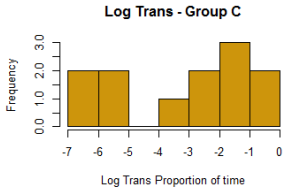


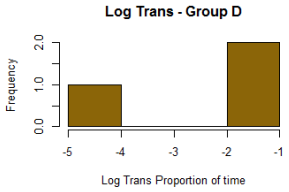












The analysis of variance was done without group D, due to lack of data.

Group A:

Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.000	0.000	0.012	0.037	0.103	0.182	0.321	0.325	0.132

Group B:

Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.003	0.010	0.035	0.061	0.091	0.124	0.235	0.311	0.084

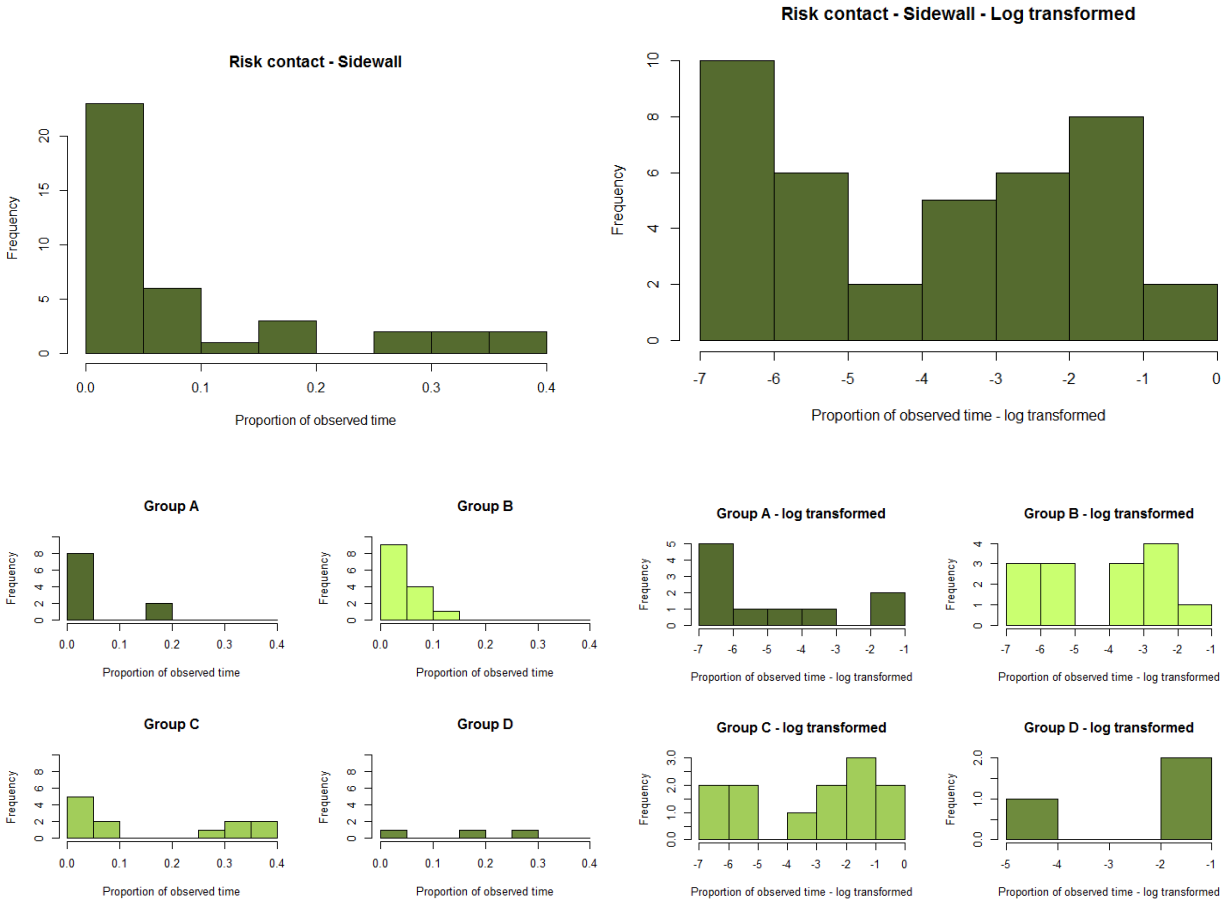
Group C:

Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.000	0.000	0.004	0.083	0.161	0.325	0.385	0.396	0.167

The analysis of variance showed (p=0.653)

Risk contact – Via Sidewall

Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.000	0.000	0.001	0.031	0.084	0.111	0.339	0.396	0.120



The analysis of variance was done without group D, due to lack of data.

Group A:

Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.000	0.000	0.000	0.003	0.039	0.031	0.171	0.172	0.070

Group B:

Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.000	0.000	0.003	0.032	0.035	0.053	0.094	0.139	0.040

Group C:

Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.000	0.000	0.005	0.083	0.160	0.325	0.393	0.396	0.168

The analysis of variance showed (p=0.112).

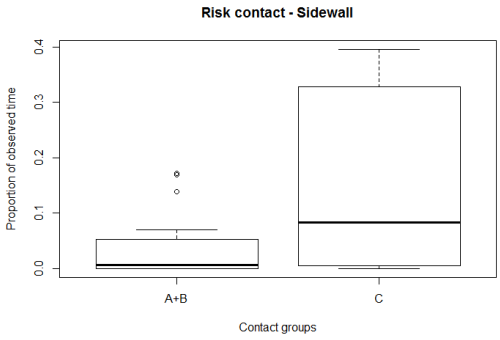
Group A and B was put in to one group (A+B) and compared to group C.

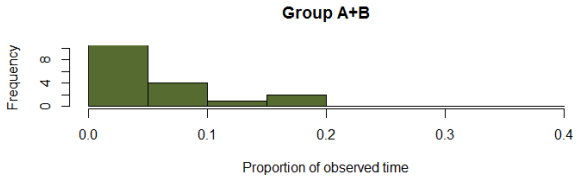
Group A+B:

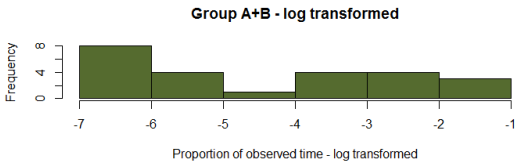
Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.000	0.000	0.000	0.006	0.037	0.053	0.164	0.172	0.053

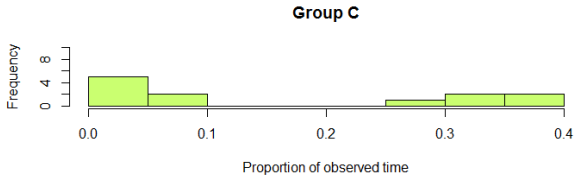
Group C:

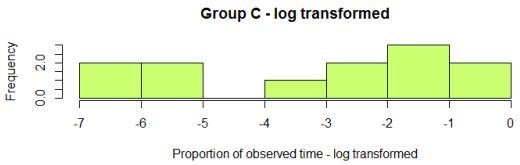
Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.000	0.000	0.005	0.083	0.160	0.325	0.393	0.396	0.168







