DISSERTATIONES SCHOLAE DOCTORALIS AD SANITATEM INVESTIGANDAM
UNIVERSITATIS HELSINKIENSIS

KATI TUOMOLA

BIT-RELATED LESIONS AND RISK FACTORS IN COMPETING TROTTERS AND EVENT HORSES

DEPARTMENT OF PRODUCTION ANIMAL MEDICINE
FACULTY OF VETERINARY MEDICINE
DOCTORAL PROGRAMME IN CLINICAL VETERINARY MEDICINE
UNIVERSITY OF HELSINKI

Department of Production Animal Medicine
Faculty of Veterinary Medicine
The Doctoral Programme in Clinical Veterinary Medicine
University of Helsinki
Finland

BIT-RELATED LESIONS AND RISK FACTORS IN COMPETING TROTTERS AND EVENT HORSES

Kati Tuomola

DOCTORAL DISSERTATION

To be presented for public discussion with the permission of the Faculty of Veterinary Medicine of the University of Helsinki, in Athena, room 302, Siltavuorenpenger 3 A Helsinki, on the 6th of May, 2022 at 13:00.

Helsinki 2022

Supervising Professor Professor Anna Valros, PhD
Department of Production Animal Medicine
Faculty of Veterinary Medicine
University of Helsinki, Finland

Supervisors Professor Anna Valros, PhD
Department of Production Animal Medicine
Faculty of Veterinary Medicine
University of Helsinki, Finland

Clinical Teacher Minna Kujala-Wirth, DVM, PhD
Department of Production Animal Medicine
Faculty of Veterinary Medicine
University of Helsinki, Finland

Assistant Professor Anna Mykkänen, DVM, PhD
Department of Equine and Small Animal Medicine
Faculty of Veterinary Medicine
University of Helsinki, Finland

Reviewed by Professor Agneta Egenvall, DVM, PhD
Department of Clinical Sciences
Faculty of Veterinary Medicine and Animal Science
Swedish University of Agricultural Sciences
Uppsala, Sweden

Senior Researcher Mette Herskin, PhD
Department of Animal Science
Aarhus University, Denmark

Opponent Senior Researcher Cecilie Mejdell, DVM, PhD,
Dip ECAWBM (WSEL)
Norwegian Veterinary Institute
Department of Animal Health, Welfare and Food Safety
Oslo, Norway

Dissertationes Scholae Doctoralis Ad Sanitatem Investigandam Universitatis Helsinkiensis

The Faculty of Veterinary Medicine uses the Ouriginal system (plagiarism recognition) to examine all doctoral dissertations

ISBN 978-951-51-8033-9 (print)
ISBN 978-951-51-8034-6 (online) ethesis.helsinki.fi
ISSN 2342–3161 (print)
ISSN 2342–317X (online)

Cover image: *469* - Kati Tuomola
Punamusta Oy
Helsinki 2022

“There is only one good, knowledge, and one evil, ignorance”

– Socrates

ABSTRACT

Bit-related oral lesions are a common and painful welfare issue in horses. Even though horses have been ridden and driven with a bit and bridle for 6000 years and bit sores have been described already in the 19th century in the veterinary literature, scientific reports on bit-related lesions and their risk factors in horses remain scarce.

The aim of this thesis was to (i) determine the occurrence of oral lesions in the bit area in Finnish trotters and event horses after competitions, (ii) create a scoring system for oral lesions in the bit area and demonstrate different lesion types and locations with photographs, (iii) investigate risk factors for bit-related lesions in trotters and event horses, (iv) further investigate different stakeholders' attitudes towards bit-related lesions in trotters.

The rostral part of the mouth of 469 horses (261 trotters, 208 event horses) was examined systematically after a competition. Trotters were examined in 10 racing events in 2017 and event horses in 8 competition events in 2018–2019. Many horses had multiple lesions, and therefore, a lesion scoring system was created in which points were given to each lesion depending on its size, type (bruise or wound), and depth (superficial or deep). Points for each lesion were summed such that each horse received a total lesion score that reflected the overall lesion status. No acute lesions were found in 42 trotters (16%), and lesion status was mild in 55 trotters (21%), moderate in 113 trotters (43%), and severe in 51 trotters (20%). In event horses, no lesions were found in 99 horses (48%), and lesion status was mild in 45 (22%), moderate in 55 (26%), and severe in 9 horses (4%).

The most common lesion location was the inner lip commissure. Lesions were also found in the bars of the mandible in front of the first lower cheek tooth, in the buccal area near the first upper cheek tooth, and in the outer lip commissures. Only a few horses had mild lesions involving the tongue and one horse in the hard palate. Although 109 event horses and 219 trotters had oral lesions in the bit area, none of the event horses and only six trotters showed external mouth bleeding. Additionally, one event horse and 26 trotters had blood inside the mouth or on the bit when it was removed from the mouth.

Associations between a horse's moderate-severe oral lesion status and potential risk factors were analyzed with multivariable logistic regression analysis. The association between bit type and lesion location was examined with Fisher's exact test. Risk factors for moderate-severe oral lesion status in trotters were the use of a Crescendo bit, a mullen mouth regulator bit, or an unjointed plastic bit (model Happy Mouth) and female sex (mare). In event horses, the risk factors were thin (10–13 mm) and thick (18–22 mm) bits, female sex (mare), and other than pony breed. In both disciplines, unjointed bits were associated with lesions in the bars of the mandible. Single-jointed snaffle bits

were the most common bit type in trotters and the least associated with moderate-severe lesions. In event horses, double-jointed 14–17 mm bits were most common. Bit thickness of 14–17 mm was the least associated with moderate-severe lesion status. However, these results may at least partly reflect driveability or rideability issues, and thus, rein tension differences because drivers/riders may change to distinctive bit designs if they have difficulty eliciting an appropriate response with rein cues.

In the pilot questionnaire study, imaginary scenarios and photographs of lesions from horses' mouths were presented to different stakeholders (veterinarians and race veterinary assistants, trainers, and others). They were asked in multiple choice questionnaires whether they allow the horse to start in the race, stipulate a health certificate before the next race, or remove the horse from the race. The association between stakeholder groups and their answers was examined with the Pearson Chi-square test. The results of this study indicated differences in attitudes towards bit-related lesions between stakeholder groups but also within a stakeholder group. This might reflect differences in conflicts of interests, moral values, empathy, or over-exposure to oral lesions. Not removing horses with severe oral lesions from the race may compromise horse welfare and society's trust in the surveillance system.

In this study, oral lesions in the bit area were common after a competition, although only few horses showed external bleeding. Oral examination and an oral lesion scoring system with an assistant recording the findings were suitable for field conditions and horses seemed to tolerate the examination well. Even though changing the bit to the bits least associated with lesions may be beneficial, horses with oral lesions might benefit from training modifications. Given the higher risk observed for mares in this study, mare oral health warrants special attention. Results of this thesis encourage adopting bit area monitoring as a new routine by horse handlers and as a welfare measure by competition organizers in order to minimize pain and negative experiences by early diagnosis and treatment of mouth lesions.

YHTEENVETO

Kuolaimiin liittyvät suuvauriot hevosilla ovat kivulias ja yleinen hevosten hyvinvointiongelma. Kuolaimia on käytetty hevosilla lähes 6000 vuotta. Suuvaurioita on kuvattu eläinlääketieteellisessä kirjallisuudessa jo 1800-luvulla, silti tieteellinen kirjallisuus kuolaimiin liittyvistä suuvaurioista ja niiden riskitekijöistä on edelleen vähäistä.

Tämä väitöskirjan tavoitteena oli (i) selvittää kuolaimen vaikutusalueen suuvaurioiden yleisyyttä suomalaisilla ravi- ja kenttäratsastushevosilla kilpailun jälkeen, (ii) luoda vaurioiden pisteytysjärjestelmä ja havainnollistaa vauriotyyppejä ja -paikkoja valokuvin (iii) selvittää suuvaurioiden riskitekijöitä, sekä (iv) selvittää eri sidosryhmien asenteita ravihevosten suuvaurioihin (aikaisemmin julkaisematon pilottitutkimus).

Suun etuosa tutkittiin systemaattisesti kilpailun jälkeen 469 hevoselta (261 ravuria ja 208 kenttäratsua). Ravihevoset tutkittiin kymmenessä kilpailutapahtumassa 2017 ja kenttäratsut kahdeksassa kilpailutapahtumassa vuosina 2018–2019. Koska monilla hevosilla oli useita vaurioita, luotiin pisteytysjärjestelmä, jossa kaikki vauriot pisteytettiin niiden koon, tyypin (mustelma tai haava) ja syvyyden (pinnallinen tai syvä) mukaan. Pisteet laskettiin yhteen siten, että jokainen hevonen sai kokonaisvauriopisteen, joka kuvasti kuolainalueen vauriotilannetta. Akuutteja suuvaurioita ei havaittu 42 ravurilla (16 %), lievä vauriostatus oli 55:llä (21 %), kohtalainen 113:a (43 %) ja vakava 51 hevosella (20 %). Kenttähevosista 99:llä ei ollut vaurioita (48 %), lievä vauriostatus oli 45:llä (22 %), kohtalainen 55:llä (26 %) ja vakava yhdeksällä (4 %) hevosella.

Tavallisin vauriopaikka oli suupielen sisäpuoli. Muita olivat hammasloma ensimmäisen alaposkihampaan edessä, posken etuosa ensimmäisen yläposkihampaan edessä ja suupielen ulkopuoli. Vain muutama vaurio todettiin kielessä ja yksi vaurio kitalaessa. Vaurioita oli 109 kenttähevosella ja 219 ravurilla. Silti yhdelläkään kenttähevosella ja ravureista vain kuudella oli suun ulkoista verenvuotoa. Kuitenkin yhdellä kenttähevosella ja 26 ravurilla oli verta suun sisällä tai kuolaimessa, kun kuolain poistettiin suusta.

Mahdollisten riskitekijöiden yhteys hevosen kohtalaiseen tai vakavaan suuvauriostatukseen tutkittiin monimuuttujanalyysillä (logistinen regressioanalyysi). Kuolaintyypin ja vauriopaikan yhteys tutkittiin Fisherin tarkalla testillä. Ravureilla kohtalaisten tai vakavien suuvaurioiden riskitekijöiksi todettiin Crescendo- kuolain, suora puoltajankuolain ja suora muovikuolain (ns. Happy Mouth -malli) ja tamma sukupuoli. Kenttäratsuilla riskitekijöitä olivat ohuet (10–13 mm) ja paksut (18–22 mm) kuolaimet, tamma sukupuoli ja muu kuin ponirotu. Molemmissa lajeissa suorat kuolaimet olivat yhteydessä hammasloman vaurioihin. Yksinivelinen ravikuolain oli yleisin kuolaintyyppi ravureilla ja se oli heikoiten yhteydessä kohtalaiseen tai vakavaan suuvauriostatukseen. Kenttähevosilla yleisin kuolain oli 14–17 mm paksu

kolmipalakuolain. Tämä kuolaimen paksuus oli heikoiten yhteydessä kohtalaiseen tai vakavaan suuvaurio statukseen. On kuitenkin mahdollista, että tulokset ainakin osittain kuvastavat ajettavuus- tai ratsastettavuusongelmia ja siten ohjaspaineiden eroja, koska ratkaisua ongelmiin saatetaan etsiä vaihtamalla kuolaintyyppiä.

Pilottikyselytutkimuksessa esitettiin kuvitteellisia tilanteita eri sidosryhmille (eläinlääkärit ja kilpailueläinlääkärin avustajat, valmentajat ja muu sidosryhmä) ja näytettiin valokuvia hevosten suusta, jossa oli vaurio kuolaimen vaikutusalueella. Vastaajia pyydettiin vastaamaan muovivalintakysymyksiin, jossa heiltä kysyttiin sallisivatko he hevosen kilpailla, pitäisikö hevoselle määrätä terveystarkastus ennen seuraavaa kilpailuun ilmoittamista vai pitäisikö hevonen poistaa kilpailusta. Sidosryhmien yhteys vastausvaihtoehtoihin tutkittiin Pearsonin khiin neliö -testillä. Kyselytutkimus antoi viitteitä, että ravureiden suuvaurioihin suhtautumisessa oli eroja sidosryhmien välillä, mutta myös sidosryhmien sisällä. Tämä saattaa heijastaa eroja eturistiriidoissa, moraalisissa arvoissa, empatiassa tai liiallisessa altistumisessa suun vaurioille. Yhteiskunnan luottamus valvontajärjestelmään voi vaarantua, jos hevosia, joilla on vakavia suun vaurioita, ei poisteta kilpailusta.

Tässä tutkimuksessa hevosten kuolaimiin liittyvät suuvauriot olivat yleisiä, vaikka ulkoista verenvuotoa ei ollut havaittavissa kuin muutamalla hevosella. Suututkimus ja vaurioiden pisteytysjärjestelmä ja avustajan käyttö havaintojen kirjaamiseen, soveltuivat hyvin kenttäolosuhteisiin. Kuolaimen vaihtaminen vähiten vaurioihin yhteydessä oleviin malleihin saattaa olla hyödyllistä, mutta hevonen, jolla suuvauriota havaitaan, voisi hyötyä muutoksista valmennuskäytänteissä. Tammojen suun terveyteen on kiinnitettävä korostetusti huomiota, koska tammoilla todettiin suurempi suuvaurioriski. Hevosten kanssa toimiville ja kilpailujen järjestäjille suositellaan suutarkastuksia uudeksi vakiintuneeksi käytännöksi, koska eläinten hyvinvoinnin kannalta olisi tärkeää minimoida kipu ja negatiiviset kokemukset sekä pyrkiä estämään tai vähintäänkin varhain diagnosoimaan ja hoitamaan mahdolliset vauriot.

CONTENTS

ABBREVIATIONS

AWIN	Animal Welfare Indicators Project
CI	95% confidence interval
FEI	Fédération Equestre Internationale
HWAP	Horse Welfare Assessment Protocol
ISES	International Society of Equitation Science
N	Newton (SI unit for force)
OR	Odds ratio
P	Pressure (P = Force/Area)
Pa	Pascal (SI unit for pressure)
ROC	Receiver operating characteristic
SLO	Social license to operate
SRL	Suomen Ratsastajainliitto, Equestrian Federation of Finland
WQ	Welfare Quality

Keywords: horse, eventing, harness racing, riding, trotter, bit, oral lesion, ulcer, animal welfare

LIST OF ORIGINAL PUBLICATIONS

This thesis is based on the following original publications, which are referred to in the text by their Roman numerals:

I Tuomola, K., Mäki-Kihniä, N., Kujala-Wirth, M., Mykkänen, A., and Valros, A. (2019) Oral Lesions in the Bit Area in Finnish Trotters After a Race: Lesion Evaluation, Scoring and Occurrence. Front. Vet. Sci. 6:206. doi: 10.3389/fvets.2019.00206.

II Tuomola, K., Mäki-Kihniä, N., Valros, A., Mykkänen, A., and Kujala-Wirth, M. (2021) Risk factors for bit-related lesions in Finnish trotting horses. Equine Vet J. 53: 1132– 1140. doi: 10.1111/evj.13401.

III Tuomola, K., Mäki-Kihniä, N., Valros, A., Mykkänen, A., and Kujala-Wirth, M. (2021) Bit-related lesions in event horses after a cross-country test Front. Vet. Sci. 8:651160. doi: 10.3389/fvets.2021.651160.

All publications are open access. In addition, some unpublished material is presented.

1 INTRODUCTION

Bit-related oral lesions are a common pain-inducing welfare issue in horses worldwide (Tell et al., 2008; Cook, 2011; Foster, 2013; Björnsdóttir et al., 2014, 2018; Mata et al., 2015; Odelros and Wattle, 2018; Uldahl and Clayton, 2019; Mellor, 2020) and a long-term citizen and veterinary concern (Youtt, 1831; Mayhew, 1862; Dwyer, 1868; Hinebauch, 1889; Russell, 1893a; Merillat, 1917). A principal welfare issue with oral lesions is the pain related to them or the anticipation of possible pain from bit contact (Mellor, 2020).

Horse sport exposes horses to potential physical and psychological harm (Campbell, 2021), and it also poses potential risks for human safety (Starling et al., 2016). Therefore, it is essential that the risks in competitions and in training are identified and minimized (Campbell, 2013). Horse welfare in competitive equine sports is under increasing scrutiny (McGreevy, 2007; McLean and McGreevy, 2010b, 2010a; Blea, 2012; Campbell, 2012, 2016; Taylor, 2022). However, only a small number of studies have investigated bit-related lesions in competition environments (Björnsdóttir et al., 2014, 2018; Mata et al., 2015; Odelros and Wattle, 2018; Uldahl and Clayton, 2019). To evaluate lesion severity, a lesion grading system is needed. Grading systems have been different in each study, preventing direct comparison of results. Little is also known about the action mechanics of different bit types and the underlying risk factors for oral lesions.

The term ‘bit-related lesion’ is used in this thesis. This term refers to oral lesions in the horse’s rostral oral cavity related to bit use. Lesion evaluation is based on visual macroscopic findings. Inner and outer lip commissure, bars of the mandible, and rostral buccal area and tongue are considered the areas affected by the bit. Bit-related lesions are inflicted injuries meaning that the injury was the result of a human action, without saying anything about the intention (Bilo et al., 2012). The terms ‘bit-induced’ or ‘injuries caused by the bit’ attribute the blame more to the equipment (Cook, 1999; Björnsdóttir et al., 2014; Mata et al., 2015; Uldahl and Clayton, 2019).

The aims were to investigate the occurrence of bit-related lesions and their risk factors in Finnish trotters and event horses after a competition and to create an oral lesion scoring system to reflect overall bit area. Vet Form 2 from the International Federation of Icelandic Horse Association served as an inspiration for the data sheet, where the findings were recorded. However, since many horses had multiple and large lesions, the data sheet required modifications. Additionally, different stakeholders’ attitudes towards bit-related lesions in trotters (unpublished data) were investigated. The overall objective of this study was to increase awareness of bit-related lesions and discussion on horse welfare and ethics in competitions.

2 REVIEW OF THE LITERATURE

2.1 Bits and horse welfare - an old but also contemporary issue

Based on evidence of dental wear in horse skulls, horses have been ridden or driven with a bit and bridle for 6000 years (Brown and Anthony, 1991; Anthony and Brown, 2000). The early bits were made from plaited vines, wood, antler, and bone (Easley, 2010; Taylor et al., 2018). Later, bits were made from bronze, copper, iron, and steel, and, more recently, from stainless steel, plastic, and synthetic materials (Easley, 2010; Taylor et al., 2018). It has been suggested that the bit material change from organic to metal ca. 750 B.C. resulted in better horse control but also dental wear and a need for first premolar (wolf tooth) extractions in Mongolian horses (Taylor et al., 2018). Horse mouth bleeding was a concern already in ancient Greece, where the painter Apelles (370–306 B.C.) had difficulties in authentically painting bloody froth in horses' mouths (Dio Chrysostom, 1951). Excessive rein tension or 'severe' bits have been supposed to lead to oral injuries already in chariot races in ancient Rome (Crittenden, 2017).

Bits are sometimes described as 'mild' or 'severe' (Bennett, 2001). It has been proposed that thickness (in diameter), unjointedness, and having no leverage effect are characteristics of 'mild' bits (Bennett, 2001). Correspondingly, thinness, jointedness, and leverage effect have been presented as properties of a 'severe' bit (Bennett, 2001). A 'severe' bit may also have spikes or a twisted mouthpiece (McMiken, 1990; Bennett, 2001). Thicker bits are generally considered 'milder' since they allow the pressure to be distributed over a larger area (Clayton and Lee, 1984). Hence, according to a well-known colloquialism, a bit is as severe as the hand that uses it (Eriksson et al., 2019). Bit position and its movements in the mouth have been studied with radiography or fluoroscopy (Clayton and Lee, 1984; Clayton, 1985; Manfredi et al., 2005, 2009).

Horses can also be controlled without a bit (McMiken, 1990; Cook and Kibler, 2019). Bitless bridles can be used to allow oral lesions to heal (Bennett, 2010) and they have been proposed as a solution for bit-related conflict behaviors or behaviors that might indicate pain (Easley, 2010; Cook and Kibler, 2019). However, some studies have not found a difference in horses' conflict behavior rates when ridden with bitless vs. bitted bridles (Scofield and Randle, 2013; Condon et al., 2022). Bit use is considered a safety measure in equitation and its use is obligatory in almost all disciplines in Finland, except showjumping, where the Hackamore is allowed (Equestrian Federation of Finland, 2021a), in western riding where the Hackamore and Bosal are allowed (Equestrian Federation of Finland, 2021b), and in Icelandic horse competitions, where

according to competition rules the judges may allow riding with a bitless bridle for a 'good reason' (International Federation of Icelandic Horse Associations, 2021).

2.2 Mechanical injuries

Mechanical injury occurs when the loading exceeds the capacity of the tissue to absorb the transferred energy (Bilo et al., 2012). Mechanical injury can be divided into blunt force trauma, sharp force trauma, or trauma caused by firearms (Kumar et al., 2004). In a blunt force trauma a moving object strikes the body or a moving body strikes a fixed object (Kumar et al., 2004). Compression, pulling, or twisting of mucosa causes static tissue loading (Bilo et al., 2012). Tangential forces and uneven pressure distribution due to bony prominence (or in the horse's mouth due to teeth, which contain the hardest tissue in the body, enamel) may cause shearing and tensile forces, leading to distortion of mucosa and underlying structures (Sheridan and Nash, 2007; Reger et al., 2010; Bilo et al., 2012). Blunt force trauma may lead to bruises, abrasions, lacerations, and avulsions (Kumar et al., 2004; Sheridan and Nash, 2007; Reger et al., 2010; Bilo et al., 2012), whereas sharp force trauma is caused by a sharp object and results in division of the full thickness of skin or other tissue (Kumar et al., 2004).

A bruise (synonyms: contusion, hematoma) is a closed injury, where the overlying skin or mucosa is intact (Kumar et al., 2004; Bilo et al., 2012). A bruise results from the escape of blood from ruptured blood vessels to the skin, mucosa, or subcutaneous tissues, resulting in a color change (Kumar et al., 2004; Bilo et al., 2012). A bruise is almost always a result of blunt force trauma or squeezing (collision, compression, or stretching) and may only occasionally result from a disease such as coagulation disorder (Nash and Sheridan, 2009; Bilo et al., 2012). The amount of pain, tenderness, distinction of margins, induration, and color in bruises may vary (Nash and Sheridan, 2009). Superficial and fresh bruises are usually red, deeper bruises are blue or almost black, and less deep bruises are purple-colored (Bilo et al., 2012). Superficial bruises may become visible immediately or within minutes after the incident, whereas deeper bruises may not be visible until several hours or even days later (Bilo et al., 2012). The size of a bruise in a certain location is to some extent proportional to the force sustained; however, the exact amount of force that is required to cause bruises is unknown (Bilo et al., 2012). Erythema, in turn, is redness of the skin or mucosa due to cutaneous vasodilation caused by a local reaction to physical agents, such as friction, rubbing, or pressure, or the application of irritating chemical substances (Bilo et al., 2012).

Open skin injuries are abrasions (synonym: scrape or erosion), superficial injuries to the epidermis or mucosa (Bilo et al., 2012) where a portion of skin or mucosa is crushed or removed by rubbing (Kumar et al., 2004); lacerations, full-thickness injuries of the skin or mucosa and subcutaneous tissues that involve tearing of tissue (Kumar et al., 2004;

Bilo et al., 2012); or incisions, clean cut wounds that are longer than deep and are caused by sharp force trauma (Kumar et al., 2004; Bilo et al., 2012).

Classification of a mechanical injury requires evaluation of injury type, severity, mechanism (biomechanics; static or dynamic loading vs. non-mechanical (physical agent), manner (accidental vs. non-accidental, non-inflicted vs. inflicted, unintentional vs. intentional, non-abusive vs. abusive/negligent), dating (recent vs. old), anatomical location, and tissue type (Bilo et al., 2012). In general, the severity, extent, and appearance of blunt trauma injuries depend on the amount of force, the time over which the force is delivered, the body region affected, and the surface area of the body over which the force is delivered (Ressel et al., 2016).

2.3 Bit-related lesions

Earlier studies and the veterinary literature describe bit-related soft tissue lesions as ulcers, abrasions, pressure lesions, soft tissue edemas, tongue lacerations, skin breaks, blisterings, erosions, thickenings of the mucosa (Björnsdóttir et al., 2014; Mata et al., 2015), bit gnathitis, bit contusions, or bit sores (Merillat, 1917). Bone lesions in the mandible have been described as periostitis, bone spurs, or exostoses (Björnsdóttir et al., 2014; Mata et al., 2015).

2.3.1 Bit-related soft tissue lesions

Examination methods

Bit-related lesions have been studied in unsedated horses in competition environments (Björnsdóttir et al., 2014, 2018; Mata et al., 2015; Odelros and Wattle, 2018; Uldahl and Clayton, 2019) and in stable environments as a part of welfare evaluation (Visser et al., 2014), and in sedated horses using an oral speculum and light source (Tell et al., 2008). Only one earlier competition study has reported the use of an oral speculum (without sedation), mouth flushing, and a light source in examination (Odelros and Wattle, 2018). In another previous study, the horses were examined visually and by palpation, without sedation and speculum and possibly without a light source (Mata et al., 2015). In a Danish riding horse study, only the mouth corners (outer lip commissures) and presence of blood were examined (Uldahl and Clayton, 2019).