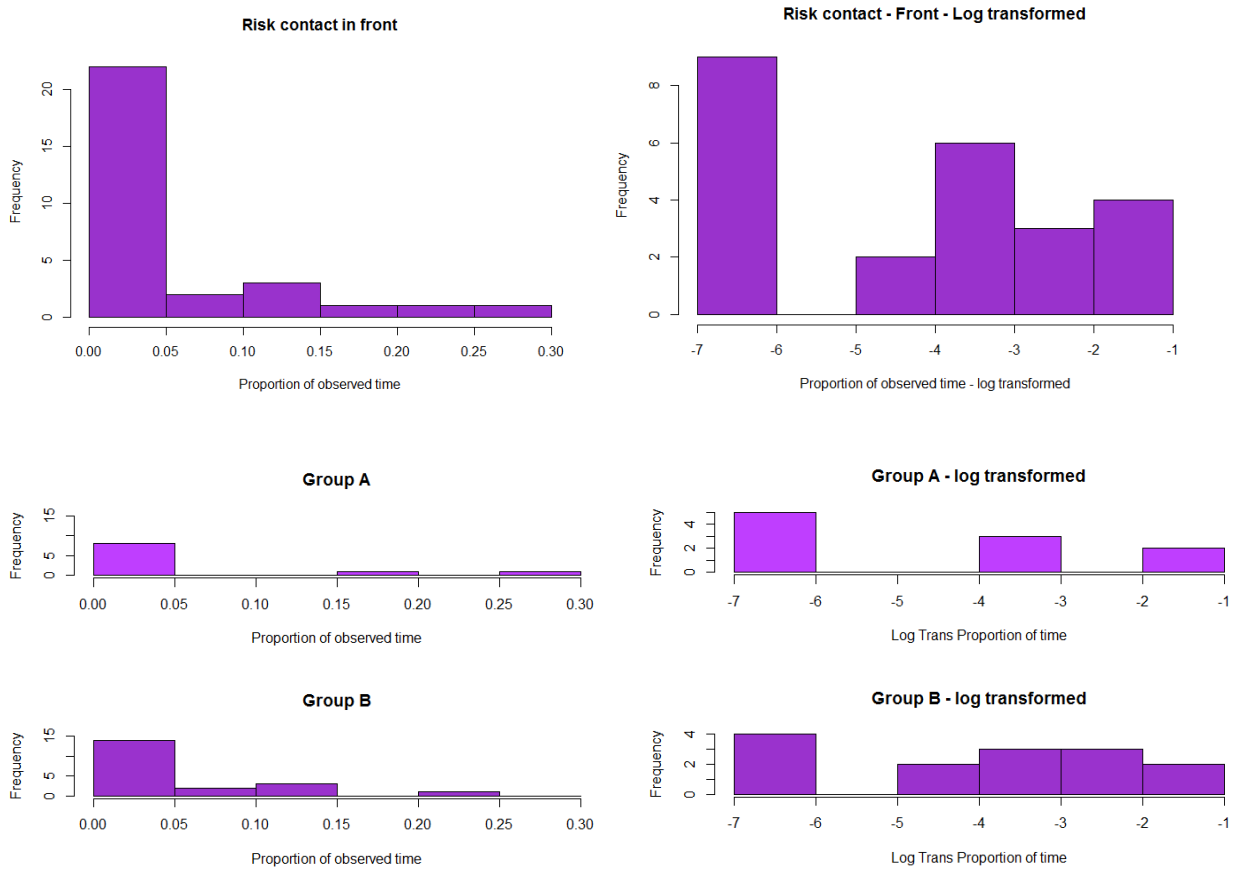




Analysis of variance show no statistical significant difference between the housing systems (p=0.057), but housing group C with a median of 0.083 spent more of the observed time on risk contact via the sidewall compared to housing group A+B with the median of 0.006.

Risk contact – In front

Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.000	0.000	0.000	0.022	0.055	0.069	0.228	0.281	0.080



Group C and D were not included in the study due to no possibility of contact in the front.

Group A:

Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.000	0.000	0.000	0.011	0.053	0.038	0.223	0.281	0.093

Group B:

Min.	5 % perc.	1st Quartile	Median	Mean	3rd Quartile	95 % perc.	Max.	SD
0.000	0.000	0.003	0.028	0.057	0.097	0.178	0.242	0.073

The analysis of variance showed p=0.436.