Lesion grading

Bit area health assessment requires a lesion grading system. Researchers have developed different methods for oral lesion status evaluation. The grading systems employed and the main results of earlier studies are presented in **Tables 1A** and **1B**. In one large-scale study, it was only possible to examine the outer lip commissures because the rules of the governing equestrian federation did not allow an intraoral examination (Uldahl and Clayton, 2019), which likely renders the majority of intraoral lesions undetected. In another study, lesions were graded as mild or severe and their location as bar region, buccal region (lip commissure or buccal mucosa), or tongue (Björnsdóttir et al., 2014). A third study reported lesions by the severity scale from 0 (no lesions) to 5 per lesion location (Mata et al., 2015), but since the horse has two bars and two lip commissures, it is difficult to estimate how many of the horses actually had lesions. A fourth study reported the number of small and large lesions and acute and chronic ulcers per location and per horse group (Tell et al., 2008). Earlier studies have not differentiated bruises from wounds (ulcers).

Lesion occurrence

Mild bit-related lesions were observed in 36% and severe lesions in 8% of 424 Icelandic horses before the competition in 2012. Oral examination was repeated for 77 horses after the competition, at which time 60% of the horses had lesions (Björnsdóttir et al., 2014). Bar lesions increased from 8% to 31% after competition (Björnsdóttir et al., 2014). The study was repeated in 2014 and 2016; the prevalence of bit-related lesions after a competition were 33% and 43%, respectively. The authors suggested that the reasons behind statistically significant lesion reduction in 2014 was the prohibition of curb bits with a port after the first study, the general improvement of oral health in competition horses, increased awareness and riding skills of riders (Björnsdóttir et al., 2018). However, when the occurrence was again higher in 2016, the authors suggested that attention to bit-related lesions might have declined (Björnsdóttir et al., 2018).

Acute soft tissue injuries were found in 88% of 144 Swedish Standardbred trotters after a race (Odelros and Wattle, 2018). These horses were compared with a retrospective control group of 80 trotters in training (Odelros and Wattle, 2018). Of these, 80% had soft tissue injuries (Odelros and Wattle, 2018). However, racing increased the lesion occurrence in the premolar region, bars, and lip commissures (Odelros and Wattle, 2018). Commissure lesions or blood was detected in 9.2% of 3143 Danish riding horses examined after a competition (showjumping, dressage, eventing, or endurance) (Uldahl and Clayton, 2019). Lip commissure and buccal ulcers opposite to the second premolar 06 were more common in horses that were currently ridden with a bit and bridle as compared with non-ridden horses such as broodmares, who had been 11 months without

a bit or riding horses that had been resting on pasture for 5 weeks (Tell et al., 2008). None of the study horses had lesions in the bars (Tell et al., 2008).

From previous studies, it can be concluded that the number, type, size, age, and location of the lesions in horses are important when assessing overall bit area condition.

Table 1A. *Earlier studies on bit-related soft tissue lesions in horses. The time and method of examination, grading system, and locations examined are presented.*

STUDY	EXAMINATION	GRADING SYSTEM	LOCATIONS EXAMINED
Björnsdóttir et al., 2014 Björnsdóttir et al., 2018	In association with competition, without sedation or oral speculum.	Max 1 cm ulcer or pressure lesion = mild, > 1 cm ulcer = severe If multiple lesions were found, only the most severe one was included in the analysis.	Buccal area (included lip commissures and buccal mucosa) Bars Tongue
Odelros & Wattle, 2018	In association with competition, without sedation, but with a light source and oral speculum. Mouth was rinsed.	Not described in poster presentation.	Lip commissures Premolar region Bars
Mata et al., 2015	In association with competition.	Lesion severity grade from 1 to 5 in lip commissures, bars, and tongue. Larger and deeper lesions got higher scores.	Grade 1 to 5 lesions were reported per lip commissures, bar bone spurs, or tongue.
Tell et al., 2008	In stable, sedated, with oral speculum, light source, but no mirror use.	< 0.5 cm = small ulcer > 0.5 cm = large ulcer Acute or chronic Number of lesions in different locations were reported per number of horses in the group.	Lip commissures Bars Area opposite 06 teeth Area opposite 07–11 teeth Behind 11 teeth Tongue Hard palate
Uldahl & Clayton, 2019	In association with competitions.	Lesions or blood in outer lip commissures.	Outer lip commissures
Visser et al., 2014	Inspection and palpation at home stable.	Irregularities (wounds, fissures, redness) detected yes/no.	Mouth corners and gums (bars).

Table 1B. *Earlier studies on bit-related soft tissue lesions in horses. The description and number of horses and the main study findings are presented.*

STUDY	HORSES	N	MAIN RESULTS
Björnsdóttir et al., 2014	In 2012, Icelandic horses before and after a competition.	424 77	36% had mild and 8% severe bit-related injuries before the competition. 60% had bit-related lesions after the competition. Bar lesions increased in competitions. Bar lesions in 15% of the horses. Curb bit with a port was a risk factor for bar lesions.
Björnsdóttir et al., 2018	In 2014 and 2016 Icelandic horses after a competition.	197 (?)	In 2014, 33% of the horses had bit-related lesions. Bar lesions in 4% of the horses. In 2016, 43% had bit-related lesions. The number of bar lesions was almost the same as in 2012.
Odelros & Wattle, 2018	Between 2011 and 2014 Swedish trotters after a race. Trotters in training.	144 80	88% of horses had acute soft tissue injuries. 80% of the horses had soft tissue injuries in the oral cavity. Racing trotters had more lesions in the premolar region, bars, and lip commissures than trotters in training.
Mata et al., 2015	English racehorses and polo horses in competition environments.	100	From racehorses 53/100 and from polo horses 15/100 lip commissures were ulcerated. From racehorses 30/100 and from polo horses 30/100 bars showed bone spurs. Oral lesions were more common and more severe in racehorses with snaffle bits than in polo horses with gag bits.
Tell et al., 2008	Swedish non-ridden broodmares (20). Riding horses in riding (70) Riding horses not ridden in 5 weeks and ridden for 7 weeks (23).	113	None of the broodmares had lip commissure ulcerations. Four broodmares had buccal ulceration opposite 06 teeth, only one of which was large. None of the horses had bar lesions. Horses that were currently ridden with a bit and bridle had more 06 area and lip commissure lesions.
Uldahl & Clayton, 2019	Danish riding horses after a competition.	3143	9.2% of the horses had outer lip commissure lesions or blood.
Visser et al., 2014	Sport and leisure horses in the Netherlands.	2717	18.5% of the horses had irregularities in mouth corners (hardened spots, redness, wounds) 3.4% of the horses had hardened spots, redness or open wounds in the bars (gums).

2.3.2 Bit-related dental wear and bone damage

Bit-related hard tissue injuries reported are *dental abrasion, periostitis (bone spurs),* and mandibular bone infection *(osteitis)* (Hague and Honnas, 1998; Dixon et al., 2000; Johnson, 2002; Cook, 2011) Even chip fractures on the mesial surface of the lower cheek teeth are reported (Cook, 2011). Repetitive forces applied to the reins or inappropriate bit use may lead even to devitalized bone fragment separating from the surrounding bone (*sequestrum*), which can be diagnosed with radiographs and may require surgery (Hague and Honnas, 1998; Dixon et al., 2000; Johnson, 2002; Lancker van et al., 2007; Kuhnke et al., 2010). In a few cases, the mandibular infection can extend to the apex of the first cheek teeth and lead to dental extraction (Dixon et al., 2000). Signs of mandibular periostitis have been found in domestic horses, but not in feral horses examined in museum specimens, indicating that bone changes might be related to bit use (Cook, 2011).

It has been suggested that a horse may take the bit between its premolars and chew on it due to anxiety or frustration (Johnson and Porter, 2006). Dentine and enamel erosion have been found in 66% of the first lower cheek teeth of domestic horses, compared with feral or Przewalski horses, none of which showed signs of dental erosion (Cook, 2011).

2.4 Teeth and sharp enamel points

Buccal mucosal abrasions and ulcerations have been associated with sharp enamel points in upper cheek teeth (Easley, 2010; Dixon et al., 2011; Simon and Herold, 2014; Salem et al., 2017). Lesions opposite the first and second upper molar, lip commissures, and bars are commonly associated with bit use, causing friction between the teeth and mucosa, whereas lesions situated caudally in the mouth, especially opposite the fifth upper molar, are related to forcible movements of the masseter muscle (Merillat, 1917; Tell et al., 2008; Björnsdóttir et al., 2014).

Horses have hypsodont teeth that erupt 2–3 mm per year (Dixon, 2000; Klugh, 2010). Due to mastication and concurrent tooth wear, sharp enamel points form, usually along the lingual edges of lower cheek teeth and the buccal edges of upper cheek teeth (Simon and Herold, 2014). Rounding of these sharp enamel points is called *floating* (synonyms: rasping, reduction of excessive sharp enamel points/enamel overgrowths) (Klugh, 2010). In a study where the whole mouth of 199 horses was examined with a mouth speculum and a headlamp, buccal ulceration or abrasions were present in 55% of the

horses (Allen, 2004). Oral mucosal injuries were found in 64.2% and sharp enamel points in 79.8% of 450 Egyptian working horses, none of which had received previous proper dental care (Salem et al., 2017). In that study, oral mucosal ulcers in two horses and laceration in one horse were considered to be bit-related (Salem et al., 2017). The horses in that study were aged 0.7–30 years (mean 6 years); it was not reported whether bits were used in all horses (Salem et al., 2017).

Oral examinations with sedation and dental mirror or endoscope and maintenance dentistry intervals of 6–12 months are recommended, but in some horses ulceration may recur already within 3 months (Johnson and Porter, 2006; Allen, 2008; Pearce, 2020). It is also important to determine whether the horse has malocclusions leading to hooks in 106 206 teeth or ramps in 306 406 teeth, which could affect the bit contact (Johnson and Porter, 2006; Foster, 2013; Eriksson et al., 2019). However, only one study has shown a positive effect of floating on the trainer's perception of the horse's response to the bit (see Easley, 2011 p. 264 for reference). Other studies have not found any association between floating and horse's improved performance in ridden work (Carmalt et al., 2006; Moine et al., 2017).

2.5 Lesion healing

Currently, the oral lesion healing time is unknown in horses. If oral lesions are found, it is considered important to let them heal properly (Foster, 2013) to minimize pain (Mellor, 2020). In humans, mucosal and gingival healing may take 1–2 months (Nanci and Wazen, 2013). However, regaining normal tissue strength can take up to 5 months (Fossum et al., 2002; Nanci and Wazen, 2013).

The oral mucosa consists of stratified squamous epithelium and an underlying connective tissue (lamina propria) (Nanci and Wazen, 2013). Tissue injury causes an immediate acute inflammatory reaction. Neutrophils, lymphocytes, mast cells, and macrophages are major cells involved in inflammation and wound healing (Nanci and Wazen, 2013). Wound healing involves three consecutive but overlapping phases: hemostasis/inflammatory phase, proliferative phase, and remodelling phase (Wang et al., 2018). The moist environment in the mouth enhances wound healing (Fossum et al., 2002; Greet and Ramzan, 2010). Prolonged inflammatory response and foreign material in the wound, such as dirt, debris, and sutures, impair wound healing (Fossum et al., 2002; Nanci and Wazen, 2013). Therefore, a proper rest from bit use is considered essential for lesion healing (Foster, 2013).

In humans skin healing is faster in women than in men (Engeland et al., 2006). However, oral mucosal healing is slower in women (Engeland et al., 2006). In animal studies, deep wound healing by second intention has been found to be faster in ponies than in horses (Wilmink et al., 1999).

Determining the age of the wound is challenging (Ressel et al., 2016). Histochemical and biochemical methods have been used for wound age determination in autopsy samples (Raekallio, 1972). Bruise color changes during healing, but it is influenced by many factors and it is not possible to date bruises or abrasion wounds accurately by their appearance (Bilo et al., 2012; Ressel et al., 2016).

2.6 Rein tension

The amount and duration of rein tension leading to oral injuries have not been studied in horses, but these are potential risk factors for bit-related injuries. Rein tension refers to the force (F) applied on the reins between the horse and human in riding or driving, and it is transmitted to different parts of the horse's rostral mouth via the bit causing pressure (P) on oral structures (Warren-Smith et al., 2007; Dumbell et al., 2019) or to the horse's nose via the noseband in the bitless bridles (Eisersiö et al., 2021b). The SI unit of force is the Newton. As an example, a 102 g weight exerts a force of one Newton due to the earth's gravity. The general definition of pressure is a force applied perpendicularly to a certain area (A) ($P = F/A$) (Takahashi et al., 2010; Bilo et al., 2012). The SI unit for pressure is Pascal (Pa), which is a force of one Newton (N) applied to an area of one square meter. In medicine, mmHg is also used as a pressure unit. Rein tension is usually reported as Newtons per rein or as the mean of the two reins, but it has been suggested that as both reins are pulling the same object the rein tension could be reported as a sum of the two reins (Eisersiö et al., 2021a). Different devices have been used for rein tension measurement and their accuracy has been debated (Pierard et al., 2015). To the author's knowledge, to date there is only one published study evaluating rein tensions in trotters. In that study, rein tension varied from 177 N to 392 N in trotters, from 18 N to 245 N in driving horses, and from 18 N to 147 N in riding horses (Preuschoft et al., 1999).

Rein tension varies continuously during riding and is affected by the rider's position in the saddle and the horse's stride cycle and gait (Clayton et al., 2003, 2005; Eisersiö et al., 2015; Egenvall et al., 2016, 2019; Dumbell et al., 2019). Peak rein tensions have been found to be lower in walk than in trot, and in trot than in canter (Clayton et al., 2005; Eisersiö et al., 2015; Dumbell et al., 2019; Toft et al., 2020).

It may be difficult for the rider to estimate applied rein tension. Even when the rider has the impression that the tension is constant and equal between the reins, rein tension data have shown that differences were present on the left and right sides and tension was characterized as spikes varying in magnitude and frequency with the horse's gait (Clayton et al., 2003; Hawson et al., 2014). In a study where riders were asked to take a medium contact with the reins on a fiberglass model horse, the tension was 3 N (1–8 N) on the right rein and 5 N (2–13 N) on the left rein (Hawson et al., 2014). When the same riders were asked to do walk-to-halt transitions, the mean rein tension on the right rein was 6 N (2–16 N) and on the left rein 9 N (3–29 N) (Hawson et al., 2014).

Studies have investigated the levels of rein tension that horses experience as aversive (Christensen et al., 2011; Piccolo and Kienapfel, 2019). Bilateral rein tension of 25 N ± 5 N vs. no rein tension increased the time horses used for intraoral behaviors such as mouthing and retracting and bulging the tongue (Manfredi et al., 2009). Maximum rein tension was significantly lower (7.5 N) without the rider when side reins were set on horses in the dressage frame than in horses ridden in the dressage frame (24 N) (Piccolo and Kienapfel, 2019). In another study, tension-naive horses were willing to take rein tension as high as 38 N when horses were lured to extend their neck to reach food from the bucket (Christensen et al., 2011). The mean bilateral rein tension on the first day was 10 N and on the following two days 6 N (Christensen et al., 2011). This indicates that instead of habituating to the bit pressure the horses learned to avoid rein tension and did not want to stretch their head as much to get food from the bucket (Christensen et al., 2011). No lesions were found in the horse's mouths that could have explained this increased aversion (Christensen et al., 2011). These results suggest that bilateral rein tension exceeding 6–10 N (0.6–1.0 kg) could cause discomfort to the horse, but when applied voluntarily and for a short time does not cause oral lesions (Christensen et al., 2011).

2.7 Negative reinforcement, rideability, driveability, and 'pullers'

Successful bit use is based on *negative reinforcement,* in other words pressure and release, which is a form of *operant conditioning* (Bennett, 2001; Lethbridge, 2009). When a horse starts to perform a desired response, e.g. decelerate or turn, it is followed by immediate removal of an aversive stimulus such as bit pressure (Lethbridge, 2009; McGreevy et al., 2018). Through repetitions in training horses learn what behavior leads to the pressure release and the horses can be taught to respond to progressively lighter rein tension signals (Eisersiö et al., 2021b).

Rideability, or analogously *driveability,* refers to how easy and comfortable the horse is to ride or drive (König von Borstel and Glißman, 2014). However, different riders may assess the horse's rideability differently (Christensen et al., 2021). Better rideability scores have been associated with lower and steadier rein tensions (König von Borstel and Glißman, 2014). It is possible to affect rein tensions by training (Eisersiö et al., 2021b). Ideally horses respond to light rein signals, but previous experiences, breed, individual differences, rider, and equipment may all affect how the horses respond (Christensen et al., 2011; Dumbell et al., 2019). Additionally, the horse's arousal level and *affective states* (*emotional states*) affect horse learning and behavior (McLean and Christensen, 2017). It has been suggested that simultaneous opposing signals (e.g. 'stop' signal with reins and 'go' signal with leg pressure), one signal eliciting two or more responses (e.g. holding the reins tight, meaning normally 'stop' but at the same time wanting a trotter to 'go' fast), or incorrect negative reinforcement (not releasing the pressure at the right moment) may cause *conflict behavior* (McGreevy et al., 2005). Conflict behaviors are described as "a category of stress-induced behavior changes that arise from conflicting motivations, especially when escape/avoidance responses are not consummated" (Mills and Marchant-Forde, 2010).

Horses that have learned not to respond to light rein signals are called *'hard-mouthed' or 'pullers'* (Dwyer, 1868; Merillat, 1917; Foster, 2013; McLean and Christensen, 2017). Horses may develop a habit of pulling (*bit lugging*) due to improper training (Merillat, 1917; Foster, 2013). However, in the earlier literature it has been suggested that some horses could be 'pullers by nature' (Merillat, 1917).

'*Heavy-handed*' riders or drivers are believed to be able to cause oral trauma and when frustrated with rideability or driveability problems they may try various bits (Dwyer, 1868; Merillat, 1917; Foster, 2013; Eriksson et al., 2019). Riders' aggression or forceful riding can also result from fear or frustration (Berkowitz, 1989), or from the notion of bravery, which is regarded as a virtue in equestrianism (McVey, 2021). Many different bit types made of different materials are available (Kau et al., 2020). It has been suggested that the multiplicity of bit designs on the market might reflect their use as a means of overcoming deficits in training or riding (McGreevy, 2007; McGreevy et al., 2018). Sometimes trainers or riders seek veterinary advice for driveability or rideability issues (Foster, 2013). When it is perceived that a 'heavy-handed' driver or rider is the cause of the oral lesions, it is sometimes difficult to offer veterinary guidance (Foster, 2013; Oskarsson, 2016). Already in 1917, the suggestion was that horses be trained with the simplest equipment and to respond to the slightest pressure (Merillat, 1917). Dental care, bit fitting, and alternating jointed and unjointed snaffle bits were offered as a cure for pulling horses (Merillat, 1917).

2.8 Oral pain and pain recognition

The horse's mouth is very sensitive (Dwyer, 1868; Eriksson et al., 2019) since oral tissues have strong somatosensory innervations (Nanci and Wazen, 2013; Haggard and de Boer, 2014). Free nerve endings are found in the mucosal epithelium and the underlying connective tissue (Nanci and Wazen, 2013). Pain is an unpleasant subjective experience (Hockenhull and Whay, 2014; Mellor, 2020) and an important protective warning system to minimize tissue damage (Muir, 1998; Sneddon, Elwood, Adamo, & Leach, 2014; Woolf, 2004). *Nociceptive pain* is a response to a noxious stimulus (heat or cold, intense mechanical force, or chemical irritants) (Woolf, 2004). *Inflammatory pain* is caused by tissue damage and inflammatory response (Woolf, 2004). *Intensity, frequency, duration, and quality* are different dimensions of pain (Hockenhull and Whay, 2014).

Inability to communicate verbally does not negate the possibility that an animal experiences pain (International Association for the Study of Pain (IASP), 2020). Pain or distress evaluation can be made in horses by observing facial expressions, abnormal behavior, or lack of normal behavior (Dalla Costa et al., 2014; Gleerup et al., 2015; Górecka-Bruzda et al., 2015; Dyson et al., 2018; Pehkonen et al., 2019). However, behavioral signs of equine distress and pain are poorly recognized (Lesimple and Hausberger, 2014; Bell et al., 2019; Pehkonen et al., 2019). If caretakers are surrounded by a large number of individuals expressing distress or pain, i.e. *over-exposure,* it may result in these behaviors going undetected and even being regarded as 'normal' (Prkachin et al., 2004; Lesimple and Hausberger, 2014).

The horse is an obligatory nose-breather and in exercise it normally keeps its mouth closed (Cook, 1999). Mouth opening, tongue moving in and out, tail swishing (lateral, vertical, or circular tail movements), head movements (tilting, rising, lowering, tossing, or going behind the vertical), teeth grinding, ear pinning, evasive behaviors (shying, rearing, bolting, fleeing), and braking the gait are behaviors that can be related to pain avoidance, frustration, or fear, indicating that the horse is experiencing mental or physical discomfort (Cook, 1999; McGreevy et al., 2005; Górecka-Bruzda et al., 2015; Hall and Heleski, 2017; Cook and Kibler, 2019; Fenner et al., 2019b; Dyson and Van Dijk, 2020; Christensen et al., 2021). It has been suggested that horses expressing discomfort, and thus, from a human point of view, seemingly resisting commands, be labeled as 'problem horses' and described with such *anthropomorphic* terms as 'lazy', 'mad', or 'stubborn' and exposed to punishment in training (McLean and McGreevy, 2010a; McGreevy et al., 2011).

2.9 Head equipment

2.9.1 Nosebands

Nosebands are used to prevent the horse from opening its mouth, to increase bit control, or in some cases to comply with competition rules (Doherty et al., 2017). It has been suggested that in addition to a bit, nosebands, hackamores, and bosals may press the cheeks onto sharp enamel points and cheek tooth edges (Johnson and Porter, 2006). In one study, a loose upper noseband was associated with a smaller outer lip commissure lesion risk, but surprisingly the absence of an upper noseband was associated with increased lip commissure lesion risk (Uldahl and Clayton, 2019). Noseband type, or the presence or tightness of the lower noseband was not associated with commissure lesion risk (Uldahl and Clayton, 2019).

The use of tight nosebands has raised concerns regarding their behavioral and physiological consequences to horses (McGreevy et al., 2012; Casey et al., 2013; Fenner et al., 2016; Doherty et al., 2017). Traditionally, it is recommended that two adult human fingers should be able to fit under the noseband at the nasal planum (Doherty et al., 2017). Since the size of human fingers may vary, use of a special device, such as the ISES taper gauge, has been suggested for the noseband tightness measurement (McGreevy et al., 2012; Doherty et al., 2017). In the study of 750 riding horses (eventing, dressage, performance hunter), post-competition examination showed that in 44% of the horses no fingers could fit under the noseband. Only 7% of the horses were in the two-finger classification (Doherty et al., 2017). Removal of a noseband and double-bridle has led to increased yawning, licking, and swallowing, indicating a *post-inhibitory rebound effect* (Fenner et al., 2016). The term means that the behavior is increased after a period of restriction (Fenner et al., 2016; Hall et al., 2018).

2.9.2 Tongue-tie

Tongue-tie is a device applied to the tongue to stabilize it to the mandible (Foster, 2013) and to restrict tongue movements (Weller et al., 2021). Tongue-tie is used in Thoroughbred and Standardbred racing to prevent or reduce airway obstruction or intermittent dorsal displacement of the soft palate (DDSP), to prevent or reduce airway noise, and to prevent the horse from moving its tongue over the bit (Barakzai et al., 2009a, 2009b; Weller et al., 2021). Tongue-tie use in racing is allowed in Finland (Finnish Trotting and Breeding Association, 2020b; Union Européenne du Trot, 2021a). Its use is forbidden in Switzerland, on three racetracks in Germany (Union Européenne du Trot, 2018b, 2021b), and in FEI competitions (Weller et al., 2021).

Common tongue-tie materials are elastics, stockings, leather, or nylon (Weller et al., 2021). In an Australian study, 62.5% (70/122) of Thoroughbred and Standardbred racehorse trainers reported tongue-tie use (Weller et al., 2021). In thoroughbred racing in the UK, the prevalence of tongue-tie use was 5% in 2001–2003 (Barakzai et al., 2009b).

A tight tongue-tie may cause the tongue to become cyanotic and induce muscle and nerve injury (Foster, 2013). When 535 Australian Standardbred trainers were asked about the most common complications in tongue-tie use, they described superficial cuts (reported by 10%), anxiety, and distress (reported by 9%) (Findley et al., 2016).

2.9.3 Overcheck

Overcheck (earlier known as a bearing rein or checkrein) is used in harness racing horses to prevent the horse from lowering its head (Youtt, 1831; Bennett, 2010). The caudal end of the overcheck is attached to the harness on the horse's back and it runs between the ears and is nowadays attached to the checkbit, jaw strap, or both. Tight bearing rein has been associated with horses' neck or back muscle cramps and when attached to the bit the bearing rein stretches the lip commissures upwards while the driver pulling the driving reins stretches the lower lips "making a very ugly feature" (Youtt, 1831; Sewell, 1877; Russell, 1893b). The association of overcheck with oral lesions has not been investigated earlier. It has been suggested that head equipment, such as nosebands, tongue-ties, and overchecks, may restrict a horse's movements and expression of discomfort (McLean and McGreevy, 2010b; Casey et al., 2013; McGreevy, 2015).

2.10 Bit-related lesions and their relation to horse welfare

Freedom from bit-related lesions is part of the welfare concept because of the pain and possible anxiety and fear when anticipating and experiencing the pain (Mellor, 2020). Physical injury is one of the main causes for welfare deterioration since it affects the animal's integrity (Lesimple, 2020). Freedom from discomfort, injuries, distress, fear, and pain are important aspects of the animal welfare regime, which has been defined in the form of Five Freedoms (Brambell, 1965; Farm Animal Welfare Council, 1979) as a first attempt to scientifically define animal welfare (Duncan, 2006; Keeling and Jensen,

2020). *The Five Domains model,* developed later, highlights that animal welfare is not just freedom from negative impacts, but also positive experiences (Mellor and Beausoleil, 2015). The disadvantage is that no good techniques exist to measure affective states (feelings) in animals (Keeling and Jensen, 2020). They can, however, be measured indirectly, mainly by examining animal behavior (Keeling and Jensen, 2020).

The five freedoms are the following:

> 1. Freedom from thirst, hunger, and malnutrition by ready access to fresh water and a diet to maintain full health and vigor.
>
> 2. Freedom from discomfort – by providing an appropriate environment including shelter and a comfortable resting area.
>
> 3. Freedom from pain, injury, or disease – by prevention or rapid diagnosis and treatment.
>
> 4. Freedom to express normal behavior – by providing sufficient space, proper facilities, and company of the animal's own kind.
>
> 5. Freedom from fear and distress – by ensuring conditions and treatment which avoid mental suffering
> (Farm Animal Welfare Council, 1993).

The term '*animal welfare*' is used increasingly; however, it can mean different things to different people (Hewson, 2003). Animal welfare is a complex and multi-faceted topic having scientific, ethical, cultural, economic, social, religious, and political dimensions (OIE - World Organisation for Animal Health, 2021). *Animal welfarism* refers to laws that allow animal use if the use does not inflict *unnecessary pain or suffering*; this means that people must balance between animal and human interests (Francione, 1993).

Welfare Quality® (WQ) was a project funded by the European Commission to meet society's concerns and consumer needs through developing on-farm welfare assessment systems for cattle, pigs, and poultry (Blokhuis et al., 2010; Viksten, 2016). The protocol uses animal-based (animal itself), resource-based (animal's environment or resources), and management-based measures (Viksten, 2016).

Welfare Monitoring System (Wageningen UR Livestock Research, 2012), *Animal Welfare Indicators project* (AWIN) (Minero et al., 2015), and *Horse Welfare Assessment Protocol* (HWAP) (Viksten, 2016) are WQ-based protocols for horses. These protocols evaluate bit-related lesions because one welfare criterion is the absence of pain caused by the use of the horse (Wageningen UR Livestock Research, 2012; Minero et al., 2015; Viksten, 2016).

In the AWIN protocol, the outer lip commissures are examined and scored: no lesions / hardened spots / redness / open wounds (Minero et al., 2015). In the HWAP protocol, mouth health is evaluated as 0 = no injuries, 1 = depigmentation or chafing, or 2 = depigmentation and chafing or open wounds (Viksten, 2016). In the Welfare Monitoring System, the examination is done by standing in the front of the horse and palpating with two thumbs simultaneously both the inner and outer lip commissures and conducting a simultaneous visual inspection. Lesions are scored as 0 = no evidence of wounds, fissures, or redness in mouth corners or 1 = wounds, fissures, and redness. Bars are assessed for old or fresh wounds or redness by palpating the upper and lower bars and checking for old wounds (hardening / irregularities) or fresh wounds and / or redness. They are scored as 0 = no evidence of wounds or 1 = evidence of wounds (Wageningen UR Livestock Research, 2012).

2.11 Legislation and competition rules

National legislation (Animal Welfare Act and Animal Welfare Decree) provides general regulations for animal handling. Competition rules in riding competitions and in harness racing define which bits and equipment are allowed in competitions. Competition rules also define what measures can be taken if bleeding from a horse is observed.

2.11.1 Animal welfare act and animal welfare decree

> "The animals must be treated well and no undue distress may be caused to them. Inflicting undue pain and distress on animals is prohibited" (Animal Welfare Act 247/1996 3§, 1996).

The Animal Welfare Decree prohibits the use of spiked bits (Animal Welfare Decree 396/1996, 1996). The presence of a veterinarian in animal competitions is regulated by the national legislation (Animal Welfare Act 247/1996, 1996).

> "If an animal may be subjected to pain, suffering or excessive exertion in a competition, the organizer of the competition must, at his or her own cost, invite a veterinarian to the competition to supervise that this Act and provisions and regulations issued under it are complied with"
> (Animal Welfare Act 247/1996, 1996).

The duty of a veterinarian is to remove an animal from a competition if it is used against the law. However, the competition veterinarian is not a government authority (situation in 2022).

> "The veterinarian must prohibit the use of an animal in competition if there is justified cause to suspect that the animal is used in a way that violates this Act or provisions or regulations issued under it"
> (Animal Welfare Act 247/1996 17§, 1996).

2.11.2 Racing rules and guidelines

In addition to duties described in legislation, racing veterinarians also have other duties defined in racing rules, e.g. monitor track conditions, conduct medication control (doping tests), and give first-aid if a horse is injured (Finnish Trotting and Breeding Association, 2021). 'Heppa' is a Finnish online database for race veterinarians where they can report race events regarding the health of individual trotters. The reports are available to the horse's trainer, race judges, and other race veterinarians for six months (situation in 2022). If the horse is not fit to compete or has multiple previous reports, the race veterinarian can mandate a veterinary health certificate before the horse can be registered for the next race (Finnish Trotting and Breeding Association, 2021). The decision is made together with race judges (Finnish Trotting and Breeding Association, 2021). If bleeding is observed from the horse's mouth before a race, a veterinarian should examine the horse and, if necessary, remove the horse from the race (Finnish Trotting and Breeding Association, 2017). If bleeding is observed from the mouth after a race, a race veterinarian can stipulate that a health certificate be acquired (Finnish Trotting and Breeding Association, 2017). However, the extent of oral damage or the number of mouth bleedings that could lead to removal from the race or require a health certificate are not defined.

Another guideline that might be applicable to bit use is that a race veterinarian could prohibit the use of equipment if it is considered to be harmful (Finnish Trotting and Breeding Association, 2021). If the equipment has caused an injury to the horse, the horse is prohibited from competing for the duration of the recovery period (Finnish Trotting and Breeding Association, 2021).

2.11.3 FEI blood rule

Blood rule means that in riding competitions if a horse shows fresh blood it could be eliminated from the competition. However, the rule depends on the discipline (Fédération Equestre Internationale, 2021a, 2021c, 2021b). In eventing, the blood rule for the dressage test is as follows: if the horse shows fresh blood, it will be eliminated (Fédération Equestre Internationale, 2021b). In the jumping test: horses with blood on the flank(s) and/or bleeding in the mouth will be eliminated. In minor cases of blood, such as where a horse appears to have bitten its tongue or lip, officials may authorize the rinsing or wiping of the mouth and allow the horse to continue; any further evidence of blood in the mouth will result in elimination (Fédération Equestre Internationale, 2021b). In the cross-country test: all athlete-induced (spurs, bit, and whip) blood on the horse must be reviewed by the Ground Jury. If the horse shows fresh blood, officials may authorize the rinsing or wiping of the mouth and if there is no further evidence of bleeding the horse will be allowed to continue (Fédération Equestre Internationale, 2021b).

3 AIMS OF THE STUDY

The overall objective of this study was to increase awareness of bit-related lesions and discussion about horse welfare and ethics in competitions. Specific study aims were as follows:

1 To determine the occurrence of oral lesions in the bit area in Finnish trotters and event horses after competitions (I, III).

2 To create a scoring system for oral lesions in the bit area and demonstrate different lesion types and locations with photographs (I).

3 To determine risk factors for bit-related lesions in trotters and event horses (II, III).

4 To investigate different stakeholder's attitudes towards bit-related lesions in trotters (unpublished pilot data).

4 MATERIALS AND METHODS

A study design overview and the main statistical analyses are presented here. Details of the materials and methods in each study (I–III) are available in the original articles included at the end of the thesis.

4.1 Ethics statement

The study was considered ethically acceptable by the University of Helsinki, Viikki Campus Research Ethics Committee (Statement 8/2018). The examination was compulsory for the trotters selected for this study as a part of the Finnish Trotting and Breeding Agency's (Suomen Hippos ry) Welfare program for trotters. Prior notice of the study was given to trainers via an announcement in the national equine sports weekly newspaper (Hevosurheilu) and on the internet page of the Finnish Trotting and Breeding Association (www.hippos.fi).

For the event horses, the examination was voluntary. The study was carried out in collaboration with the Equestrian Federation of Finland (Suomen Ratsastajainliitto, SRL). The participants received information concerning the study upon online registration for competitions and from an information leaflet pertaining to the study handed out on the 1st day when they checked in at the competition office. Consent was given verbal due to field conditions in competitions. Riders, drivers, and trainers were anonymized for the data analysis.

The horses experienced some inconvenience, which was deemed to be slight, when their tongues were held during the examination, which lasted no more than one to two minutes. In general, the horses tolerated the examination well. The examination was discontinued and the horse excluded from the study if the horse expressed obvious avoidance behavior during the examination (3/264 trotters and 7/215 event horses).

4.2 Horses and study designs

Harness racing is the largest horse sport in Finland, with 6000–7000 horses competing yearly (National Equine Competence Association of Finland, 2017). Racing events are organized 540 times a year (Finnish Trotting and Breeding Association, 2020a). In Finland, there are approximately 20 000 Finnhorses, 25 000 Standardbreds, 20 000 riding horses, and 10 000 ponies (National Equine Competence Association of Finland, 2019). Standardbreds compete internationally; however, various coldblooded breeds compete mainly in Sweden, Norway, and Finland. In addition to harness racing, it was considered important to also evaluate horses in riding competitions. Eventing was chosen for the discipline in this study. At the time of the study, no scientific reports existed on oral lesions in event horses and the discipline is demanding for the horse and rider since the competition consists of three phases: dressage, showjumping, and a cross-country test where the horses jump solid obstacles through fields and wooded areas.

In total, 469 private-owned bit-using horses were examined for this thesis. The official sample size calculations were not made prior to the study. The sample size was partly based on two previous studies (Björnsdóttir et al., 2014; Mata et al., 2015) and partly on what is possible to achieve in practice. Characteristics of the horses are shown in **Table 2**. The aims and study designs are described below.

Table 2. *Characteristics of the horses in Studies I–III (N = 469). In Study II, the horses are the same as in Study I, but ponies were excluded from the risk factor analysis.*

VARIABLE	TROTTERS (N = 261) Studies I and II	EVENT HORSES (N = 208) Study III
BREED		
Standardbred	151	0
Finnhorse or other coldblood	78	52
Warmblood	0	127
Pony	32	29
SEX		
Mare	121	75
Gelding	110	120
Stallion	30	13
AGE (YEARS)	Mean 7.0 (3–15)	Mean 10.7 (4–19)

Study I

Aims: To analyze the occurrence of oral lesions in a sample of Finnish trotters. To create a simple and practical oral lesion scoring system that takes into consideration the total number of lesions as well as lesion type (bruise or wound), size, depth (superficial or deep), and age (old or acute injury) and to investigate lesion locations at inner and outer lip commissures, bars of the mandible, tongue, hard palate, and buccal area near 106 206 premolar teeth.

Design: The rostral part of the oral cavity (bit area) of 261 horses was examined after a trot race in 10 harness racing events from 115 starts in Western Finland in 2017. Horses were examined 5–20 minutes after a race. Horses located near to each other according to their harnessing booth number and competing in the same race were selected as possible candidates for the study. Horses examined in previous competitions were excluded. The first horse to arrive to the harnessing booth after a race was selected for the study. Normally 2 to 3 horses were examined from the same race. The second and third horse examined were the horses situated nearby and still in their harnessing booth. The examinations of that particular race ceased when all possible candidate horses had left. For the next race, the examiners moved to another 'cluster' of harnessing booths to wait for the competitors to arrive. The sample collection was not therefore completely random to ensure collection of an adequate sample size in the limited timeframe between races. Oral lesions were graded and recorded. Some lesions were photographed by taking frames from video recordings.

Study II

Aims: To investigate whether mouth lesions found in Study I were associated with certain bit types, trotter's equipment, race performance, or horse characteristics.

Design: Data from 229 horses (from Study I) were included in the logistic regression analysis to evaluate risk factors for oral lesions. Fisher's exact test was used to investigate the association between lesion location and bit type. Trotting ponies were excluded due to small sample size, over-representation of the snaffle trotting bit used in ponies, and the fundamental difference between betting and non-betting races.

Study III

Aims: To analyze the occurrence of bit-related lesions in a sample of Finnish event horses and the potential associations of lesions with equipment, such as noseband, bit type, and thickness, and other factors, such as breed, age, sex, competition level, or competition placement.

Design: The rostral part of the oral cavity of 208 event horses was examined after their participation in a cross-country test. Horses participating in eventing competitions are hereafter referred to as event horses. The study was performed in eight eventing competitions (seven national and one international competition) during the summers of 2018 and 2019 in Western Finland. Horses were examined approximately 5–30 minutes after their competition. Examination and lesion scorings were the same as in Study I. All competitions were two-day events. Dressage and show jumping tests were held on the first day. Examination was carried out on the second day, after competitors had completed the cross-country test and approached the horse trailer area. An invitation to participate was extended to as many competitors as possible to maximize the sample size, but horses examined in previous competitions were excluded.

4.3 Bit area examination in competitions

The rostral area of the mouth was examined 5–30 minutes after a race or a competition. Examination was performed from the left and right sides of a horse without sedation or mouth speculum, and with disposable nitrile gloves and an efficient headlamp (Lumonite Navigator 3000 headlamp set at 420–1300 lumens) by a single experienced veterinarian (KT).

In harness races (I, II), trotters were examined without the bridle and wearing only a halter. The majority of the event horses (III) were examined with their bridle on because according to Finnish riding competition rules horses must be bridled in the competition venue for safety reasons. Noseband and curb chain, if present, were unlatched, allowing the examiner to open the horse's mouth. The fingers were used to lift the bit to achieve better visibility.

The examination began with the examiner standing on the left side of the horse. The examination is described in **Figures 1–4**. An assistant (NM-K) verified and recorded the findings of the oral examination and the horse's bit type and equipment on a data sheet. An assistant video recorded some of the typical lesions with a digital camera (Panasonic DMC-GX7; lens H-FS14140, 14–140).

***Figure 1**. Preparative phase. The examiner is standing on the left side of the horse wearing an efficient headlamp and gloves. The tongue is gently guided externally with the right hand. The left thumb touching the palate facilitates mouth opening. Satu Cozens / Kummakko-Design.*

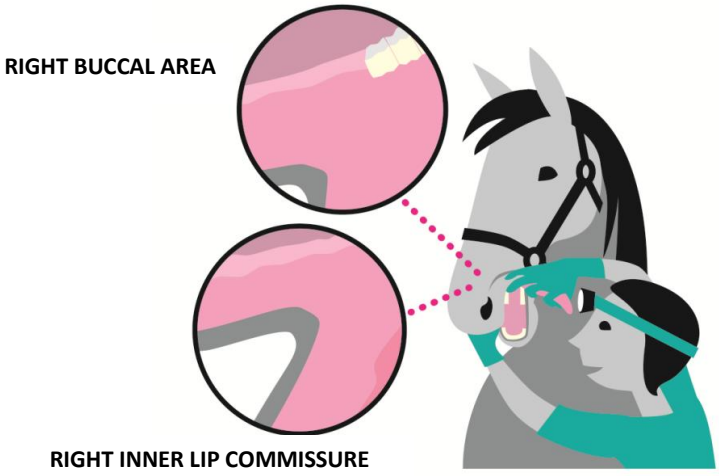


***Figure 2**. First phase of the bit area examination. Contralateral inner lip commissure and buccal area, tongue, and hard palate examination. Fully extending the contralateral lip commissure with the left thumb is sometimes necessary to improve visibility. Illustration Satu Cozens / Kummakko-Design.*

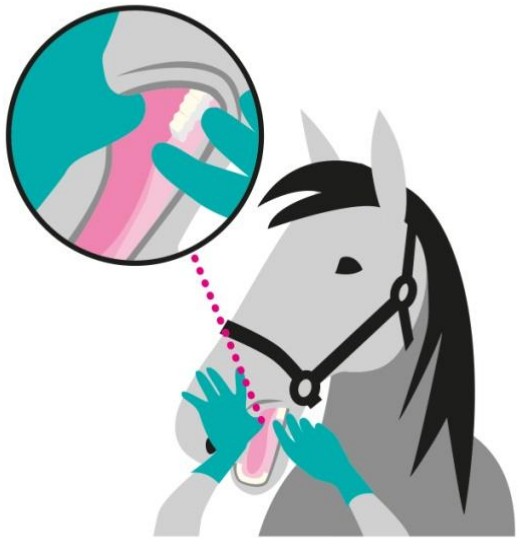


Figure 3. *Second phase. The tongue is released and the examiner is now standing at the 5 o'clock position (7 o'clock position when on the other side). This is safer than standing directly in the front of the horse. The examiner palpates the left bar area with the right index finger and at the same time visually and carefully examines the area in front of the first lower cheek tooth. The left thumb can be used for lifting the upper lip. Illustration Satu Cozens / Kummakko-Design.*

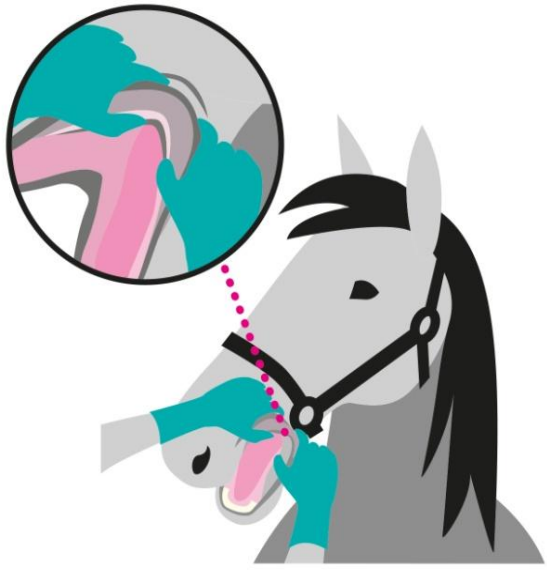


Figure 4. *Third phase. The examiner uses both hands to extend and examine the outer lip commissure. All phases are repeated from the other side. Illustration Satu Cozens / Kummakko-Design.*

4.4 Oral lesion scoring and oral lesion status

Lesions were visually evaluated as acute or old. Acute lesions included bruises and wounds. Old lesions included depigmented outer lip commissures, healed wounds, scars, and old bruises where the color had fainted. Since many horses had several lesions, a score was established that considered all acute lesions in each horse.

A bruise was determined as a submucosal bleeding, but with the mucosa visually intact. Bruises were given points from 1 to 4 according to their size (maximum diameter). A lesion was determined as a wound if the mucosal surface was damaged. Wounds were visually classified as deep if there was extensive damage to the submucosal tissue. Wounds were given points from 2 to 10 after evaluation of size and depth (**Figure 5**). Many of the lesions were of mixed type. If the same lesion had signs of bruising and wounding, the lesion was graded as a wound. If the lesion had signs of both acuteness and chronicity, the lesion was graded as acute (**Figure 6**). Points from all acute lesions were summed to yield a *total lesion score* that reflected the lesion severity status of each horse as well as the overall bit area damage (**Figure 7**). Old lesions were recorded separately. Lesions outside the mouth were not included in the study (**Figure 8**).

LESION SIZE	LESION TYPE		
	Bruise	Wound	Wound: superficial or deep?
< 5 mm	**1**	**2**	if deep, add **+ 2**
≤ 1 cm	**2**	**4**	
< 3 cm	**3**	**6**	
≥ 3 cm	**4**	**8**	

Figure 5*. Bit-related lesions were given points according to their type, size, and depth. Figure reproduced from Studies I and III.*

Figure 6. *Event horse after a competition. Signs of wound chronicity in the outer lip commissure (white and thickened wound margins). If such a wound was not fully healed and there was redness in the wound, the lesion was graded as acute in this study. Photo reproduced from Study III.*

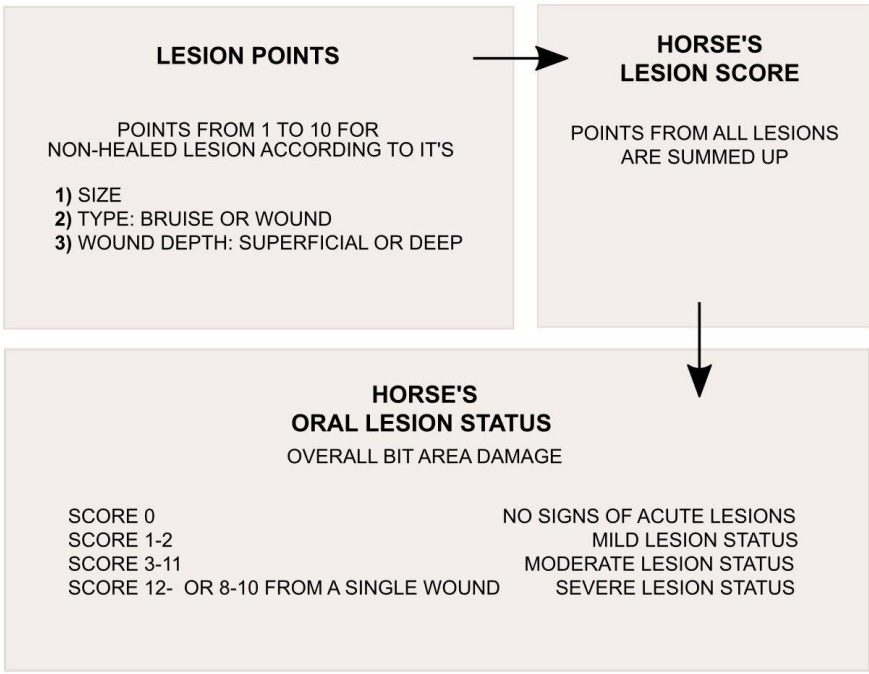


Figure 7. *Scoring system for bit-related lesions to describe overall bit area damage.*

***Figure 8**. Event horse after a competition (Study III). Bridle or bit ring may cause lesions also to the skin. This lesion was not included in the study. Photo: Nina Mäki-Kihniä.*

4.5 Recorded variables

Recorded variables in trotters and event horses are presented in **Tables 3 and 4**, respectively. An example of trotters' equipment is presented in **Figure 9**.

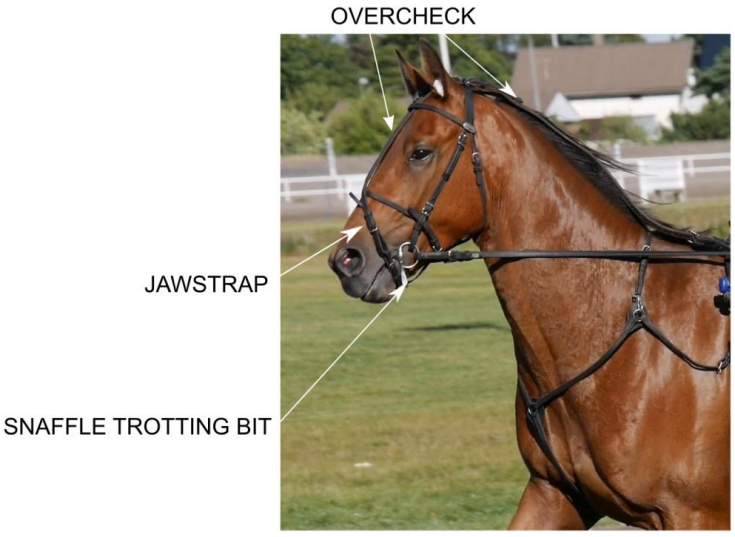


***Figure 9.** Trotter (not participating in the study) in warm up on the track before the race. Photo: Nina Mäki-Kihniä.*

Table 3. Recorded variables in trotters.

VARIABLE	CATEGORY
Breed	Standardbred / Finnhorse / Pony (Shetland/Gotland Russ)
Sex	Mare / Stallion / Gelding
Age	Years
Bit type	Snaffle trotting bit, single-jointed metal Crescendo Mullen mouth regulator Straight Plastic (*Happy Mouth*) Nurmos or moisturizer Dr. Bristol Other: · Snaffle bit single-jointed, loose ring · Regulator, single-jointed, leather · Snaffle trotting bit, single-jointed, plastic · Snaffle trotting bit, single-jointed, leather · Straight trotting bit, leather · Double-jointed bit, loose ring, metal · Single-jointed, copper roller, D-rings · Single-jointed, with checkbit · Neue Schule Turtle Top, double-jointed · Neue Schule Turtle Tactio, double-jointed · Single-jointed, Olympic, with leverage (monté) · Järvsöfax · Mullen mouth regulator, Australian model · Snaffle bit, double-jointed, magic metal · Straight trotting bit, rubber · Straight trotting bit, plastic · Straight trotting bit, metal
Bit thickness	Measured near the bit ring in millimeters
Overcheck	Yes / No
Checkbit	Yes / No
Checkbit type	Straight basic Crit Davis, leather-covered Straight, rubber-covered Crit Davis Straight, leather-covered Burch Crit Davis, open McKerron Single-jointed Straight with leather biting plate
Jaw strap	Yes / No
Checkbit and jaw strap	Yes / No
Tongue-tie	Yes / No
Tongue-tie material	Leg bandage Vetflex or Vet Wrap Stocking Leather Nylon Fabric Synthetic
Placement in the top three	Yes / No
Money earned in the race	Yes / No
Galloping during the race	Yes / No
Competed in last 14 days	Yes / No
Start type	Auto / Volt
Race distance	1600 / 2100 / 2600 m
Driver's license type	A / B / C
Trainer's license type	Professional / Other

Table 4. *Recorded variables in event horses.*

VARIABLE	CATEGORY
Breed	Warmblood / Coldblood / Pony
Sex	Mare / Stallion / Gelding
Age	Years
Bit type *The following ten double-jointed bit types with distinctive designs were considered to be formed:*	Double-jointed basic Double-jointed formed: · Bombers Colin Miles · Bombers Elliptical Roller · Happymouth · Neue Schule Turtle Tactio · Neue Schule Turtle Top · Rotary bit · Sprenger Dynamic RS · Sprenger KK Ultra · Sprenger Novocontact · Stubben Golden Wing Single-jointed Unjointed Myler-type Waterford Other: · Bombers Williams 2½ cable bit · Single-jointed Lock Up
Bit thickness	Measured near the bit ring in millimeters
Noseband type	Cavesson Cavesson with flash Micklem Mexican Drop PS of Sweden™ high jump or similar
Lower noseband	Yes / No
Bit leverage effect *The following 14 bit types were considered to have a leverage effect:*	Yes / No · Baucher · Bombers 2½ ring · B-ring · Gag · Kimblewick · Neue Schule Jumpers Choice · Neue Schule Tranz Universal · Neue Schule Turtle Top Beval · Olympia · Pelham · Pessoa · Sprenger Dynamic RS Multiring · Stubben Golden Wing · Tom Thumb Butterfly
Competition placement	Placement / No placement / No result
Competition level	60–80 / 90–95 / 100–120 cm

4.6 Outcome variables

For the risk factor analysis, a binary outcome variable was created (II, III). Lesion severity categories were merged and horses were divided into two categories: no lesions or mild lesion status (0–2 points) vs. moderate or severe lesion status (over 2 points).

In the lesion location analysis, the outcome variable was lesions in the bars (yes/no), inner lip commissures (yes/no), or buccal area near 106 or 206 teeth (yes/no). The number of horses having acute lesions in the outer lip commissures was too small to perform an analysis.

4.7 Pilot questionnaire study (unpublished)

Aims: To investigate differences in horse trainers, veterinarians or race veterinary assistants (referred to as 'assistants'), and other horse industry stakeholders' attitudes towards bit-related oral lesions in horses in harness racing.

Design: In autumn 2018, individuals (N = 93) attended two separate educational events regarding trotters' oral health. Before the lecture, they were asked to respond anonymously to 12 multiple choice questions. Twelve photos of oral lesions in the bit area were shown and different scenarios in racing events were described to the respondents. Questions and photos were presented with PowerPoint slides. Respondents were asked to act as a race veterinarian and to express their opinion regarding whether a horse with a shown lesion and in the described situation was fit to compete or not (photos are presented in the Results section of this thesis on pages 52–56).

Participants responded to the answer sheet by circling the option A, B, or C for questions 1–7 and A or B for questions 8–12. They indicated their professions by circling the correct response to this question. Response options were veterinarian, assistant, trainer, groom, or other. Permission to use the responses for research purposes was requested at the end of the answer sheet.

Respondents were veterinarians (mainly race veterinarians) (n = 14), assistants (n = 14), horse trainers (n = 32), or horse enthusiasts interested in participating in an educational event (n = 33) such as horse grooms.

QUESTIONS 1–7 REGARDING THE SITUATION BEFORE THE RACE

Q1. Race judges call that the driver has pulled heavily from the reins in the warm up. You examine the horse before the race. The horse does not have previous reports in the Heppa system. The horse has a Happy Mouth bit. What will you do?

A. The horse is allowed to start, but you record the findings in the Heppa system.
B. The horse is allowed to start, but after the race you stipulate a health certificate (from another veterinarian) before the horse can start again.
C. You remove the horse from the race.

Q2. Race judges call that the driver has pulled heavily from the reins in the warm up. You examine the horse before the race. The horse does not have previous reports in the Heppa system. The horse has a mullen mouth regulator bit. What will you do?

A. The horse is allowed to start, but you record the findings in the Heppa system.
B. The horse is allowed to start, but after the race you stipulate a health certificate before the horse can start again.
C. You remove the horse from the race.

Q3. Race judges call that the driver has pulled heavily from the reins in the warm up. You examine the horse before the race. The horse does not have previous reports in the Heppa system. The horse has a single-jointed snaffle trotting bit. What will you do?

A. The horse is allowed to start, but you record the findings in the Heppa system.
B. The horse is allowed to start, but after the race you stipulate a health certificate before the horse can start again.
C. You remove the horse from the race.

Q4. Race judges call that the driver has pulled heavily from the reins in the warm up. You examine the horse before the race. The horse does not have previous reports in the Heppa system. The horse has a single-jointed snaffle trotting bit. What will you do?

A. The horse is allowed to start, but you record the findings in the Heppa system.
B. The horse is allowed to start, but after the race you stipulate a health certificate before the horse can start again.
C. You remove the horse from the race.

Q5. Race judges call that the driver has pulled heavily from the reins in the warm up. You examine the horse before the race. The horse does not have previous reports in the Heppa system. The horse has a Dr. Bristol bit. What will you do?

A. The horse is allowed to start, but you record the findings in the Heppa system.
B. The horse is allowed to start, but after the race you stipulate a health certificate before the horse can start again.
C. You remove the horse from the race.

Q6. Race judges call that the driver has pulled heavily from the reins in the warm up. You examine the horse before the race. The horse does not have previous reports in the Heppa system. The horse has a single-jointed snaffle trotting bit. But you notice some blood in the mouth. What will you do?

A. The horse is allowed to start, but you record the findings in the Heppa system.
B. The horse is allowed to start, but after the race you stipulate a health certificate before the horse can start again.
C. You remove the horse from the race.

Q7. Race judges call that the driver has pulled heavily from the reins in the warm up. You examine the horse before the race, which is the final race in the biggest Finnhorse competition (Kuninkuusravit) and the horse is the competition favorite. The horse has a WTP™ trotting bit. What will you do?

A. The horse is allowed to start, but you record the findings in the Heppa system
B. The horse is allowed to start, but after the race you stipulate a health certificate before the horse can start again.
C. You remove the horse from the race.

QUESTIONS 8–12 REGARDING THE SITUATION AFTER THE RACE

Q8. The horse was bleeding from the mouth after a race. The horse has no previous reports in the Heppa database. The horse has not been registered in any future races. You examine the mouth. The horse has a Crescendo bit. What will you do?	A. You record the findings in the Heppa system. B. You stipulate a health certificate (from another veterinarian) before the horse can start again.
Q9. The horse was bleeding from the mouth after a race. The horse has no previous reports in the Heppa database. The horse has not been registered in any future races. You examine the mouth. The horse has a single-jointed snaffle trotting bit. What will you do?	A. You record the findings in the Heppa system. B. You stipulate a health certificate before the horse can start again.
Q10. The horse was bleeding from the mouth after a race. The horse has one previous report of mouth bleeding one month earlier in the Heppa database. The horse has been registered for the next race in three days' time. You examine the mouth. The horse has a straight Happy Mouth bit. What will you do?	A. You record the findings in the Heppa system. B. You stipulate a health certificate before the horse can start again.
Q11. The horse was bleeding from the mouth after a race. The horse has no previous reports in the Heppa database and has not been registered for future races. You examine the mouth. The horse has a mullen mouth regulator bit. What will you do?	A. You record the findings in the Heppa system. B. You stipulate a health certificate before t again
Q12. The horse was bleeding from the mouth after a race. The horse has one previous report of mouth bleeding one month earlier in the Heppa database and has been registered for the next race in three days' time. You examine the mouth. The horse has a mullen mouth regulator bit. What will you do?	A. You record the findings in the Heppa system. B. You stipulate a health certificate before the horse can start again.

4.8 Statistical analyses

An overview of the main statistical analysis is presented here. Details of the Materials and Methods in each study (I–III) are available in the original articles included at the end of the thesis.

Study I

Only descriptive results of oral lesions were presented.

Studies II and III

Data were analyzed statistically using Stata IC version 16 (Stata Corporation, TX, USA). Horses were divided into three age categories based on assumed experience in training; age categories in trotters were 3–6, 7–9, and 10–15 years (II) and in event horses 4–7, 8–12, and 13–19 years (III). In trotters, bits were divided according to their thickness into the following four categories: 10–13 mm, 14–17 mm, 18–22 mm, and 23–30 mm (II), and in eventing into three categories: 10–13 mm, 14–17 mm, and 18–22 mm. Data classification in bit thickness was based on visual evaluation of frequencies in histograms and natural breaks in the data. In eventing, three competition level categories (obstacle height 60–80 cm, 90–95 cm, and 100–120 cm) were created.

First, Pearson Chi-square or Fisher's exact test was used to test associations between potential risk factors and the binary outcome (no lesions or mild lesion status vs. moderate or severe oral lesion status). Second, logistic regression analysis was used for risk factor analysis. Relationships between categorical predictor variables were evaluated by Chi-square tests. The logistic regression models were built with manual stepwise backward and forward procedures, and explanatory variables were eliminated until all remaining variables had an association with moderate-severe lesion status ($P \leq 0.05$), except breed in the trotter model, which was considered a biologically relevant confounder. At each step, the removed variables were evaluated for confounding effects by checking whether the coefficients for the remaining variables changed substantially. Models were evaluated using tests for sensitivity, specificity, ROC curve (Receiver Operating Characteristic), and goodness of fit and visually from the graphs of the residuals, leverage, and delta-betas per covariate pattern.

Fisher's exact test was applied to analyze associations between lesion location and bit type. It was also used to analyze associations between blood observed and lesion severity. A P-value of ≤ 0.05 was considered statistically significant in all analyses. For trotting ponies, only descriptive results have been presented (II).

Pilot questionnaire study

Statistical analyses were conducted with IBM SPSS Statistics for Windows, version 28 (IBM Corp., Armonk, NY, USA). For the analysis, veterinarians (n = 14) and assistants (n = 14) were combined in the same group VET (n = 28) due to their low numbers and because both can examine oral lesions in competitions. If a veterinarian had also circled the trainer option, veterinarian (VET) was chosen for the profession. If a respondent had circled both the trainer and groom options, TRAINER was chosen for their profession. In the group OTHER (n = 33), 'grooms' (n = 11) and 'others' were combined (n = 22) due to their low numbers.

For the analysis, responses A and B to questions 1–7 were combined because both of these options actually allowed the horse to race on that day and only response C prohibited racing.

Chi-square test was used to analyze associations between stakeholder groups VET (n = 28), TRAINER (n = 32), and OTHER (n = 33) and their responses. In questions 1–7, the outcome was that the horse is allowed to start: yes (options A and B) or no (option C). In questions 8–12, the outcome was oral lesions recorded in the Heppa system (option A) or a health certificate stipulated before the next race (option B). A pairwise z-test post hoc analysis with Bonferroni correction was used to compare column proportions. A P-value of ≤ 0.05 was considered statistically significant.

5 RESULTS

The main results of the thesis are presented here. More detailed information can be found in the original articles (I–III) at the end of the thesis.

5.1 Study I: Bit-related lesions in trotters

Oral lesion status in trotters comprised no signs of acute lesions for 16% (42/261), mild lesion status for 21% (55/261), moderate lesion status for 43% (113/261), and severe lesion status for 20% (51/261) (**Figure 10**). Bruises were more common than wounds, and inner lip commissure was the most common lesion location. In addition to bruises and wounds, redness and swelling were seen at the bars, especially with unjointed bits. However, the extent of redness and swelling is difficult to evaluate, and therefore, these findings were not systematically recorded. Blood was observed in 12% of the horses. In 2% of the horses, blood was visible outside the mouth. In 5%, blood was observed on the bit when it was removed from the mouth and in 5% on the wound inside the mouth at examination. Severe lesion status was found in 10/14 horses and moderate status in 4/14 horses having blood on the bit. From the horses having blood outside their mouths, five had severe lesion status and one had bitten its tongue. Blood outside the mouth or on the bit was associated with severe oral lesion status (Fisher's exact test, $P < 0.001$). The occurrence of different lesion types and locations is described in **Table 5**. Of the 51 horses with severe lesion status, 33 competed again within two weeks, 13 within one week, and two on the following day.

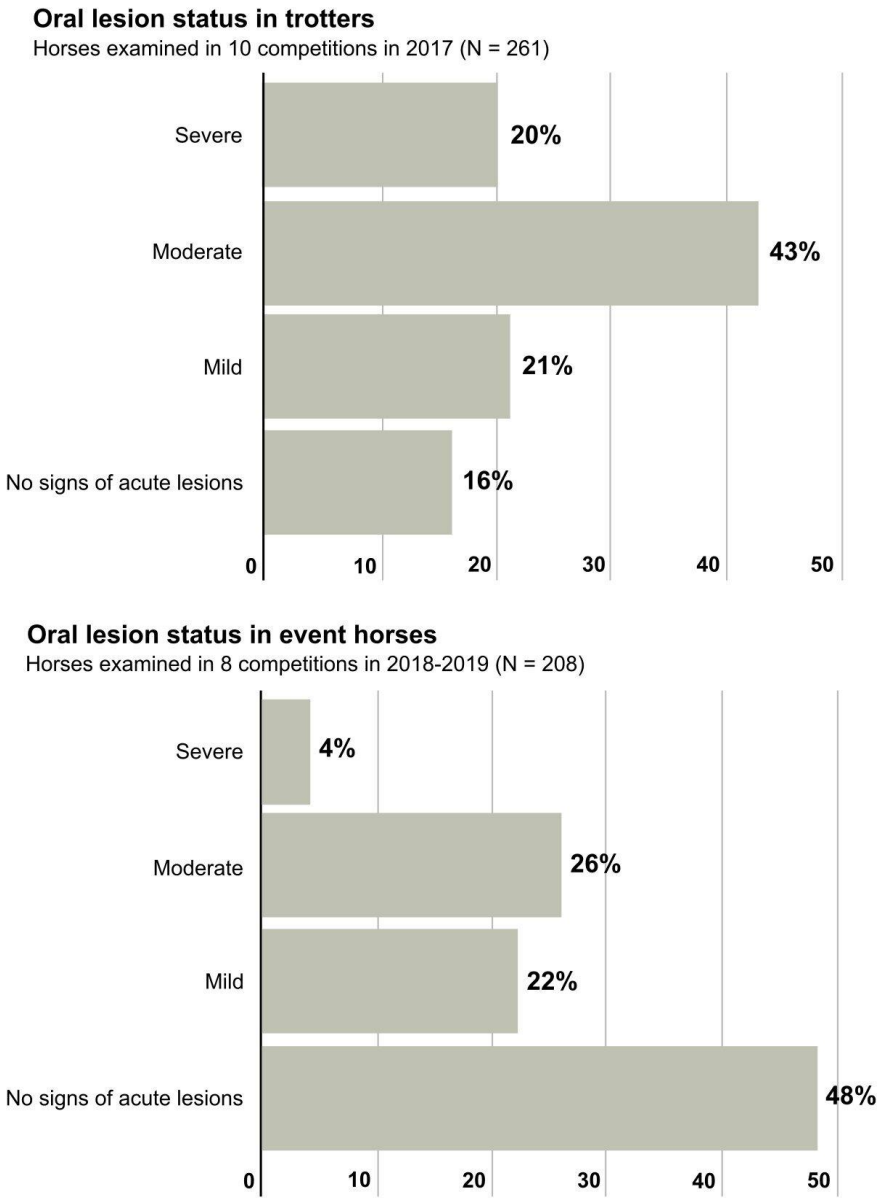


***Figure 10**. Oral lesion status in trotters and event horses after a competition. Tables reproduced from Studies I and III.*

Table 5. *Occurrence of different oral lesions and their locations or presence of blood in trotters (N = 261) and event horses (N = 208) after a competition.*

ORAL LESION OR BLOOD	TROTTERS Study I		EVENT HORSES Study III	
LESION LOCATION	**n**	**%**	**n**	**%**
Inner lip commissure lesion	168	64	81	39
Bar lesion	68	26	24	12
Buccal lesion near 106 or 206	68	26	12	6
Outer lip commissure depigmentation	25	10	108	52
Outer lip commissure lesion	16	6	18	9
Tongue lesion	9	3	2	1
Hard palate lesion	1	0.4	0	0
LESION TYPE				
Bruises without wounds	114	44	67	32
Bruises and wounds	68	26	18	9
Wounds without bruises	37	14	25	12
Old wound	19	7	20	10
Scar	4	2	6	3
Old bruise	3	1	10	5
BLOOD				
Blood somewhere	32	12	1	0.5
Blood only on the bit	14	5	0	0
Blood only inside the mouth	12	5	1	0.5
Blood outside the mouth	6	2	0	0

5.2 Study II: Risk-factors for bit-related lesions in trotters

A binary logistic regression analysis was conducted with data for 229 horses (151 Standardbreds and 78 Finnhorses) (**Figure 11**). The risk model with horse breed, sex, and bit type together significantly predicted whether a horse would have an oral lesion status of moderate or severe. A significant association was found between bit type, horse sex, and oral lesion status. Horses racing with a Crescendo bit (n = 38, OR 3.6; CI 1.4–8.9), mullen mouth regulator bit (n = 25, OR 9.9; CI 2.2–45.2), and straight plastic bit (model *Happy Mouth*) (n = 14, OR 13.7; CI 1.7–110) and mares (n = 102, OR 2.2; CI 1.2–4.2) had an elevated risk for moderate-severe oral lesion status compared with horses racing with a single-jointed snaffle trotting bit (n = 98, reference group) (P = 0.002) and geldings (n = 98, reference group) (P = 0.049). Horses racing with unjointed bit types had more bar lesions (67%, 33/49) than horses racing with single-jointed bits (17%, 33/193) or double-jointed bits (11%, 2/19) (Fisher's exact test, P < 0.001).

A tongue-tie was fitted on 72% of the trotters and overcheck on 87%. In this sample of trotters, their use was not associated with moderate-severe oral lesion status.

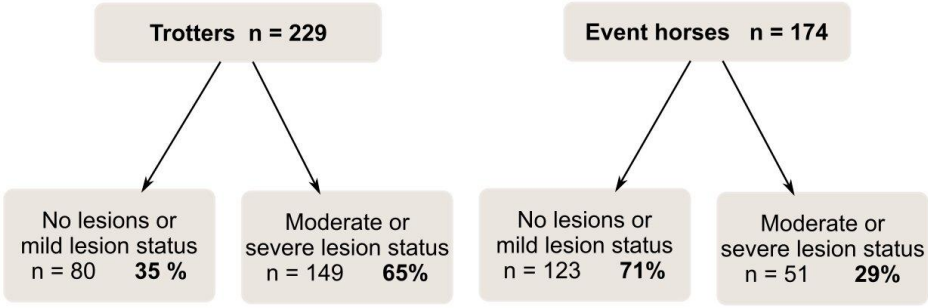


Figure 11. *For the risk factor analyses, trotters (n = 229) and event horses (n = 174) were divided in two groups; horses having no acute lesions or mild lesion status vs. horses having moderate or severe lesion status.*

5.3 Study III: Bit-related lesions in event horses

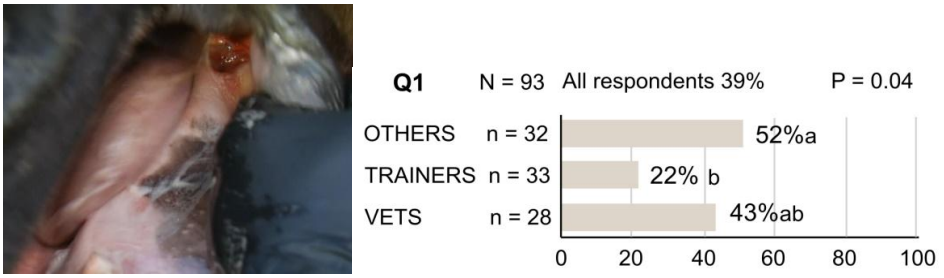
Oral lesion status in event horses after a cross-country test was the following: no signs of acute lesions for 48% (99/208), mild for 22% (45/208), moderate for 26% (55/208), and severe for 4% (9/208) (**Figure 10**). Blood was observed in one horse inside the mouth. The occurrence of different oral lesion types and their locations are presented in **Table 5**.

A binary logistic regression analysis was conducted using data for 174 horses (**Figure 11**). The model with horse breed, sex, and bit thickness together significantly predicted whether a horse would have moderate or severe oral lesion status compared with having no or mild lesions. Horses competing with thin (n = 34, OR 3.5; CI 1.4–8.7) or thick bits (n = 38, OR 3.4; CI 1.5–8.0), mares (n = 68, OR 2.2; CI 1.1– 4.5), and those representing a breed other than pony (warmbloods n = 109, reference group and coldbloods n = 39, OR 2.0; CI 0.88–4.7) had a higher risk for moderate-severe oral lesion status than horses competing with medium-sized bits (n = 102, reference group) (P = 0.003), geldings (n = 106, reference group) (P = 0.03), and ponies (n = 26, OR 0.2; CI 0.04–0.87) (P = 0.02). Bar lesions were more common in horses with unjointed bits (40%, 8/20) than with basic double-jointed (10%, 5/52), formed double-jointed (8%, 6/78) or single-jointed bits (5%, 2/40) (Fisher's exact test, P = 0.002).

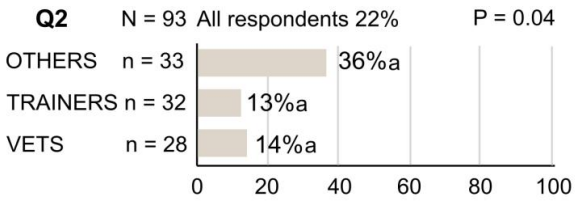
5.4 Pilot questionnaire study (unpublished)

The response rates for questions varied from 98% to 100%. If a respondent had circled two options for the same question or had not answered at all, the response was excluded. Statistical differences emerged between group responses in six (Q1, Q2, Q3, Q6, Q7, Q9) of 12 questions. In all of these six questions, OTHERS were most willing to prevent a horse with a lesion from competing. Some of the OTHERS had written their role in the horse industry; in addition to grooms (n = 11), the group consisted of horse owners (n = 3), a financier (n = 1), and a person helping with horses (n =1). In four questions, VETS and in two questions TRAINERS were numerically most reluctant to withdraw the horse from the race or to stipulate a health certificate. Lesion photos and proportions of responses are presented in **Figure 12**.

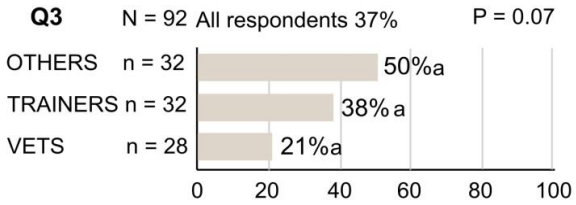
Figure 12. *Responses to questions 1–12 regarding bit-related lesions in racing horses. P-values are from Chi-square tests. Q1–Q7: How many of the respondents would have removed the horse from the race. Q8–Q12: How many of the respondents would have stipulated a health certificate before the next race. VETS included 14 (mainly race) veterinarians and 14 race veterinary assistants, TRAINERS were trot horse trainers, and OTHERS were other stakeholders such as grooms. The result of a pairwise z-test post hoc analysis with Bonferroni correction is reported as subscript letter a, b, or ab. Different subscript letters indicate statistical differences between stakeholder groups. A P-value < 0.05 was considered statistically significant.*



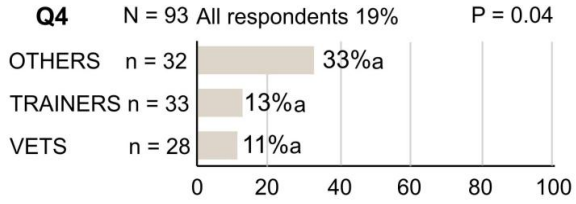
Question 1. *Wound in the left bar of the mandible. Proportion of respondents removing the horse from the race. Photo reproduced from Study I.*



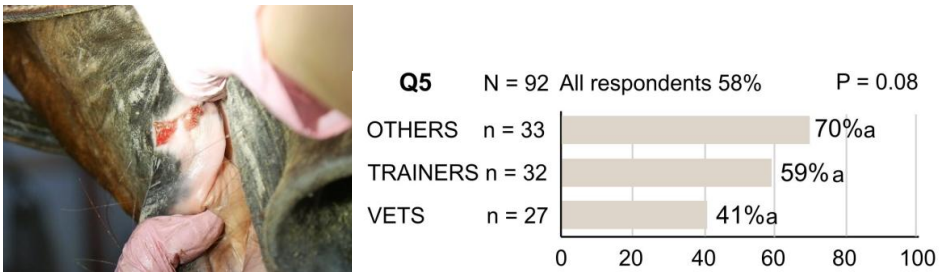
***Question 2**. Wound in the left bar of the mandible. Proportion of respondents removing the horse from the race. Photo reproduced from Study I.*



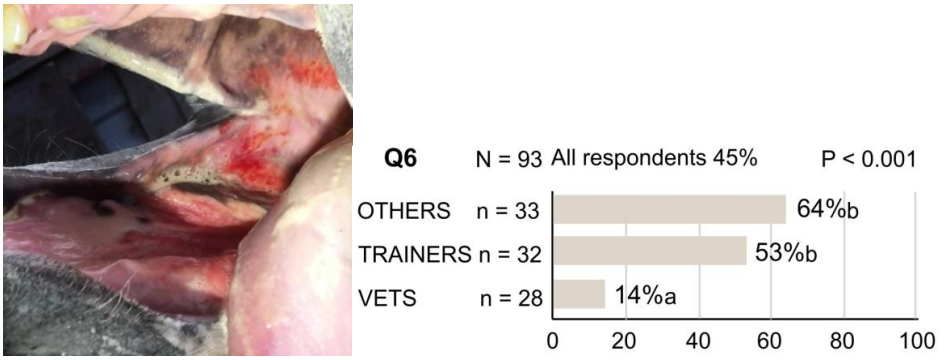
***Question 3.** Wound in the left outer lip commissure. Proportion of respondents removing the horse from the race. Photo reproduced from Study I.*



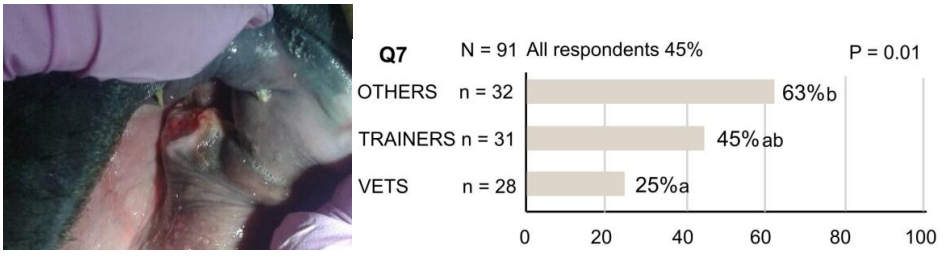
***Question 4.** Wound in the right inner lip commissure. Proportion of respondents removing the horse from the race. Photo reproduced from Study III.*



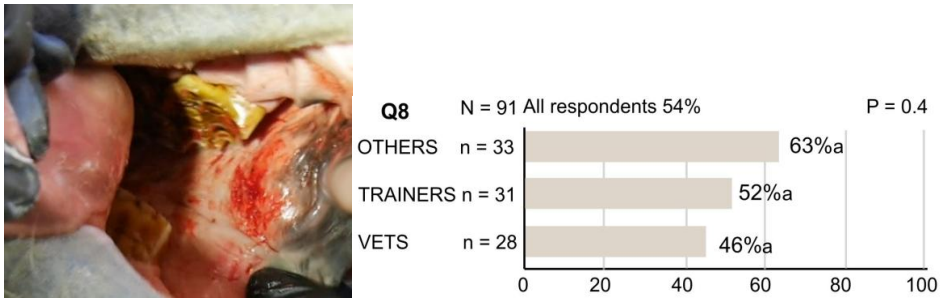
Question 5. *Wound in the right outer lip commissure. Proportion of respondents removing the horse from the race. Photo reproduced from Study I.*



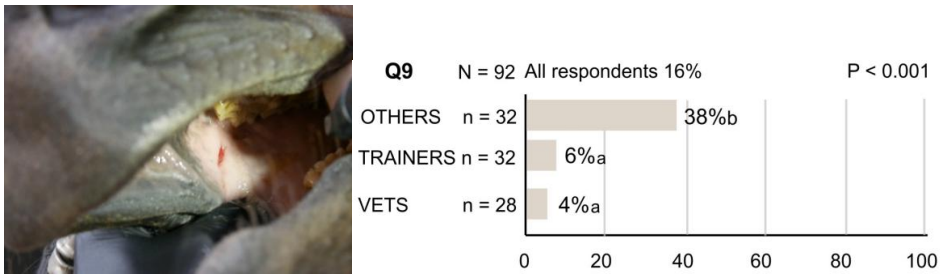
Question 6. *Wound in the right inner lip commissure. Proportion of respondents removing the horse from the race. Photo from a trotter before the race. The horse was not part of Studies I–III.*



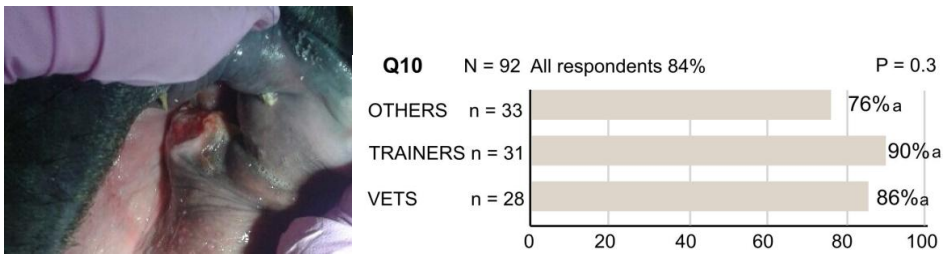
Question 7. *Wound in the left bar of the mandible. Proportion of respondents removing the horse from the race. Photo from a trotter after the race. The horse was not part of Studies I–III.*



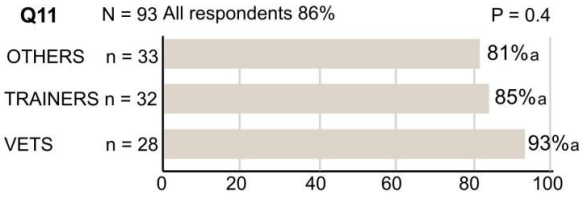
Question 8. *Wound in the left inner lip commissure extending to the buccal area after a race. Proportion of respondents stipulating a health certificate before the next race. Photo reproduced from Study I.*



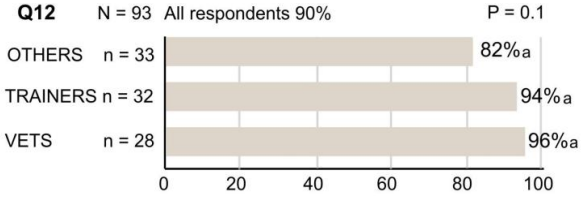
Question 9. *Wound in the right buccal area after a race. Proportion of respondents stipulating a health certificate before the next race. Photo reproduced from Study I.*



Question 10. *Wound in the left bar of the mandible after a race. Proportion of respondents stipulating a health certificate before the next race. Photo from a trotter after the race. The horse was not part of Studies I–III.*



Question 11. *Wounds in the right lip commissure after a race. Proportion of respondents stipulating a health certificate before the next race. Photo from a trotter after the race. The horse was not part of Studies I–III.*



Question 12. *Wound in the left lip commissure after a race. Proportion of respondents stipulating a health certificate before the next race. Photo from a trotter after the race. The horse was not part of Studies I–III.*

6 DISCUSSION

The focus of this thesis is on bit-related lesions in competing trotters and event horses. Three peer-reviewed articles describe oral examination during field conditions and investigation of risk factors for lesions. In addition, this thesis contains previously unpublished results of a pilot questionnaire study investigating attitudes towards bit-related lesions in trotters.

6.1 Oral examination

The examination of the horse's rostral oral cavity (bit area) and the lesion scoring method were found to be suitable for field conditions since the examination lasted only from one to two minutes and minimal equipment (headlamp, disposable gloves, and data sheet) was necessary. Horses seemed to tolerate the examination well. Seven of the event horses and three of the trotters showed clear avoidance behavior at examination such that the examination was discontinued.

Removal of all head equipment before the examination was found to be critical in trotters because the multiplicity of equipment and especially the overcheck with jaw strap can prevent mouth opening, hindering proper examination (**Figure 9**). Careful palpation and visual assessment of the bars and the area in front of the lower cheek teeth was found to be necessary since some of the bar lesions were hidden behind swollen mucosal folds and thick mucus. In some cases, bar lesions became visible only after the mucosal fold was pulled rostrally with the index finger. Some trainers provided water for the horse after the race. It facilitated the examination by removing excessive mucus. In event horses, the examination was usually done with the horse's bridle on because bridle use is obligatory in competition area. The examination was possible when the noseband and possible curb chain was unlatched so that the mouth could be opened. The bit was lifted with a thumb to achieve better visibility.

Examination in the present studies was otherwise similar to that in a previous study in Icelandic horses, where the examination was performed visually and by palpation and holding the tongue (Björnsdóttir et al., 2014). However, in that study the use of light source was not reported (Björnsdóttir et al., 2014). In that study the lesion was graded as severe if mucosal soreness was observed (Björnsdóttir et al., 2014). In the present study, pain evaluation was not a part of the examination protocol because it would have been

difficult to reliably evaluate lesion soreness in the competition environment after a race when horses are excited. However, two of the trotters having the highest lesion points showed avoidance behavior and two of the three trotters that showed strong avoidance behaviour and were excluded from the study had blood on the bit and very likely oral lesions. Given that avoidance behavior may be a sign of pain, it is considered important to perform a complete oral examination for these horses later under sedation and with an oral speculum to find possible reasons for the observed behavior.

In the Animal Welfare Indicators Project (AWIN) and Horse Welfare Assessment Protocol (HWAP) protocols, lesions related to bit use are assessed mainly at the outer lip commissures and the Welfare Monitoring System assesses also lesions in the inner lip commissures and bars (Wageningen UR Livestock Research, 2012; Minero et al., 2015; Viksten, 2016). In the Welfare Monitoring system, palpation is done by standing in the front of the horse (Wageningen UR Livestock Research, 2012). Not examining the whole bit area systematically with a headlamp is likely to leave many lesions undetected since it is not possible to see well inside a dark mouth. In a competition environment, which may be unfamiliar for the horse, standing directly in the front of a horse while examining both bars simultaneously is not necessarily safe for the examiner. For safety reasons or due to disinfection requirements, speculum use is not practical in a competition environment, even though speculum use, sedation, and a light source could be considered a 'gold standard' for detecting all bit-related lesions.

6.2 Bit-related lesions and lesion scoring

The occurrence of lesions was higher and the lesions were more severe in trotters than in event horses. The results may reflect rein tension differences. In eventing, in addition to the bit, riders can communicate with the horse with their legs and seat (Lethbridge, 2009). In harness racing, multiple horses and people are competing simultaneously, possibly leading to increased anxiety (König von Borstel et al., 2017). Drivers have the possibility to lean back in the sulky, support the legs in the foot rests, and use handholds in lines (Foster, 2013), all of which may increase rein tension and thus injuries compared with eventing. It is also possible that if the trotter is running too fast, the reins are more or less constantly pulled and not released to keep the horse at the desired speed (Foster, 2013), which is contradictory to the principles of learning theory and negative reinforcement, where pressure is released when the horse performs the desired response (McGreevy et al., 2018). It has been suggested that not releasing the pressure may function as a punishment for the horse and have behavioral and physiological consequences that shorten the horse's working life (McGreevy, 2007) and likely

increase the risk of injury. It has been suggested that poor understanding of learning theory, which has been found to be common even among professionals, may impair horse welfare and prevent effective training (McGreevy, 2007; Warren-Smith and McGreevy, 2008; Telatin, 2017; Pearson et al., 2020).

Lesion scoring

The previous version of the Vet Form 2 from the International Federation of Icelandic Horse Association served as the inspiration for the data sheet, where the findings were recorded. The cut-off points for lesion size categories of less than 0.5 cm, 0.5–1 cm, and greater than 1 cm were the same as in the Vet Form 2. However, at the first race event we found that many horses had multiple and large lesions, and thus, the data sheet required immediate modifications.

The difficulty in the bit-related lesion evaluation is that a horse may have different types and sizes of lesions in multiple locations in the mouth. In the present study, this problem was solved by giving points to each lesion according to its size, type, and depth. Points from each lesion were summed such that each horse got a total lesion score reflecting the overall bit area damage (lesion status).

Earlier studies have solved this problem in different ways. For example, in Icelandic horses if the horse had multiple lesions, only the most severe one was included in the analysis (Björnsdóttir et al., 2014). In that study, two separate logistic regressions for risk analysis were performed for buccal lesions (including lip commissure lesions) and bar lesions (Björnsdóttir et al., 2014). In a race and polo horse study, lesions were reported by their location (commissures, tongue, or bar bone spurs) from grade 0 to 5 according to their severity (Mata et al., 2015), but this makes it difficult to evaluate how many horses actually had lesions. In Swedish riding horses, lesions were reported per location (lip commissures, bars, opposite to 06, opposite to 07–11, and caudal to 11) and size (small, or large over 0.5 cm) and age (acute or chronic) (Tell et al., 2008). This reporting does not reveal if the same horse had lesions in multiple locations.

In the present study, outer lip commissure refers to the area covered by skin, not the mucosa. Inner lip commissure refers to the area covered by oral mucosa and situated rostrally from the cheek teeth. In earlier studies, the area has usually been referred to as ‘lip commissures’ or ‘corners of the mouth’, making it difficult to estimate whether these terms include both inner and outer lip commissure lesions. Old lesions, such as scars, depigmentation of outer lip commissures, old wounds with no redness visible, and old bruises with faint coloring, were not included in the lesion scoring because these lesions would probably not be acutely painful. Tongue lesions were not included in the lesion scoring because they were not clearly bit-related in the study horses. Only 9 trotters and 2 event horses had bruises or wounds in the tongue. Four trotters had bitten

the tip of the tongue, and others had bruises under or at the sides of the tongue. Of the trotters with tongue lesions, 8 of 9 wore a tongue-tie.

It can be argued that the scoring system was too lenient since in the present studies a single ulcer larger than 0.5 cm in diameter was considered moderate if it was less than 3 cm in diameter and was not deep. Compared with the study of Swedish riding horses, an ulcer larger than 0.5 cm in diameter was considered large (Tell et al., 2008). In an Icelandic horse study, an ulcer larger than 1 cm was regarded as severe (Björnsdóttir et al., 2014), compared with the present study, where an ulcer larger than 1 cm was considered moderate if it was not deep and was less than 3 cm in diameter. In the Swedish Equestrian Federation's lesion grading, bruises larger than 2 cm and wounds larger than 1.5 cm are included in the most severe grade (V), whereas the lesions of this size in our study were graded as moderate if the lesion was not deep (**Table 6**). Based on more intensive tissue damage, it was considered that wounds over bruises, deeper wounds over superficial wounds, and multiple lesions over a single lesion are more likely to be painful and take more time to heal. Therefore, in the present study, the cut-off points for moderate lesion status (3 points) and for severe lesion status (8 points) from a single wound or from multiple lesions (12 points) were determined.

Table 6. *Swedish Equestrian Federation's lesion grading (Munkollen) and recommended competition rest compared with the present study lesion grading. Modified from Svensk Ridsport Förbundet (2020).*

MUNKOLLEN			**PRESENT STUDY**	
Grade	**Lesion type and diameter**	**Recommended competition rest**	**Lesion points**	**Horse's lesion status**
I	Bruise < 0.5 cm	Follow up	1	mild
II	Bruise max 1 cm Wound < 0.5 cm	1–3 weeks	2	mild
III	Bruise >1 cm <1.5 cm Wound max 1 cm Chronic wound < 0.5 cm	1 month	3–4	moderate
IV	Bruise > 1.5 cm Wound > 1 cm Chronic wound 0.5–1 cm	2 months	3–6	moderate
V	Bruise > 2 cm Wound > 1.5 cm	3 months	3–6	moderate

6.3 Bleeding

Race and competition veterinarians monitor if the horse shows bleeding from the mouth or elsewhere from the body. However, only 2% of the trotters and none of the event horses showed external mouth bleeding, although severe lesions were found in 20% and 4%, respectively. In addition, 10% of the trotters (I) and one event horse (III) had blood on the bit or inside the mouth at examination (**Figure 13**). In the present study, blood outside the mouth or on the bit was an indicator that the horse had severe oral lesion status. When mouth bleeding is observed after a race, it is often suspected that the horse might have bitten its tongue (author's personal observation). In this study, six trotters had external mouth bleeding. Only one of them had bitten its tongue and the rest had severe oral lesion status.

Figure 13. *Blood on the bit after a race (Study I). Photo: Nina Mäki-Kihniä.*

6.4 Lesion healing and possible consequences

In this study, 33 trotters with severe lesions competed again within two weeks and two of them already on the next day (I). It is very plausible that severe lesions will not heal completely in this time. Mouth lesions are generally considered to heal quickly because of the moist environment and abundant blood supply (Greet and Ramzan, 2010; Nanci

and Wazen, 2013). However, a bit in the mouth may function as a foreign material, preventing wound healing. Restricting bit use is considered essential for lesion healing (Foster, 2013; Oskarsson, 2016). The Swedish Equestrian Federation has regulated a start ban for 21 days in all oral lesions, except for bruises smaller than 5 mm, and a 3-month competition rest is recommended in severe cases (Svensk Ridsportförbundet, 2020). The start ban can be shortened if the horse is deemed to be healthy at a veterinary examination at least seven days after (Svensk Ridsportförbundet, 2020) (**Table 6**).

The lesion scoring system may give some guidance for lesion healing since it is plausible that larger and deeper lesions take more time to heal. However, the extent of lesion chronicity was not included in the scoring. Some lesions showed clear signs of chronicity such as thickened and rounded wound margins or white wound margins in the outer lip commissure. Chronic wounds are defined as wounds that "have failed to proceed through the normal phases of wound healing in an orderly and timely manner" (Frykberg and Banks, 2015). In bit-related lesions, this is probably the result of repeated oral trauma.

6.5 Lesions and their relation to teeth and sharp enamel points

The majority of the lesions found in these studies were situated rostrally to the cheek teeth. However, when excessive rein tension is applied, the bit moves caudally in the mouth (Clayton and Lee, 1984) and may push the mucosa against the mesial surface of the first lower cheek teeth or the buccal or mesial surface of upper cheek teeth. Therefore, some of the buccal and inner lip commissure lesions may have been exacerbated by sharp enamel points in the first upper cheek teeth (**Figures 14–17)**. In contrast, lesions in the outer lip commissures and bars are not related to sharp enamel points.

Figure 14. *Trotter with an inner lip commissure 10-point lesion extending to the buccal area near the 206 tooth. When excessive rein tension is applied, the bit moves caudally in the mouth (Clayton and Lee, 1984) and may push the mucosa against the buccal or mesial surface of upper cheek teeth. It is possible that, in this case, a small hook on 206 exacerbated the lesion. Photo reproduced from Study I.*

Figure 15. *Trotter with an inner lip commissure 10-point lesion. Inner lip commissure is located rostrally relative to the teeth, but excessive rein tension may pull the inner lip commissure backwards and push the tissue against the upper cheek teeth, which may have sharp enamel points. If the mucosa is pinched between the bit and the tooth, the soft mucosa may become injured. Photo reproduced from Study I.*

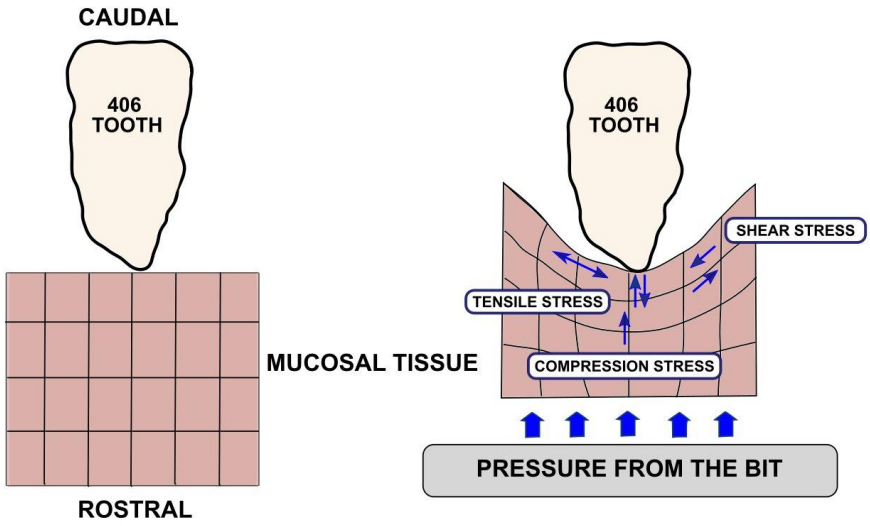


Figure 16. *Hypothesized figure of how unjointed bits are associated with bar lesions. When excessive rein tension is applied, the bit moves caudally (Clayton and Lee, 1984) and may push the mucosa against the mesial surface of the first lower cheek teeth. Blunt force trauma and static loading in addition to compression stress may lead to shear stress and tensile stress, resulting in contusions, abrasions, or lacerations (Sheridan and Nash, 2007; Reger et al., 2010). Original image inspiration from Takahaski et al. (2010). Image adapted to model forces affecting the oral mucosal tissue.*

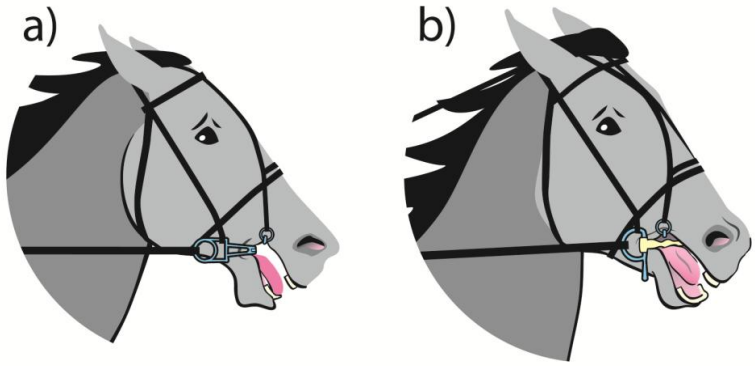


Figure 17. *a) Rein tension is applied to the Crescendo bit and it potentially compresses the lip commissures against the upper cheek teeth and tongue. b) Rein tension is applied to the unjointed plastic bit and it potentially compresses the lip commissures and bars against the lower cheek teeth and the tongue. Illustrations based on photographs from a racing event. Horses in the illustrations were not study participants. Illustration Satu Cozens / Kummakko-Design.*

6.6 Risk factors

6.6.1 Bits

Trotters wearing a Crescendo bit, unjointed mullen mouth regulator bit, or straight plastic bit were at higher risk for moderate-severe oral lesion status than horses racing with a single-jointed snaffle trotting bit (II). Event horses competing with thin or thick bits were at higher risk of moderate-severe lesion status than horses competing with a medium-sized bit (III). Unjointed bits were associated with bar lesions in both disciplines (II, III). When rein tension is applied, bit type may affect the pressure distribution on different oral structures and bit movements in the mouth (Manfredi et al., 2005). Physical bit properties, such as unjointed form and friction caused by leather in the mullen mouth regulator bit or plastic in the *Happy Mouth* bit or thin metal rails of the Crescendo bit, may explain the study results since lesion development is in general affected by the mass, size, shape, and angle of impact of an object (Ressel et al., 2016). In event horses, thin bits were associated with moderate-severe lesions. Thin bits may cause increased oral pressure, as pressure is the amount of force applied to a certain area. However, thick bits were also associated with moderate-severe lesions in event horses. The distance between the maxilla and mandible varies individually (Engelke and Gasse, 2003), and thick bits may potentially cause more discomfort in horses with small oral cavities (Clayton and Lee, 1984).

Statistical analysis only shows that these particular bit types and sizes were associated with moderate-severe oral lesion status, but it does not reveal anything about the causality. The use of bits associated with moderate-severe lesion status may reflect driveability or rideability issues, and thus, rein tension differences because drivers/riders may change to distinctive bit designs if they have difficulty eliciting an appropriate response with rein cues (**Figure 18**).

In earlier studies, Icelandic horses competing with curb bits with a port (jointed and unjointed) had more bar lesions than horses competing with a snaffle or traditional Icelandic curb bit (Björnsdóttir et al., 2014). Racing horses with snaffle bits (jointed or unjointed, but without leverage) had multiple and more severe oral lesions than polo horses with gag bits (Mata et al., 2015).

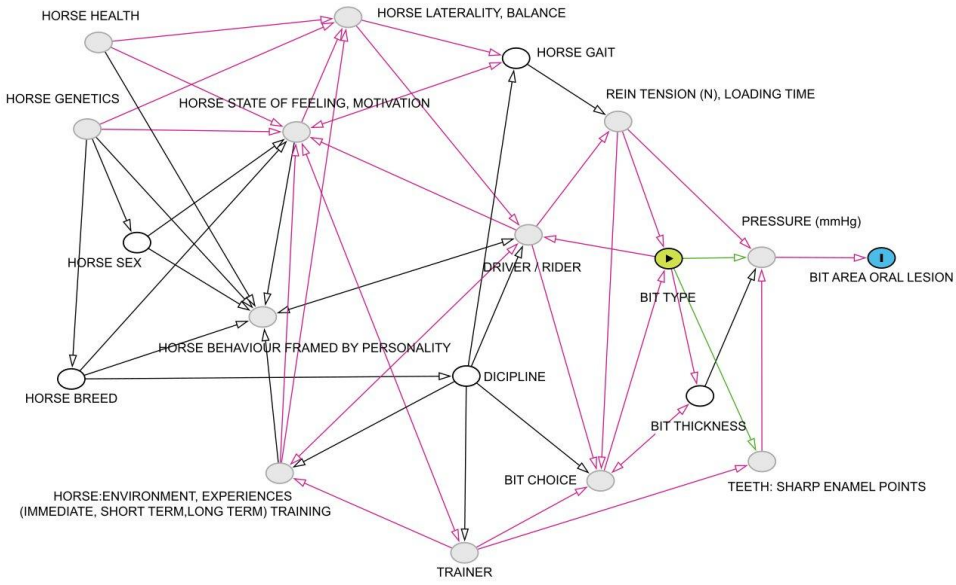


Figure 18. *Directed Acyclic Graphs (DAG) 'DAGitty'. Hypothesized causal diagram for bit area oral lesions. Circle colors: gray: unobserved variable, white: adjusted variable, green arrow: exposure variable, blue: outcome. Red paths are biasing paths caused by the confounding effect of the rein tension and loading time likely associated with the outcome (oral lesions) and the bit choice (Textor et al., 2016; Dumbell et al., 2019). Rider's or driver's previous experiences with a horse's rideability or driveability, and thus, rein tension, may affect their bit choice, indicating that the association between bit type and oral lesion is not completely causal.*

6.6.2 Horse characteristics

In harness racing and eventing, mares were at higher risk for moderate-severe lesions than geldings (II, III). In eventing, ponies were at lower risk than horse breeds (III). Also trotting ponies had bit-related lesions after racing, however, only one pony had severe lesion status (II). Most of the ponies were ridden and driven by children, who may use less rein tension (Tell et al., 2008). Another possibility is that wounds in ponies heal more rapidly (Wilmink et al., 1999).

Earlier studies have either not reported horse's sex (Björnsdóttir et al., 2014; Mata et al., 2015; Uldahl and Clayton, 2019) or if sex was reported some horse groups included only mares or geldings so an analysis of an association between horse sex and lesions could not be conducted (Tell et al., 2008). Therefore, it was interesting that in our study an association emerged between female sex (mare) and moderate-severe oral lesion status. This warrants further studies, but it is possible that mare oral wound healing is slower, as this has been found in women (Engeland et al., 2006). In an earlier questionnaire study about personality traits, horse handlers evaluated mares to be more anxious than geldings (Duberstein and Gilkeson, 2010). It is possible that oral lesions in

mares exacerbate if their pain-related behaviors are ignored because the literature suggests that sex-based attitudes may affect horse welfare if pain-related behaviors are falsely interpreted as being caused by 'mareness' (Fenner et al., 2019a).

Horse's older age was in one study associated with mouth corner lesions (Visser et al., 2014). In the present studies, this association was not found (II, III). A horse working more hours per week and smaller housing area have also been associated with higher mouth corner lesion frequency in an earlier welfare study in horses (Visser et al., 2014).

6.7 Some previously proposed solutions for lesions

In addition to bit change, 'light hands', dental care (Merillat, 1917; Foster, 2013), and invasive procedures have been conducted in an attempt to resolve oral lesions or rideability or driveability issues. In some cases with chronic lip commissure wounds, scar tissue has been surgically removed and the wound has been closed with sutures (Oskarsson, 2016). Bit seating or even removing the first molar teeth [*sic*] have been attempted as a solution for horses not responding to light rein signals (Merillat, 1917). A *bit seat* is a term used to describe rounding of the mesial borders of the first cheek teeth (Merillat, 1917; Scoggins, 2001; Pence, 2002; Easley, 2010; Klugh, 2010). However, in this procedure direct or indirect iatrogenic pulp exposure is possible if reduction of the teeth is aggressive or if there is excessive heat formation during reduction (Klugh, 2010). There has been controversy regarding the necessity of these bit seats (Pence, 2002; Easley, 2010). Bit seating is not commonly used in Finland (author's personal observation).

6.8 Attitudes towards lesions

Veterinarians are required to make judgments on horse welfare in a variety of circumstances, including competitions (Hockenhull and Whay, 2014). The aim of the pilot questionnaire study was to survey horse industry stakeholder's attitudes towards bit-related lesions in trotters. Surprisingly, other horse enthusiasts, e.g. horse grooms, were more willing to exclude the horse from the race than horse trainers and veterinarians or assistants. Veterinarians and assistants were, in some cases, the most reluctant to withdraw a horse from the race. Respondent groups were more unanimous

in cases where the situation was after a race and horse had bleeding and previous reports.

In Q1, Q2, and Q7, the horse had an oral lesion graded as severe before the race, and still the majority of respondents would have allowed the horse to race. In all of these questions, lesion location was at the bars and it is possible that it was difficult for respondents to understand the location from photographs even when it was explained.

The horse industry is considered economically important (Jones and McGreevy, 2010), and this influences ethical decisions (Blea, 2012). The annual number of racing trotters in Europe is 60 000 of which 6000 horses race in Finland (Union Européenne du Trot, 2019). In Finland, trotting races are organized on 363 days per year, and the annual sales in race betting in 2019 was 210 million euros (National Equine Competence Association of Finland, 2019). The betting turnover in Europe was 7300 million euros and the prize money awarded was 446 million euros in 2018 (Union Européenne du Trot, 2018a).

Possible reasons for response differences between groups may be that race veterinarians as private veterinarians may be pressured to let horses compete. Trainers may have financial pressure to compete. Veterinarians and assistants might have earlier experiences of how trainers may react if their horse is prohibited from racing. It is also possible that veterinarians and assistants have earlier been exposed to relatively large amounts of oral lesions and a high number of lesions may have become the standard and is thus regarded as 'normal'. This phenomenon (*over-exposure*) has been studied in relation to pain evaluation in humans and abnormal behavior evaluation in horses (Prkachin et al., 2004; Lesimple and Hausberger, 2014). Empathy has been noted to decrease over the course of medical training, which might be a coping mechanism to handle various stress factors (Neumann et al., 2011). Lower empathy levels could explain this result, as it may impair animal pain recognition (Norring et al., 2014; Luna et al., 2018).

In addition to attitude differences between stakeholder groups, there were attitude differences within a group regarding whether a horse with an oral lesion should be removed from a competition. In an earlier study, equine practitioners have been asked to evaluate horses' pain level based on digital photographs of various horse diseases (Luna-Fernández et al., 2016). There was a poor level of agreement in estimation of the extent of pain in various diseases (Luna-Fernández et al., 2016). The agreement was stronger in diseases with higher pain scores such as open tibia fracture or septic arthritis in a foal (Luna-Fernández et al., 2016).

In addition to laws and regulations, internal values of what is right and wrong *(morals*) affect our opinions and moral decisions (Lesser, 2012). Not removing horses with severe oral lesions from the race may compromise horse welfare and undermine trust in the surveillance system. Education and discussion are important to ensure adequate oral

health level in competing horses since, from an animal welfare point of view, it is essential to minimize negative experiences by preventing or at least rapidly diagnosing and treating injuries and ensuring conditions that diminish suffering (Farm Animal Welfare Council, 1993; Mellor, 2016).

6.9 Bit-related lesions, horse welfare and ethics in competitions

Ethical issues in animal welfare arise from the fact that humans use animals for their own purposes (Dawkins, 2006). Conflicts may arise between competition demands and the horse's needs (Furtado et al., 2021). Higher financial investments in the horse industry may predispose competing horses to greater pressures to succeed, further compromising the animal's welfare (Furtado et al., 2021). It has been questioned whether it is even possible to fulfill the Five Freedoms in equine sports (Campbell, 2016). The Five Freedoms have also been interpreted in the form of 'as free as possible' since complete freedom from negative experiences is not possible over an animal's lifespan (Campbell, 2016; Mellor, 2016). Accepting the 'as free as possible' approach allows provision of the best welfare possible in circumstances where the ideal is unobtainable (Campbell, 2016). Owners, trainers, and riders are considered to have a crucial role in horse welfare (Jones and McGreevy, 2010; Viksten, 2016) since most horse use takes place on horse farms and is not visible to the public eye (Jones and McGreevy, 2010).

Freedom from bit-related lesions is a part of horse welfare, given that good health and freedom of discomfort, injuries, pain, fear, and distress are considered essential welfare criteria (Farm Animal Welfare Council, 1979; Minero et al., 2015).

"That animals should not be made to suffer unnecessarily is a widely recognized moral principle" (Hurnik and Lehman, 1982); it is forbidden in the national legislation in Finland (Animal Welfare Act 247/1996, 1996). However, the line between necessary and unnecessary suffering is not clear (Hurnik and Lehman, 1982). Necessity of animal suffering is also related to cost and resources (Hurnik and Lehman, 1982).

> "Suffering of animals is unnecessary suffering if it is not essential for purposes of sufficient importance or if it could be avoided by adopting alternative practices that would achieve the same important purposes, but would result in less suffering, providing that such alternative practices were not too expensive for the community in question to bear" (Hurnik and Lehman, 1982).

Oral lesions likely cause the horse pain (Mellor, 2020). Lesion pain might be incessant or intermittent, present only when the bit is touching or stretching the affected area. The later impact of the negative experiences from lesions on the horse's life is unknown. Classical (Pavlovian) conditioning takes place when a stimulus is followed by an occurrence (Mendl and Nicol, 2020). If a stimulus, e.g. arriving at the competition area, is associated with oral lesions and pain, the horse may start to anticipate this aversive experience, which could manifest in the horse's behavior (McBride and Mills, 2012).

Good performance depends on many factors and is still often held as an indicator of good welfare (Odberg and Bouissou, 1999; Heleski and Anthony, 2012; Schuurman, 2015). In the present studies (II, III), we failed to demonstrate an association between bit-related lesions and horse performance, meaning that well-performing horses are not necessarily free from welfare concerns. However, 37% of the trotters and 70% of the event horses managed to compete with no lesions or mild lesion status, thus, it is possible to compete without lesions or with minimal injuries (I, III).

A good human-animal interaction is one welfare criterion (Blokhuis et al., 2010; Mellor et al., 2020). Animals subjected to aversive human contact (such as oral lesions resulting from bit use) may become fearful (Zulkifli, 2013) and such equipment as bits, tongue-ties, or tight nosebands used with marked or severe pressure may have negative effects on the horse-human relationship (Mellor et al., 2020) and prevent animals' natural behaviors (Farm Animal Welfare Council, 1979). Welfare problems in horses may in turn have negative consequences on humans and predispose them to accidents (Luke et al., 2022). Injuries or improper training are thought to lead to unwanted behaviors and wastage, meaning that the horse is not suitable for its intended purpose (McLean and McGreevy, 2006, 2010b).

It is common that different parties (stakeholders) have different interests, and economics influences ethical decisions (Blea, 2012; Campbell, 2021). In utilitarianism, ethical decisions aim for the best possible consequences, taking into account all stakeholders (Appleby et al., 2018). Stakeholders regarding bit-related oral lesions could be, in addition to the horses (horses in training and in competitions, retired or wasted horses), human stakeholders such as horse owners, trainers, breeders, drivers, riders, grooms, veterinarians, animal trainers, horse equipment manufacturers and suppliers, policy

makers, members of the public interested in animal welfare or horses (spectators and punters), animal welfare or animal rights associations, and media (list modified from Campbell, 2021).

Science provides important information on animals, which can be utilized for decision making, but ultimately it is an ethical decision by society that determines the acceptable welfare level (Hemsworth and Coleman, 2011; Heleski and Anthony, 2012). Society's views on what is ethical is constantly changing (Campbell, 2013; Bergmann, 2019). The social license to operate (SLO) refers to society 'giving' a certain activity or business the 'license to operate' if it thinks that the activity is morally 'acceptable' (McLean and McGreevy, 2010b; Campbell, 2016; Duncan et al., 2018; Heleski et al., 2020). Different ethical frameworks can be used as an analytical tool to identify important aspects of an ethical dilemma (Campbell, 2021). It does not offer 'correct' answers, but it may help to make judgments about which stakeholder's interests are most important (Campbell, 2021). However, depending on the framework used, the result may be different.

6.10 Study limitations

The studies have certain limitations:

1) The horse selection for the studies was not random in a statistical sense. In trotters, horses locating near to each other based on harnessing booth number and competing in the same race were selected as possible candidates for the study. The first horse to arrive to the harnessing booth after a race was selected to the study. The second and third horses examined were the horses situated nearby and still in their harnessing booths. The examinations of that particular race ceased when all possible candidate horses had left. For the next race, the examiners moved to another 'cluster' of harnessing booths to wait for the competitors to arrive. The sample collection was not therefore completely random to ensure collection of an adequate sample size in the limited timeframe between races. In event horses, the examination was voluntary for the riders. An invitation to participate was extended to as many competitors as possible to maximize the sample size, but horses examined in previous competitions were excluded. The examiners could not have predicted whether horses have lesions and if so what kind.

The sample of horses represented 3% of the Standardbreds (151/4824), 4% of Finnhorses (78/2058), and 5% of trotting ponies (32/603) competing in 2017 in Finland (National Equine Competence Association of Finland, 2017) and 25% of the event horses (208/831) competing in seasons 2018–2019 (the number of competing event horses was received from the Equestrian Federation of Finland's KIPA database).

2) Neither intraobserver nor interobserver reliability of the lesion scoring system, i.e. whether the same or different observers, respectively, would score the same lesions similarly, has been tested. To counter this limitation, the research assistant verified the findings when they were recorded on the data sheet and some of the lesions were photographed.

3) The numbers of coldblooded horses and other than double-jointed bits were small in the event horse study (III), which may lead to type II error, meaning that possible associations go undetected.

4) The number of unjointed *Happy Mouth* bits was small (II), and the confidence interval was large, and thus, this result should be confirmed in a larger horse population.

5) Horses were not examined before the competitions, and therefore, we cannot draw definite conclusions about whether all of the lesions occurred during the competition event and with that particular bit. However, if the lesions were present before the competition, it further emphasizes the need for racing awareness and control of oral lesions. As the study was executed in a competition setting, the bit choice for the horses was made by riders or horse trainers.

6) All horses were examined within 30 minutes after a competition. It is possible that some deep bruises may have gone undetected since they can appear after several hours or even days (Bilo et al., 2012).

7) The scoring system is based on visual evaluation. A histological evaluation, although unfeasible in this context, might have led to grading of some wounds as bruises. While the cut-off points for mild, moderate, and severe lesion status are partly based on the extent and degree of tissue damage, the system also has an anthropocentric built-in moral value charge, meaning that different people might evaluate lesions or their combinations differently. It is possible that work as a trot race veterinarian has over-exposed the author KT to oral lesions, leading to an underestimation of lesion severity. However, this study was conducted in field conditions and it is possible later to change the cut-off points and decide which level of oral damage (if any) is acceptable in horse sports in the future.

8) The participants for the pilot questionnaire study were lecture participants, and thus, the answers reflect only their attitudes. Further investigations are needed to verify these findings.

6.11 Practical implications

Based on these study results, a single-jointed snaffle trotting bit for a trotter and a 14–17 mm bit (probably double-jointed) for an event horse are recommended. However, since some of these horses had severe lesions even with the 'best' bits in the study (ten trotters racing with single-jointed snaffle trotting bit and three event horses wearing 14–17 mm double-jointed bits had severe lesion status), it can be concluded that the problem runs much deeper and is not likely to be resolved in all cases by changing the bit. Regular oral examination for any pathologies or sharp enamel points is important (Johnson and Porter, 2006; Pearce, 2020). It is also critical to investigate other problems, such as lameness, that could be behind the pulling (Foster, 2013), and possibly conduct training modifications so that the horses do not become pullers over time (Merillat, 1917; Foster, 2013) (**Figure 18**). Mare oral health warrants special attention since study mares were at higher risk of having moderate-severe oral lesions.

Absence of external mouth bleeding was not a reliable sign of adequate bit area health. Regular bit area self-monitoring is advisable for horse handlers.

Since horses competing with certain bit types were at higher risk, the competition organizers could use this information as a tool for risk-based sampling in competitions. It is important to perform the examination with the headlamp and to carefully examine the inner lip commissures by holding the tongue, bars, outer lip commissures, and buccal area as described earlier. Removal of all head equipment before the examination in trotters and opening the noseband and curb chain in riding horses was found to be critical for a reliable visual inspection.

If lesions are found, they should be allowed to heal properly, and bit use should be discontinued (Foster, 2013). Suggested measures for preventing bit-related lesions are presented in **Figure 19**.

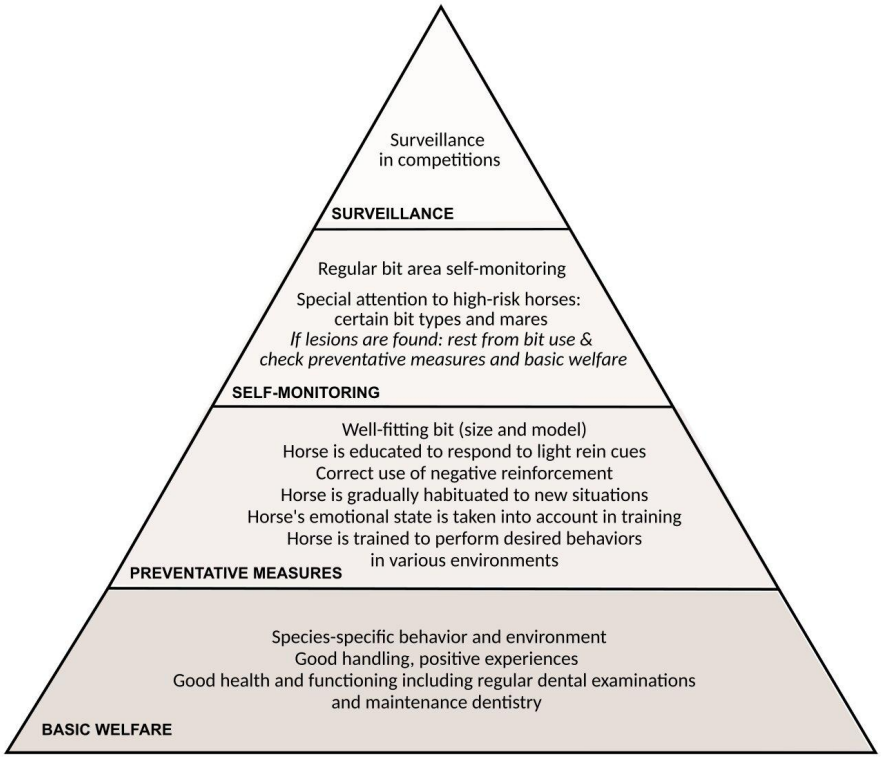


Figure 19. *Suggested measures for preventing bit-related lesions in horses (Johnson and Porter, 2006; Lethbridge, 2009; Easley, 2011; Foster, 2013; Companion and Hobby Animal Welfare Council, 2015; International Society for Equitation Science, 2018).*

6.12 Future research

Loading time and magnitude play a major role in the development of pressure ulcers (Bergstrand, 2009). Currently, the amount and duration of rein tension leading to bit-related lesions are unknown, as is the time needed for lesion healing in horses. To the author's knowledge, only one study exists on trotter's rein tension (Preuschoft et al., 1999). The scoring used in this study reflects the extent of tissue damage in the bit area. The extent of tissue damage is very likely related to some degree to lesion healing time. However, the scoring does not evaluate the amount of chronicity in the lesions, which is very likely another important component in lesion healing. In future studies, the amount

of chronicity could be evaluated and categorized as mild, moderate, or severe since it probably affects lesion healing time.

Studies on oral lesions and their healing and association with rein tension and loading times are warranted. It would be also important to study horse's behaviour and its association with lesions and rein tension. It would also be interesting to know how bit-related lesions could be prevented with change of bit or training modifications.

7 CONCLUSIONS

Based on the findings from the studies included in this thesis and the existing literature, the following conclusions can be made:

1 Bit-related lesions were common after a race or competition. The most common lesion location was the inner lip commissure, followed by the bars of the mandible, buccal area near 106 and 206 teeth, and outer lip commissure. Trotters had more lesions and lesions of greater severity than event horses. Results of this thesis encourage adopting bit area monitoring as a new routine by horse handlers and as a welfare measure by competition organizers since oral lesions in the bit area were common despite only six trotters showing external mouth bleeding.

2 Oral examination and the lesion scoring system for bit-related lesions were suitable for field conditions and the horses tolerated the examination well. Video recordings from lesions were more suitable than photographs for documenting oral lesions.

3 Crescendo bit, unjointed mullen mouth regulator bit, and straight plastic bit (model *Happy Mouth*) and female sex (mare) were recognized as risk factors for moderate or severe oral lesions in trotters. In event horses, thin or thick bits, mare sex, and breed other than pony were risk factors. Horses wearing unjointed bits were at higher risk of sustaining bar lesions than horses wearing jointed bits. However, it is possible that these results may reflect at least partly rein tension differences because trainers or riders may revert to options other than basic bit type and size if they encounter driveability or rideability issues.

4 The pilot questionnaire study indicated differences in attitudes towards bit-related lesions between stakeholder groups but also within a group. This might reflect differences in conflicts of interests, moral values, empathy, or over-exposure to oral lesions. Not removing horses with severe oral lesions from the race may compromise horse welfare and undermine trust in the surveillance system.

8 ACKNOWLEDGMENTS

The research presented in this thesis was carried out at the Centre of Animal Welfare Research, Department of Production Animal Medicine at the Faculty of Veterinary Medicine, University of Helsinki, Finland. The trotter studies were originally funded by the *Finnish Trotting and Breeding Association* (Suomen Hippos), and the event horse study was conducted with the collaboration of the *Equestrian Federation of Finland* (Suomen Ratsastajainliitto). I'm very honored that multiple foundations regarded this research as important. This work was funded by the *Finnish Foundation of Veterinary Research, the Finnish Veterinary Foundation (Mercedes Zachariassen Foundation), the Finnish Cultural Foundation (Pirkanmaa regional fund), Orion Research Foundation, the Juliana von Wendt Foundation, SEY Animal Welfare Finland (Heli Castrén grant), the Erkki Rajakoski Foundation,* and the *Doctoral School in Health Sciences, University of Helsinki.*

I'm deeply grateful to all horse *owners, trainers*, and *riders* for allowing us to examine their horses and for their interest in improving horse welfare. All competition organizers are thanked for making it possible to examine the horses in competitions.

Several people have contributed to this work, and I extend my sincere gratitude to all of them. The following individuals warrant special mention:

My three super supervisors: *Anna Valros, Minna Kujala-Wirth*, and *Anna Mykkänen*. I am deeply grateful to Professor Valros for guiding me through this project. She gently and wisely responded to my countless e-mails and questions, and, for example, advised me to participate in the Equitation Science course in Sweden, which proved to be immensely useful. Minna Kujala-Wirth, from the Saari Unit, I thank for teaching me so much about statistics. Without her supervision and help with logistic regression and epidemiology, this thesis would not have been possible. I also thank Anna Mykkänen, from the Equine Hospital. I truly admire her for her positive attitude, humor, and calmness. She has brought an equine veterinary view to this research, for which I'm deeply grateful. All and all, I have had the best supervisors for me; thank you for your guidance and for believing in me.

I am most grateful to the reviewers, Professor *Agneta Egenvall* and Senior Researcher *Mette Herskin,* for their valuable time and effort in critically and constructively reviewing this thesis. Special thanks to Senior Researcher *Cecilie Mejdell* for agreeing to serve as opponent at my dissertation defense. My author-editor *Carol Ann Pelli* is thanked for her careful review of the manuscript.

First-class research assistant and co-author, pocket-rocket *Nina Mäki-Kihniä*, without her help this work would not have progressed. Since 2017, when this project started, we

have had numerous meetings and good discussions and long hours in the Tikkula ABC meeting room. She was with me to see all of the horses, took video recordings and photographs, and with her language skills has been a tremendous help in editing the texts. Riding instructor and animal trainer *Anna Kilpeläinen*, whom I got to know along the way. I thank you for help with editing this thesis and the many good discussions that we have had.

Veterinarians *Katja Hautala* and *Reija Junkkari*, who at the time worked at Suomen Hippos and made this study possible. I'm forever grateful for you. Professors *Timo Soveri* and *Riitta-Mari Tulamo*, I'm grateful for your advice at the beginning of this work. Veterinarian *Kirsi Norkio* for assistance in some of the eventing competitions and veterinarians *Mirjami Anttila* and *Pirkko Valmari* for discussions on bits and lesion scorings.

Satu Cozens from Kummakko Design for excellent illustrations and *Pauli Impola* for trotter photographs in Study II. Docent *Laura 'twitter' Hänninen* for social media and other support. Race veterinary assistant *Johanna Virtanen* for helping me with the photography and assisting in the questionnaire study. Thank you, Johanna, for your interest in this topic. All of the teachers at the Doctoral School of Health. My fellow doctoral students for their loyal support. I am especially grateful to my friends and fellow doctoral students *Riitta Niemi* for the many discussions we had on statistics, research, and life and *Elli Valtonen* for interesting conversations.

My friend *Rita Harmaajärvi*, whose life experience and good advice have been invaluable. *Marjo-Riitta Piisi*, my long-time friend for always good discussions. My dear friends and relatives *Helene Hänninen, Mia Astala*, *Katja Ylitalo, Liisa Tontti, and Minna-Liisa Karjalainen* – thank you for your support. My French teachers *Ana Poljak-Klaric*, *Marie-Glaude Anttonen*, and *Tiina Martikainen* for valuable guidance regarding my conference presentation in Tours, France in 2019.

I thank *Anna-Mari Olbricht, Marja Bergstöm, Sanna Mäki-Tuuri, Mette Pökkelmann*, and *Tuulia Appleby* for valuable knowledge for the Oral Health Guide for Trotters. *Tuire Kaimio, Susanna Särkijärvi, Heta Rautianen*, and *Annica Hirvi* are thanked for interesting discussions at the Equitation Science course.

All journalists who have been interested in this topic and interviewed me along the way: thank you!

A special thanks to my family. I'm grateful to my mother *Tuula*, who came to help in eventing competitions and has always supported me. My brother *Tomi* for explaining physics to me. My beloved partner, *Jarno*, for taking care of me, making coffee and sandwiches, helping with 'computer problems' such as Teams, Zoom, etc., and especially for patiently listening to and reading my 'horse stories' over and over again.

9 REFERENCES

Allen, T. E. (2004). Incidence and Severity of Abrasions on the Buccal Mucosa Adjacent to the Cheek Teeth in 199 Horses | IVIS. in *50 th annual AAEP Convention* (Denver, USA), 31–36. Available at: https://www.ivis.org/library/aaep/aaep-annual-convention-denver-2004/incidence-and-severity-of-abrasions-on-buccal-mucosa-adjacent-to-cheek-teeth-199-horses [Accessed July 8, 2021].

Allen, T. E. (2008). *Manual of Equine Dentistry*. , eds. L. Fathman and J. Gower Usa: Mulleicorn Press.

Animal Welfare Act 247/1996 (1996). Available at: https://www.finlex.fi/fi/laki/kaannokset/1996/en19960247_20061430.pdf [Accessed July 31, 2021].

Animal Welfare Act 247/1996 17§ (1996). Finland Available at: https://www.finlex.fi/fi/laki/kaannokset/1996/en19960247_20061430.pdf.

Animal Welfare Act 247/1996 3§ (1996). Finland, Finland Available at: https://www.finlex.fi/fi/laki/kaannokset/1996/en19960247_20061430.pdf.

Animal Welfare Decree 396/1996 (1996). Available at: https://www.finlex.fi/fi/laki/kaannokset/1996/en19960396_20060401.pdf [Accessed October 24, 2021].

Anthony, D. W., and Brown, D. R. (2000). Eneolithic horse exploitation in the Eurasian steppes: Diet, ritual and riding. *Antiquity* 74, 75–86. Available at: https://search-proquest-com.libproxy.helsinki.fi/docview/1293811172?pq-origsite=primo [Accessed March 5, 2021].

Appleby, M. C., Olsson, I. A. S., and Galindo, F. (2018). "Introduction," in *Animal Welfare*, eds. M. C. Appleby, I. A. S. Olsson, and F. Galindo (Oxfordshire, UK: CABI International), 3–15.

Barakzai, S. Z., Finnegan, C., and Boden, L. A. (2009a). Effect of 'tongue tie' use on racing performance of Thoroughbreds in the United Kingdom. *Equine Vet. J.* 41, 812–816. doi:10.2746/042516409X434134.

Barakzai, S. Z., Finnegan, C., Dixon, P. M., Hillyer, M. H., and Boden, L. A. (2009b). Use of tongue ties in thoroughbred racehorses in the United Kingdom, and its association with surgery for dorsal displacement of the soft palate. *Vet. Rec.* 165, 278–281. doi:10.1136/vr.165.10.278.

Bell, C., Rogers, S., Taylor, J., and Busby, D. (2019). Improving the recognition of equine affective states. *Animals* 9, 1–13. doi:10.3390/ani9121124.

Bennett, D. G. (2001). Bits and Bitting: Form and Function. in *Proceedings of the Annual Convention of the AAEP* (San Diego, Usa), 1–8. Available at: https://www.ivis.org/sites/default/files/library/aaep/2001/91010100130.pdf [Accessed August 28, 2021].

Bennett, D. G. (2010). "Bits, bridles and accessories," in *Equine Dentistry*, eds. J. Easley, P. M. Dixon, and J. Schumacher (Edinburg, London, New York, Oxford, Philadelphia, St Louis, Sydney, Toronto: Saunders Elsevier), 27.

Bergmann, I. (2019). *He loves to race – or does he? Ethics and Welfare in Racing*. 1st ed. , eds. J. Bornemark, P. Andersson, and U. Ekström von Essen New York: Routledge doi:10.4324/9781351002479-9.

Bergstrand, S. (2009). Tissue Blood Flow Responses to External Pressure Using LDF and PPG: Testing a System Developed for Pressure Ulcer Research. Available at: https://www.diva-portal.org/smash/get/diva2:278058/FULLTEXT01.pdf.

Berkowitz, L. (1989). Frustration-Aggression Hypothesis: Examination and Reformulation. *Psychol. Bull.* 106, 59–73. doi:10.1037/0033-2909.106.1.59.

Bilo, R. A. C., Oranje, A. P., Shwayder, T., and Hobbs, C. J. (2012). *Cutaneous manifestations of child abuse and their differential diagnosis: Blunt force trauma*. Heidelberg New York Dordrecht London: Springer-Verlag Berlin Heidelberg doi:10.1007/978-3-642-29287-3.

Björnsdóttir, S., Frey, R., Kristjansson, T., and Lundström, T. (2014). Bit-related lesions in Icelandic competition horses. *Acta Vet. Scand.* 56, 1–7. doi:10.1186/s13028-014-0040-8.

Björnsdóttir, S., Frey, R., Kristjansson, T., and Lundström, T. (2018). Welfare indicator for competition horses. Bit-related lesions. in *Poster presentation, Nordic Equine Veterinary Congress, (2018)* (Bergen, Norway).

Blea, J. A. (2012). Ethical Issues for the Racetrack Practitioner: A Daily Requirement. in *Proceedings of the AAEP Annual Convention* (Anaheim,CA: Ivis), 83–84. Available at: https://www.ivis.org/library/aaep/aaep-annual-convention-anaheim-2012/ethical-issues-for-racetrack-practitioner-a-daily-requirement [Accessed June 27, 2021].

Blokhuis, H. J., Veissier, I., Miele, M., and Jones, B. (2010). The welfare quality® project and beyond: Safeguarding farm animal well-being. *Acta Agric. Scand. A Anim. Sci.* 60, 129–140. doi:10.1080/09064702.2010.523480.

Brambell, F. G. R. (1965). Report of the Technical Committee to Enquire into the Welfare of Animals kept under Intensive Livestock Husbandry Systems. in (London, Her Majesty's Stationary Office), 89.

Brown, D., and Anthony, D. (1991). The origins of horseback riding. *Antiquity* 65, 22–38. doi:10.1017/S0003598X00079278.

Campbell, M. L. H. (2012). "Ethical Analysis of the Use Of Animals for Sport," in *Veterinary & Animal Ethics* (Oxford, UK: Blackwell Publishing Ltd), 201–215. doi:10.1002/9781118384282.ch14.

Campbell, M. L. H. (2013). When does use become abuse in equestrian sport? *Equine Vet. Educ.* 25, 489–492. doi:10.1111/eve.12087.

Campbell, M. L. H. (2016). Freedoms and frameworks: How we think about the welfare of competition horses. *Equine Vet. J.* 48, 540–542. doi:10.1111/evj.12598.

Campbell, M. L. H. (2021). An Ethical Framework for the Use of Horses in Competitive Sport: Theory and Function. *Animals* 11, 1725. doi:10.3390/ani11061725.

Carmalt, J. L., Carmalt, K. P., and Barber, S. M. (2006). The effect of occlusal equilibration on sport horse performance. *J. Vet. Dent.* 23, 226–230. doi:10.1177/089875640602300405.

Casey, V., McGreevy, P. D., O'Muiris, E., and Doherty, O. (2013). A preliminary report on estimating the pressures exerted by a crank noseband in the horse. *J. Vet. Behav.* 8, 479–484. doi:10.1016/j.jveb.2013.06.003.

Christensen, J. W., Munk, R., Hawson, L. A., Palme, R., Larsen, T., Egenvall, A., et al. (2021). Rider effects on horses' conflict behaviour, rein tension, physiological measures and rideability scores. *Appl. Anim. Behav. Sci.* 234, 105184. doi:10.1016/J.APPLANIM.2020.105184.

Christensen, J. W., Zharkikh, T. L., Antoine, A., and Malmkvist, J. (2011). Rein tension acceptance in young horses in a voluntary test situation. *Equine Vet. J.* 43, 223–228. doi:10.1111/j.2042-3306.2010.00151.x.

Clayton, H. M. (1985). A fluoroscopic study of the position and action of different bits in the horse's mouth. *J. Equine Vet. Sci.* 5, 68–72. doi:10.1016/S0737-0806(85)80050-2.

Clayton, H. M., and Lee, R. (1984). A fluoroscopic study of the position and action of the jointed snaffle bit in the horse's mouth. *J. Equine Vet. Sci.* 4, 193–196. doi:10.1016/S0737-0806(84)80141-0.

Clayton, H. M., Singleton, W. H., Lanovaz, J., and Cloud, G. L. (2003). Measurement of rein tension during horseback riding using strain gage transducers. *Exp. Tech.* 27, 34–36. doi:10.1111/j.1747-1567.2003.tb00112.x.

Clayton, H. M., Singleton, W. H., Lanovaz, J. L., and Cloud, G. L. (2005). Strain gauge measurement of rein tension during riding: a pilot study. *Equine Comp. Exerc. Physiol.* 2, 203–205. doi:10.1079/ecp200553.

Companion and Hobby Animal Welfare Council (2015). Määritelmä eläinten hyvinvoinnille (Transl. Definition of Animal Welfare). Available at: https://www.elaintieto.fi/wp-content/uploads/2016/02/shehvnk-hyvinvoinnin-määritelmä.pdf [Accessed June 29, 2020].

Condon, V. M., McGreevy, P. D., McLean, A. N., Williams, J. M., and Randle, H. (2022). Associations between commonly used apparatus and conflict behaviors reported in the ridden horse in Australia. *J. Vet. Behav.* 49, 1–14. doi:10.1016/J.JVEB.2021.10.014.

Cook, W. R. (1999). Pathophysiology of bit control in the horse. *J. Equine Vet. Sci.* 19, 196–204. doi:10.1016/S0737-0806(99)80067-7.

Cook, W. R. (2011). Damage by the bit to the equine interdental space and second lower premolar. *Equine Vet. Educ.* 23, 355–360. doi:10.1111/j.2042-3292.2010.00167.x.

Cook, W. R., and Kibler, M. (2019). Behavioural assessment of pain in 66 horses, with and without a bit. *Equine Vet. Educ.* 31, 551–560. doi:10.1111/eve.12916.

Crittenden, M. (2017). The Welfare and Veterinary Care for the Roman Racehorse at the Circus Maximus. *Univ. Kent*, 1–72. Available at: https://www.researchgate.net/publication/320373419_The_Welfare_and_Veterinary_Care_for_the_Roman_Racehorse_at_the_Circus_Maximus [Accessed June 30, 2021].

Dalla Costa, E., Minero, M., Lebelt, D., Stucke, D., Canali, E., and Leach, M. C. (2014). Development of the Horse Grimace Scale (HGS) as a pain assessment tool in horses undergoing routine castration. *PLoS One* 9, 1–10. doi:10.1371/journal.pone.0092281.

Dawkins, M. S. (2006). A user's guide to animal welfare science. *Trends Ecol. Evol.* 21, 77–82. doi:10.1016/J.TREE.2005.10.017.

Dio Chrysostom (1951). "Discourse 63 On Fortune Translated by H. Lamar Crosby," in *Discourses 61-80. Fragments. Letters.* (Cambridge,MA: Loeb Classical Library 385. Harvard University Press), 73–86. Available at: https://www.loebclassics.com/view/LCL385/1951/volume.xml.

Dixon, P. M. (2000). Removal of equine dental overgrowths. *Equine Vet. Educ.* 12, 68–81. doi:10.1111/j.2042-3292.2000.tb01768.x.

Dixon, P. M., du Toit, N., and Dacre, I. T. (2011). "Equine Dental Pathology," in *Equine Dentistry*, eds. J. Easley, P. M. Dixon, and J. Schumacher (Edinburgh, London, New York, Oxford, Philadelphia, St Louis, Sydney, Toronto: Saunders Elsevier), 129–147.

Dixon, P. M., Tremaine, W. H., Pickles, K., Kuhns, L., Hawe, C., McCann, J., et al. (2000). Equine dental disease Part 3: A long-term study of 400 cases: Disorders of wear, traumatic damage and idiopathic fractures, tumours and miscellaneous disorders of the cheek teeth. *Equine Vet. J.* 32, 9–18. doi:10.2746/042516400777612099.

Doherty, O., Casey, V., McGreevy, P. D., and Arkins, S. (2017). Noseband Use in Equestrian Sports – An International Study. *PLoS One* 12, 1–18. doi:10.1371/journal.pone.0169060.

Duberstein, K. J., and Gilkeson, J. A. (2010). Determination of sex differences in personality and trainability of yearling horses utilizing a handler questionnaire. *J.A. Gilkeson / Appl. Anim. Behav. Sci.* 128, 57–63. doi:10.1016/j.applanim.2010.09.012.

Dumbell, L., Lemon, C., and Williams, J. (2019). A systematic literature review to evaluate the tools and methods used to measure rein tension. *J. Vet. Behav.* 29, 77–87. doi:10.1016/j.jveb.2018.04.003.

Duncan, E., Graham, R., and McManus, P. (2018). 'No one has even seen… smelt… or sensed a social licence': Animal geographies and social licence to operate. *Geoforum* 96, 318–327. doi:10.1016/j.geoforum.2018.08.020.

Duncan, I. J. H. (2006). The changing concept of animal sentience. *Appl. Anim. Behav. Sci.* 100, 1–19. doi:10.1016/j.applanim.2006.04.011.

Dwyer, F. (1868). *On Seats and Saddles: Bits and Bitting and the Prevention and Cure of Restiveness in Horses*. Second. Edinburg and London: William Blackwood and Sons doi:10.5962/bhl.title.18346.

Dyson, S., Berger, J., Ellis, A. D., and Mullard, J. (2018). Development of an ethogram for a pain scoring system in ridden horses and its application to determine the presence of musculoskeletal pain. *J. Vet. Behav.* 23, 47–57. doi:10.1016/j.jveb.2017.10.008.

Dyson, S., and Van Dijk, J. (2020). Application of a ridden horse ethogram to video recordings of 21 horses before and after diagnostic analgesia: Reduction in behaviour scores. *Equine Vet. Educ.* 32, 104–111. doi:10.1111/eve.13029.

Easley, J. (2010). "Seating the bit" - necessary or nonsense? in *Proceedings of the 49th British Equine Veterinary Association Congress* (Birmingham, UK), 25.

Easley, J. (2011). "Corrective dental procedures," in *Equine Dentistry*, eds. J. Easley, P. M. Dixon, and J. Schumacher (Edinburgh, London, New York, Oxford, Philadelphia, St Louis, Sydney, Toronto: Saunders Elsevier), 261–277.

Egenvall, A., Clayton, H. M., Eisersiö, M., Roepstorff, L., and Byström, A. (2019). Rein Tension in Transitions and Halts during Equestrian Dressage Training. *Animals* 9. doi:10.3390/ANI9100712.

Egenvall, A., Roepstorff, L., Rhodin, M., Eisersiö, M., and Clayton, H. M. (2016). Maximum and minimum peaks in rein tension within canter strides. *J. Vet. Behav. Clin. Appl. Res.* 13, 63–71. doi:10.1016/j.jveb.2016.03.007.

Eisersiö, M., Byström, A., Yngvesson, J., Baragli, P., Lanata, A., and Egenvall, A. (2021a). Rein Tension Signals Elicit Different Behavioral Responses When Comparing Bitted Bridle and Halter. *Front. Vet. Sci.* 1, 652015. doi:10.3389/fvets.2021.652015.

Eisersiö, M., Rhodin, M., Roepstorff, L., and Egenvall, A. (2015). Rein tension in 8 professional riders during regular training sessions. *J. Vet. Behav. Clin. Appl. Res.* 10, 419–426. doi:10.1016/j.jveb.2015.05.004.

Eisersiö, M., Yngvesson, J., Byström, A., Baragli, P., and Egenvall, A. (2021b). A rein tension signal can be reduced by half in a single training session. *Appl. Anim. Behav. Sci.*, 105452. doi:10.1016/J.APPLANIM.2021.105452.

Engeland, C. G., Bosch, J. A., Cacioppo, J. T., and Marucha, P. T. (2006). Mucosal wound healing: The roles of age and sex. *Arch. Surg.* 141, 1193–1197. doi:10.1001/archsurg.141.12.1193.

Engelke, E., and Gasse, H. (2003). An anatomical study of the rostral part of the equine oral cavity with respect to position and size of a snaffle bit. *Equine Vet. Educ.* 15, 158–163. doi:10.1111/j.2042-3292.2003.tb00235.x.

Equestrian Federation of Finland (2021a). Kilpailusäännöt III Esteratsastus (Transl. Competition Rules in Show Jumping). 52. Available at: https://www.ratsastus.fi/site/assets/files/21495/ks_iii_2021_master_unu.pdf [Accessed November 5, 2021].

Equestrian Federation of Finland (2021b). Kilpailusäännöt VI Lännenratsastus (Transl. Competition Rules in Western Riding). 17. Available at: https://www.ratsastus.fi/site/assets/files/20476/saannot_2021_lannenratsastus_puhdas-1.pdf [Accessed October 27, 2021].

Eriksson, A., Nyman, S., Nyberg, J., Lundström, T., Van Dooren, R., and Wallén, A. (2019). *Horse management and training - respecting the nature of the horse*. 1 st engli. Sweden: Equitellus AB.

Farm Animal Welfare Council (1979). Five Freedoms press statement. Surrey, England Available at: https://webarchive.nationalarchives.gov.uk/20121010012428/http://www.fawc.org.uk/pdf/fivefreedoms1979.pdf.

Farm Animal Welfare Council (1993). Report on Priorities for Animal Welfare Research and Development. Tolworth Tower, Surbiton, Surrey, England Available at: https://edepot.wur.nl/134980.

Fédération Equestre Internationale (2021a). FEI Dressage rules Article 430 7.6. Switzerland Available at: https://inside.fei.org/sites/default/files/FEI_Dressage_Rules_2021_Clean_Version.pdf [Accessed February 26, 2021].

Fédération Equestre Internationale (2021b). FEI Eventing Rules Article 526.4. Available at: https://inside.fei.org/sites/default/files/Eventing Rules for 2021 - clean version - 10.12.2020_0.pdf [Accessed March 20, 2021].

Fédération Equestre Internationale (2021c). FEI Jumping Rules Article 241 3.31. Switzerland Available at: https://inside.fei.org/sites/default/files/Jumping_Rules_2021_clean.pdf [Accessed March 20, 2021].

Fenner, K., Caspar, G., Hyde, M., Henshall, C., Dhand, N., Probyn-Rapsey, F., et al. (2019a). It's all about the sex, or is it? Humans, horses and temperament. *PLoS One* 14 (5), 1–18. doi:10.1371/journal.pone.0216699.

Fenner, K., McLean, A. N., and McGreevy, P. D. (2019b). Cutting to the chase: How round-pen, lunging, and high-speed liberty work may compromise horse welfare. *J. Vet. Behav.* 29, 88–94. doi:10.1016/j.jveb.2018.05.003.

Fenner, K., Yoon, S., White, P., Starling, M., and McGreevy, P. D. (2016). The Effect of Noseband Tightening on Horses' Behavior, Eye Temperature, and Cardiac Responses. *PLoS One* 11, e0154179. doi:10.1371/journal.pone.0154179.

Findley, J. A., Sealy, H., and Franklin, S. . (2016). Factors Associated with Tongue Tie use in Australian Standardbred Racehorses. *Equine Vet. J.* 48, 18–19. doi:10.1111/evj.32_12612.

Finnish Trotting and Breeding Association (2017). Kilpailueläinlääkärikansio (Transl. Instructions for race veterinarians- online folder). Available at: www.hippos.fi [Accessed July 3, 2020].

Finnish Trotting and Breeding Association (2020a). Raviurheilu Suomessa (transl. Harness racing in Finland). Available at: https://www.hippos.fi/raviurheilu/raviurheilu_lajina/raviurheilu_suomessa [Accessed July 4, 2020].

Finnish Trotting and Breeding Association (2020b). Raviurheilun Varusteopas (Transl. Equipment regulations). 40. Available at: https://www.hippos.fi/files/27684/Varusteopas_2020.pdf [Accessed October 15, 2020].

Finnish Trotting and Breeding Association (2021). Ravikilpailusäännöt (Transl. Rules of Racing) 8 § 22 § 47 §. Available at: https://www.hippos.fi/files/29726/Ravikilpailusaannot_2021.pdf [Accessed March 1, 2021].

Fossum, T. W., Hedlund, C. S., Hulse, D. A., Johnson, A. L., Howard, H. B., Willard, M. D., et al. (2002). "Surgery of the Integumentary System," in *Small Animal Surgery (2002)* (Usa: Mosby Inc), 136.

Foster, D. L. (2013). The Gold Standard of Dental Care for the Adult Performance Horse. *Vet. Clin. North Am. Equine Pract.* 29, 505–519. doi:10.1016/j.cveq.2013.04.012.

Francione, G. L. (1993). Animals, Property and Legal Welfarism: Unnecessary Suffering and the Humane Treatment of Animals. *Rutgers Law Rev.* 46, 721–770.

Frykberg, R. G., and Banks, J. (2015). Challenges in the Treatment of Chronic Wounds. *Adv. Wound Care* 4, 582. doi:10.1089/WOUND.2015.0635.

Furtado, T., Preshaw, L., Hockenhull, J., Wathan, J., Douglas, J., Horseman, S., et al. (2021). How Happy Are Equine Athletes? Stakeholder Perceptions of Equine Welfare Issues Associated with Equestrian Sport. *Anim. 2021, Vol. 11, Page 3228* 11, 3228. doi:10.3390/ANI11113228.

Gleerup, K., Forkman, B., Lindegaard, C., and H Andersen, P. (2015). An equine pain face. *Vet. Anaesth. Analg.* 42, 103–114. doi:10.1111/vaa.12212.

Górecka-Bruzda, A., Kosińska, I., Jaworski, Z., Jezierski, T., and Murphy, J. (2015). Conflict behavior in elite show jumping and dressage horses. *J. Vet. Behav.* 10, 134–146. doi:10.1016/j.jveb.2014.10.004.

Greet, T., and Ramzan, P. H. L. (2010). “Head and Dental Trauma,” in *Equine Dentistry*, eds. J. Easley, P. M. Dixon, and J. Schumacher (Edinburgh, London, New York, Oxford, Philadelphia, St Louis, Sydney, Toronto: Saunders Elsevier), 115.

Haggard, P., and de Boer, L. (2014). Oral somatosensory awareness. *Neurosci. Biobehav. Rev.* 47, 469–484. doi:10.1016/j.neubiorev.2014.09.015.

Hague, B. A., and Honnas, C. M. (1998). Traumatic dental disease and soft tissue injuries of the oral cavity. *Vet. Clin. North Am. Equine Pract.* 14, 333–347. doi:10.1016/S0749-0739(17)30201-8.

Hall, C., and Heleski, C. R. (2017). The role of the ethogram in equitation science. *Appl. Anim. Behav. Sci.* 190, 102–110. doi:10.1016/j.applanim.2017.02.013.

Hall, C., Randle, H., Pearson, G., Preshaw, L., and Waran, N. (2018). Assessing equine emotional state. *Appl. Anim. Behav. Sci.* 205, 183–193. doi:10.1016/j.applanim.2018.03.006.

Hawson, L. A., Salvin, H. E., McLean, A. N., and McGreevy, P. D. (2014). Riders’ application of rein tension for walk-to-halt transitions on a model horse. *J. Vet. Behav. Clin. Appl. Res.* 9, 164–168. doi:10.1016/j.jveb.2014.04.001.

Heleski, C. R., and Anthony, R. (2012). Science alone is not always enough: The importance of ethical assessment for a more comprehensive view of equine welfare. *J. Vet. Behav.* 7, 169–178. doi:10.1016/J.JVEB.2011.08.003.

Heleski, C. R., Stowe, C. J., Fiedler, J., Peterson, M. L., Brady, C., Wickens, C., et al. (2020). Thoroughbred Racehorse Welfare through the Lens of ‘Social License to Operate—With an Emphasis on a U.S. Perspective. *Sustainability* 12, 1706. doi:10.3390/su12051706.

Hemsworth, P. H., and Coleman, G. J. (2011). “Introduction: the Stockperson as a Professional – Skills, Knowledge and Status,” in *Human-Livestock Interactions: The Stockperson and the Productivity and Welfare of Intensively Farmed Animals* (Oxfordshire, UK: CABI Publishing), 1–20. doi:10.1079/9781845936730.0000.

Hewson, C. J. (2003). What is animal welfare? Common definitions and their practical consequences. *Can. Vet. J.* 44, 496–499. Available at: /pmc/articles/PMC340178/ [Accessed August 4, 2021].

Hinebauch, T. D. (1889). *Veterinary Dental Surgery: For the Use of Students, Practitioners and Stockmen*. Lafayette Indiana: Hinebauch T.D. Purdue University doi:10.5962/bhl.title.42517.

Hockenhull, J., and Whay, H. R. (2014). A review of approaches to assessing equine welfare. *Equine Vet. Educ.* 26, 159–166. doi:10.1111/eve.12129.

Hurnik, F., and Lehman, H. (1982). Unnecessary Suffering: Definition and Evidence. *J. Study Anim. Probl.* 3, 131–137.

International Association for the Study of Pain (IASP) (2020). IASP Announces Revised Definition of Pain . Available at: https://www.iasp-pain.org/publications/iasp-news/iasp-announces-revised-definition-of-pain/ [Accessed October 27, 2021].

International Federation of Icelandic Horse Associations (2021). General Rules and Regulations Sport Rules and Regulations . 47. Available at: https://www.feiffengur.com/documents/FEIF_Sport_Rules_Regulations_2021_v3.pdf [Accessed October 27, 2021].

International Society for Equitation Science (2018). ISES 10 training principles . Available at: https://equitationscience.com/learning-theory [Accessed August 2, 2021].

Johnson, T. J. (2002). Surgical Removal of Mandibular Periostitis (Bone Spurs) Caused by Bit Damage. in *48th Annual Convention of the AAEP, 2002 - Orlando, Florida, USA* (Florida, USA), 458–462.

Johnson, T. J., and Porter, C. M. (2006). Dental Conditions Affecting the Mature Performance Horse (5 - 15 Years) | IVIS. in *AAEP Focus Meeting - Equine Dentistry - Indianapolis, 2006* (Indianapolis), 1–8. Available at: https://www.ivis.org/library/aaep/aaep-focus-meeting-equine-dentistry-indianapolis-2006/dental-conditions-affecting-0 [Accessed July 19, 2021].

Jones, B., and McGreevy, P. D. (2010). Ethical equitation: Applying a cost-benefit approach. *J. Vet. Behav. Clin. Appl. Res.* 5, 196–202. doi:10.1016/j.jveb.2010.04.001.

Kau, S., Potz, I. K., Pospisil, K., Sellke, L., Schramel, J. P., and Peham, C. (2020). Bit type exerts an influence on self-controlled rein tension in unridden horses. *Sci. Rep.* 10, 2420. doi:10.1038/s41598-020-59400-w.

Keeling, L. J., and Jensen, P. (2020). “Abnormal behaviour, Stress and Welfare,” in *The Ethology of Domestic Animals An Introductory Text*, ed. P. Jensen (Linköping: CABI), 126–127.

Klugh, D. O. (2010). *Principles of Equine Dentistry*. , eds. J. Northcott and J. Brocklesby London: Manson Publishing Ltd.

König von Borstel, U., and Glißman, C. (2014). Alternatives to Conventional Evaluation of Rideability in Horse Performance Tests: Suitability of Rein Tension and Behavioural Parameters. *PLoS One* 9. doi:10.1371/journal.pone.0087285.

König von Borstel, U., Visser, E. K., and Hall, C. (2017). Indicators of stress in equitation. *Appl. Anim. Behav. Sci.* 190, 43–56. doi:10.1016/j.applanim.2017.02.018.

Kuhnke, S., Dumbell, L., Gauly, M., Johnson, J. L., McDonald, K., and König von Borstel, U. (2010). A comparison of rein tension of the rider’s dominant and non-dominant hand and the influence of the horse’s laterality. *Comp. Exerc. Physiol.* 7, 57–63. doi:10.1017/S1755254010000243.

Kumar, A., Kandpal, A., Bhagat, T., and Jain, R. (2004). *Guide to Forensic Medicine & Toxicology*. , ed. B. Jain New Delhi, India: B. Jain Publishers.

Lancker van, S., van den Broeck, W., and Simoens, P. (2007). Incidence and morphology of bone irregularities of the equine interdental spaces (bars of the mouth). *Equine Vet. Educ.* 19, 103–106. doi:10.2746/095777307X179882.

Lesimple, C. (2020). Indicators of horse welfare: State-of-the-art. *Animals* 10, 294. doi:10.3390/ani10020294.

Lesimple, C., and Hausberger, M. (2014). How accurate are we at assessing others' well-being? The example of welfare assessment in horses. *Front. Psychol.* 5, 21. doi:10.3389/fpsyg.2014.00021.

Lesser, F. R. (2012). Decisions That Matter: The Complementary Roles of Law, Morals, and Ethics in Equine Practice. in *Proceedings of the AAEP Annual Convention* (Anaheim, CA: IVIS), 62–68. Available at: https://www.ivis.org/library/aaep/aaep-annual-convention-anaheim-2012/decisions-matter-complementary-roles-of-law-morals-and-ethics-equine-practice [Accessed June 26, 2021].

Lethbridge, E. (2009). *Knowing You Horse. A Guide to Equine Learning, Training and Behaviour*. Oxford - Iowa: Wiley-Blackwell.

Luke, K. L., McAdie, T., Smith, B. P., and Warren-Smith, A. K. (2022). New insights into ridden horse behaviour, horse welfare and horse-related safety. *Appl. Anim. Behav. Sci.* 246, 105539. doi:10.1016/J.APPLANIM.2021.105539.

Luna-Fernández, D., Yañez-López, J. M., and Tadich-Gallo, T. A. (2016). Level of agreement in the recognition of pain among equine practitioners in Chile. *Vet. México OA* 3. doi:10.21753/VMOA.3.1.356.

Luna, D., Vásquez, R. A., Yáñez, J. M., and Tadich, T. (2018). The relationship between working horse welfare state and their owners' empathy level and perception of equine pain. *Anim. Welf.* 27, 115–123. doi:10.7120/09627286.27.2.115.

Manfredi, J., Clayton, H. M., and Rosenstein, D. (2005). Radiographic study of bit position within the horse's oral cavity. *Equine Comp. Exerc. Physiol.* 2, 195–201. doi:10.1079/ecp200564.

Manfredi, J. M., Rosenstein, D., Lanovaz, J. L., Nauwelaerts, S., and Clayton, H. M. (2009). Fluoroscopic study of oral behaviours in response to the presence of a bit and the effects of rein tension. *Comp. Exerc. Physiol.* 6, 143–148. doi:10.1017/S1755254010000036.

Mata, F., Johnson, C., and Bishop, C. (2015). A cross-sectional epidemiological study of prevalence and severity of bit-induced oral trauma in polo ponies and race horses. *J. Appl. Anim. Welf. Sci.* 18, 259–268. doi:10.1080/10888705.2015.1004407.

Mayhew, E. (1862). *The illustrated horse doctor*. Philadelphia: J. B Lippincott & Co. doi:10.5962/bhl.title.42702.

McBride, S. D., and Mills, D. S. (2012). Psychological factors affecting equine performance. *BMC Vet Res* 8, 1–11. doi:10.1186/1746-6148-8-180.

McGreevy, P. D. (2007). The advent of equitation science. *Vet. J.* 174, 492–500. doi:10.1016/j.tvjl.2006.09.008.

McGreevy, P. D. (2015). Right under our noses. *Equine Vet. Educ.* 27, 503–504. doi:10.1111/eve.12445.

McGreevy, P. D., Christensen, J. W., König von Borstel, U., and McLean, A. N. (2018). *Equitation Science*. 2nd ed. Chichester, UK: Wiley-Blackwell.

McGreevy, P. D., McLean, A. N., Buckley, P., McConaghy, F., and McLean, C. (2011). How riding may affect welfare: What the equine veterinarian needs to know. *Equine Vet. Educ.* 23, 531–539. doi:10.1111/j.2042-3292.2010.00217.x.

McGreevy, P. D., McLean, A. N., Warren-Smith, A. K., Waran, N. K., and Goodwin, D. (2005). Defining the terms and processes associated with equitation. in *Conference: Proceedings of the 1st International Equitation Science Symposium* (Melbourne), 1–44. Available at: https://www.researchgate.net/publication/289530030_Defining_the_terms_and_processes_associated_with_equitation [Accessed May 14, 2021].

McGreevy, P. D., Warren-Smith, A., and Guisard, Y. (2012). The effect of double bridles and jaw-clamping crank nosebands on temperature of eyes and facial skin of horses. *J. Vet. Behav. Clin. Appl. Res.* 7, 142–148. doi:10.1016/j.jveb.2011.08.001.

McLean, A. N., and Christensen, J. W. (2017). The application of learning theory in horse training. *Appl. Anim. Behav. Sci.* 190, 18–27. doi:10.1016/j.applanim.2017.02.020.

McLean, A. N., and McGreevy, P. D. (2006). Reducing wastage in the trained horse: Training principles that arise from learning theory. in *Proceedings of the 2nd International Equitation Science Symposium* (Milan). Available at: https://www.researchgate.net/publication/289529963 [Accessed April 3, 2021].

McLean, A. N., and McGreevy, P. D. (2010a). Ethical equitation: Capping the price horses pay for human glory. *J. Vet. Behav.* 5, 203–209. doi:10.1016/j.jveb.2010.04.003.

McLean, A. N., and McGreevy, P. D. (2010b). Horse-training techniques that may defy the principles of learning theory and compromise welfare. *J. Vet. Behav. Clin. Appl. Res.* 5, 187–195. doi:10.1016/j.jveb.2010.04.002.

McMiken, D. F. (1990). Ancient origins of horsemanship. *Equine Vet. J.* 22, 73–78. doi:10.1111/J.2042-3306.1990.TB04214.X.

McVey, R. J. (2021). An Ethnographic Account of the British Equestrian Virtue of Bravery, and Its Implications for Equine Welfare. *Anim. 2021, Vol. 11, Page 188* 11, 188. doi:10.3390/ANI11010188.

Mellor, D. J. (2016). Updating Animal Welfare Thinking: Moving beyond the “Five Freedoms” towards “A Life Worth Living.” *Animals* 6, 1–21. doi:10.3390/ani6030021.

Mellor, D. J. (2020). Mouth Pain in Horses: Physiological Foundations, Behavioural Indices, Welfare Implications, and a Suggested Solution. *Animals* 10, 572. doi:10.3390/ani10040572.

Mellor, D. J., and Beausoleil, N. J. (2015). Extending the “Five Domains” model for animal welfare assessment to incorporate positive welfare states. *Anim. Welf.* 24, 241–253. doi:10.7120/09627286.24.3.241.

Mellor, D. J., Beausoleil, N. J., Littlewood, K. E., McLean, A. N., McGreevy, P. D., Jones, B., et al. (2020). The 2020 Five Domains Model: Including Human–Animal Interactions in Assessments of Animal Welfare. *Anim. 2020, Vol. 10, Page 1870* 10, 1870. doi:10.3390/ANI10101870.

Mendl, M., and Nicol, C. J. (2020). “Learning and Cognition,” in *The Ethology of Domestic Animals An Introductory Text*, ed. P. Jensen (Oxfordshire, UK: CABI International), 63.

Merillat, L. A. (1917). “Animal dentistry and diseases of the mouth Volume I,” in *Veterinary Surgery* (Chicago: Alexander Eger), 214–215. doi:10.5962/bhl.title.56458.

Mills, D. S., and Marchant-Forde, J. N. (2010). *The encyclopedia of applied animal behaviour and welfare*. , eds. D. . Mills, J. N. Marchant-Forde, D. B. Morton, C. J. . Phillips, P. D. McGreevy, C. J. Nicol, et al. Oxfordshire, UK: CABI.

Minero, M., Dalla Costa, E., Dai, F., Scholz, P., and Lebelt, D. (2015). AWIN Welfare assessment protocol for horses. 1–80. doi:10.13130/AWIN_HORSES_2015.

Moine, S., Flammer, S. A., de Jesus Maia-Nussbaumer, P., Klopfenstein Bregger, M. D., and Gerber, V. (2017). Evaluation of the effects of performance dentistry on equine rideability: a randomized, blinded, controlled trial. *Vet. Q.* 37, 195–199. doi:10.1080/01652176.2017.1329598.

Nanci, A., and Wazen, R. (2013). “Repair and regeneration of Oral Tissues,” in *Ten Cate’s Oral Histology. Development, Structure and Function (2013)*, ed. A. Nanci (St. Louis, MO: Elsevier, Mosby Inc), 278–340.

Nash, K. R., and Sheridan, D. J. (2009). Can one accurately date a bruise? State of the science. *J. Forensic Nurs.* 5, 31–37. doi:10.1111/J.1939-3938.2009.01028.X.

National Equine Competence Association of Finland (2017). Hevostalous lukuina 2017 (Transl. The Horse Industry by The Numbers). Ypäjä: Hippolis Available at: https://www.hippos.fi/uploads/sites/1/2021/03/0f7c7020-hevostalous_lukuina_2017_lopullinen.pdf [Accessed February 28, 2022].

National Equine Competence Association of Finland (2019). Hevostalous lukuina 2019 (Transl. The Horse Industry by the Numbers). Ypäjä Available at: https://www.hippos.fi/uploads/sites/1/2021/03/f928d5f8-hevostalous_lukuina_2019_.pdf [Accessed March 21, 2021].

Neumann, M., Edelhäuser, F., Tauschel, D., Fischer, M. R., Wirtz, M., Woopen, C., et al. (2011). Empathy decline and its reasons: A systematic review of studies with medical students and residents. *Acad. Med.* 86, 996–1009. doi:10.1097/ACM.0b013e318221e615.

Norring, M., Wikman, I., Hokkanen, A.-H., Kujala, M. V, and Hänninen, L. (2014). Empathic veterinarians score cattle pain higher. *Vet. J.* 2014, 186–190. doi:10.1016/j.tvjl.2014.02.005.

Odberg, F. O., and Bouissou, M. F. (1999). The development of equestrianism from the baroque period to the present day and its consequences for the welfare of horses. *Equine Vet. J. Suppl.*, 26–30. doi:10.1111/j.2042-3306.1999.tb05152.x.

Odelros, E., and Wattle, O. (2018). Influence of racing on oral health in Standardbred trotters. Abstract. in *Poster presentation, Nordic Equine Veterinary Congress, (2018)* (Bergen, Norway).

OIE - World Organisation for Animal Health (2021). Animal Welfare. Available at: https://www.oie.int/en/what-we-do/animal-health-and-welfare/animal-welfare/ [Accessed July 31, 2021].

Oskarsson, E. (2016). Sår i mungiporna - den skamliga åkomman. *Hippson*. Available at: https://www.hippson.se/artikelarkivet/veterinar/sar-i-mungiporna-den-skamliga-akomman.htm [Accessed January 21, 2022].

Pearce, C. J. (2020). Recent developments in equine dentistry. *N. Z. Vet. J.* 68, 178–186. doi:10.1080/00480169.2020.1722971.

Pearson, G., Reardon, R., Keen, J., and Waran, N. (2020). Difficult horses – prevalence, approaches to management of and understanding of how they develop by equine veterinarians. *Equine Vet. Educ.* 33, 522–530. doi:10.1111/eve.13354.

Pehkonen, J., Karma, L., and Raekallio, M. (2019). Behavioral Signs Associated With Equine Periapical Infection in Cheek Teeth. *J. Equine Vet. Sci.* 77, 144–150. doi:10.1016/J.JEVS.2019.03.005.

Pence, P. (2002). *Equine Dentistry: A Practical Guide*. , ed. D. Troy Baltimore, Philadelphia: Lippincott Williams & Wilkins.

Piccolo, L., and Kienapfel, K. (2019). Voluntary rein tension in horses when moving unridden in a dressage frame compared with ridden tests of the same horses—a pilot study. *Animals* 9, 1–10. doi:10.3390/ani9060321.

Pierard, M., Hall, C., König von Borstel, U., Averis, A., Hawson, L. A., McLean, A. N., et al. (2015). Evolving protocols for research in equitation science. *J. Vet. Behav. Clin. Appl. Res.* 10, 255–266. doi:10.1016/j.jveb.2015.01.006.

Preuschoft, H., Witte, H., Recknagel, S., Bär, H., Lesch, C., and Wüthrich, M. (1999). Über die Wirkung gebräuchlicher Zäumungen auf das Pferd. *Dtsch. Tieratzliche Wochenschrift* 106, 167–175.

Prkachin, K. M., Mass, H., and Mercer, S. R. (2004). Effects of exposure on perception of pain expression. *Pain* 111, 8–12. doi:10.1016/j.pain.2004.03.027.

Raekallio, J. (1972). Determination of the age of wounds by histochemical and biochemical methods. *Forensic Sci.* 1, 3–16. doi:10.1016/0300-9432(72)90144-6.

Reger, S., Ranganathan, V., Orsted, H., Ohura, T., and Gefen, A. (2010). Shear and friction in context. London: Wounds International Available at: https://www.woundsinternational.com/resources/details/international-review-pressure-ulcer-prevention-pressure-shear-friction-and-microclimate-context [Accessed January 15, 2021].

Ressel, L., Hetzel, U., and Ricci, E. (2016). Blunt Force Trauma in Veterinary Forensic Pathology. *Vet. Pathol.* 53, 941–961. doi:10.1177/0300985816653988.

Russell, M. (1893a). How "pullers" are made- A study of methods of bitting the colt. *San Fr. Call* 75, 15. Available at: https://cdnc.ucr.edu/?a=d&d=SFC18931217.2.145&e=-------en--20--1--txt-txIN--------1 [Accessed July 13, 2020].

Russell, M. (1893b). The Bearing Rein. *San Fr. Call* 74, 11. Available at: https://cdnc.ucr.edu/?a=d&d=SFC18930917.2.150&e=-------en--20--1--txt-txIN--------1 [Accessed July 13, 2020].

Salem, S. E., Townsend, N. B., Refaai, W., Gomaa, M., and Archer, D. C. (2017). Prevalence of oro-dental pathology in a working horse population in Egypt and its relation to equine health. *Equine Vet. J.* 49, 26–33. doi:10.1111/EVJ.12533.

Schuurman, N. (2015). Conceptions of Equine Welfare in Finnish Horse Magazines. *Soc. Anim.* 23, 250–268. doi:10.1163/15685306-12341268.

Scofield, R., and Randle, H. (2013). Preliminary comparison of behaviors exhibited by horses ridden in bitted and bitless bridles. *J. Vet. Behav.* 8, e20–e21. doi:10.1016/J.JVEB.2012.12.046.

Scoggins, R. D. (2001). Bits, Bitting and Dentistry. in *Proceedings of the Annual Convention of the AAEP (2001)* (San Diego, Usa), 138–151.

Sewell, A. (1877). *Black Beauty His Grooms and Companions, The Autobiography of a Horse*. London, UK: Jarrold & Sons.

Sheridan, D. J., and Nash, K. R. (2007). Acute Injury Patterns of Intimate Partner Violence Victims: *Trauma Violence Abus.* 8, 281–289. doi:10.1177/1524838007303504.

Simon, T., and Herold, I. (2014). *Dentisterie Équine*. Courbevoie, France: Les Editions du point Vétérinaire.

Starling, M. J., McLean, A. N., and McGreevy, P. D. (2016). The Contribution of Equitation Science to Minimising Horse-Related Risks to Humans. *Animals* 6, 15. doi:10.3390/ani6030015.

Svensk Ridsportförbundet (2020). Svenska Ridsportförbundets veterinärmedicinska graderingar och rekommenderade tävlings-uppehåll samt startförbud enligt TR I vid påvisade bett-/betselskador i munhålan på häst. *Munstegen*. Available at: https://www.ridsport.se/tavling/hastvalfard/Munkollen/Munstegen?epslanguage=sv [Accessed January 21, 2022].

Takahashi, M., Black, J., Dealey, C., and Gefen, A. (2010). Pressure in context. London Available at: https://www.woundsinternational.com/resources/details/international-review-pressure-ulcer-prevention-pressure-shear-friction-and-microclimate-context [Accessed January 15, 2021].

Taylor, J. (2022). *"I can't watch anymore" An open letter to the IOC*. Copenhagen, Denmark: Epona Media.

Taylor, W. T. T., Bayarsaikhan, J., Tuvshinjargal, T., Bender, S., Tromp, M., Clark, J., et al. (2018). Origins of equine dentistry. *Proc. Natl. Acad. Sci.* 115, E6707–E6715. doi:10.1073/PNAS.1721189115.

Telatin, A. (2017). Knowledge and Practical Application of Learning Theory in Equine Training. Available at: https://etd.adm.unipi.it/theses/available/etd-12142017-142522/unrestricted/AngeloTelatinPhDThesis.pdf [Accessed March 23, 2021].

Tell, A., Egenvall, A., Lundström, T., and Wattle, O. (2008). The prevalence of oral ulceration in Swedish horses when ridden with bit and bridle and when unridden. *Vet. J.* 178, 405–410. doi:10.1016/j.tvjl.2008.09.020.

Textor, J., van der Zander, B., Gilthorpe, M. S., Liśkiewicz, M., and Ellison, G. T. (2016). Robust causal inference using directed acyclic graphs: The R package "dagitty." *Int. J. Epidemiol.* 45, 1887–1894. doi:10.1093/ije/dyw341.

Toft, K., Kjeldsen, S. T., Otten, N. D., van Galen, G., Fjeldborg, J., Sinding, M., et al. (2020). Evaluation of Dynamic Structural Disorders in the Upper Airways and Applied Rein Tension in Healthy Dressage Horses During Riding in Different Gaits and Head–Neck Positions. *J. Equine Vet. Sci.* 87, 102934. doi:10.1016/J.JEVS.2020.102934.

Uldahl, M., and Clayton, H. M. (2019). Lesions associated with the use of bits, nosebands, spurs and whips in Danish competition horses. *Equine Vet. J.* 51, 154–162. doi:10.1111/evj.12827.

Union Européenne du Trot (2018a). Annual report 2018. *2018 Annu. Rep.* Available at: https://www.uet-trot.eu/images/pdf-uet/en/publications/uet_annual_report.pdf.

Union Européenne du Trot (2018b). Règlementation de l'UET relative au bien-être animal, Suisse. *Règlementation l'UET Relat. au bien-être Anim. Suisse*, 21. Available at: https://www.uet-trot.eu/images/pdf-uet/fr/animal_welfare/suisse.pdf [Accessed July 3, 2020].

Union Européenne du Trot (2019). Annual report 2019. Available at: https://www.uet-trot.eu/images/pdf-uet/en/publications/uet_annual_report.pdf [Accessed July 3, 2020].

Union Européenne du Trot (2021a). UET animal welfare regulation, Finland. Available at: https://www.uet-trot.eu/images/pdf-uet/en/animal_welfare/finland.pdf [Accessed July 16, 2021].

Union Européenne du Trot (2021b). UET animal welfare regulation,Germany. 5. Available at: https://www.uet-trot.eu/images/pdf-uet/en/animal_welfare/germany.pdf [Accessed July 16, 2021].

Viksten, S. M. (2016). Improving Horse Welfare through Assessment and Feedback. Available at: https://hastsverige.se/content/uploads/2018/06/viksten-sm-160814.pdf [Accessed July 23, 2021].

Visser, E. K., Neijenhuis, F., de Graaf-Roelfsema, E., Wesselink, H. G. M., de Boer, J., van Wijhe-Kiezebrink, M. C., et al. (2014). Risk factors associated with health disorders in sport and leisure horses in the Netherlands. *J. Anim. Sci.* 92, 844–855. doi:10.2527/JAS.2013-6692.

Wageningen UR Livestock Research (2012). Welfare monitoring system : assessment protocol for horses Version 2.0. Lelystad Available at: https://edepot.wur.nl/238619 [Accessed July 24, 2021].

Wang, P.-H., Huang, B.-S., Horng, H.-C., Yeh, C.-C., and Chen, Y.-J. (2018). Wound healing. *J. Chinese Med. Assoc.* 81, 94–101. doi:10.1016/j.jcma.2017.11.002.

Warren-Smith, A. K., Curtis, R. A., Greetham, L., and McGreevy, P. D. (2007). Rein contact between horse and handler during specific equitation movements. *Appl. Anim. Behav. Sci.* 108, 157–169. doi:10.1016/j.applanim.2006.11.017.

Warren-Smith, A. K., and McGreevy, P. D. (2008). Equestrian coaches' understanding and application of learning theory in horse training. *Anthrozoos* 21, 153–162. doi:10.2752/175303708X305800.

Weller, D., Franklin, S., White, P., Shea, G., Fenner, K., Wilson, B., et al. (2021). The Reported Use of Tongue-Ties and Nosebands in Thoroughbred and Standardbred Horse Racing—A Pilot Study. *Animals* 11, 622. doi:10.3390/ani11030622.

Wilmink, J. M., Stolk, P. W. T., Weeren, P. R., and Barneveld, A. (1999). Differences in second-intention wound healing between horses and ponies: macroscopic aspects. *Equine Vet. J.* 31, 53–60. doi:10.1111/j.2042-3306.1999.tb03791.x.

Woolf, C. J. (2004). Pain:moving from symptom control toward mechanism-specific pharmacologic management. *Ann. Intern. Med.* 140, 441–451. doi:10.7326/0003-4819-140-8-200404200-00010.

Youtt, W. (1831). *The Horse with a Treatise on Draught*. First edit. London: Baldwin & Cradock doi:10.5962/bhl.title.28539.

Zulkifli, I. (2013). Review of human-animal interactions and their impact on animal productivity and welfare. *J. Anim. Sci. Biotechnol. 2013 41* 4, 1–7. doi:10.1186/2049-1891-4-25.

I

frontiers in Veterinary Science

ORIGINAL RESEARCH
published: 12 July 2019
doi: 10.3389/fvets.2019.00206

Oral Lesions in the Bit Area in Finnish Trotters After a Race: Lesion Evaluation, Scoring, and Occurrence

Kati Tuomola[1], Nina Mäki-Kihniä[2], Minna Kujala-Wirth[3], Anna Mykkänen[4] and Anna Valros[1]*

[1] Department of Production Animal Medicine, Research Centre for Animal Welfare, University of Helsinki, Helsinki, Finland, [2] Independent Researcher, Pori, Finland, [3] Department of Production Animal Medicine, Faculty of Veterinary Medicine, University of Helsinki, Helsinki, Finland, [4] Department of Equine and Small Animal Medicine, Faculty of Veterinary Medicine, University of Helsinki, Helsinki, Finland

OPEN ACCESS

Edited by:
Jessica Gimpel,
Pontifical Catholic University of Chile, Chile

Reviewed by:
Tamara Alejandra Tadich,
Universidad de Chile, Chile
Lesley Ann Hawson,
Harness Racing Victoria, Australia

***Correspondence:**
Kati Tuomola
kati.tuomola@helsinki.fi

Specialty section:
This article was submitted to Animal Behavior and Welfare, a section of the journal Frontiers in Veterinary Science

Received: 27 February 2019
Accepted: 11 June 2019
Published: 12 July 2019

Citation:
Tuomola K, Mäki-Kihniä N, Kujala-Wirth M, Mykkänen A and Valros A (2019) Oral Lesions in the Bit Area in Finnish Trotters After a Race: Lesion Evaluation, Scoring, and Occurrence. Front. Vet. Sci. 6:206. doi: 10.3389/fvets.2019.00206

Oral lesions in the bit area are common in horses, but not comprehensively studied in harness racing horses. This study describes the type and occurrence of oral soft tissue lesions in the area affected by the bit, hereafter called the bit area, in trotters after a race. Based on our results, we suggest a system for scoring lesions according to size, type (bruise or wound), age, and depth (superficial or deep). The data was collected during a welfare program for trotters, conducted by The Finnish Trotting and Breeding Association (Suomen Hippos ry). The rostral part of the mouth of 261 horses (151 Standardbreds, 78 Finnhorses, and 32 ponies) was examined after a race in a systematic manner, using a bright light source without sedation or a mouth gag. The lip commissures (outside and inside), bars of the mandible, buccal area near the second upper premolar teeth, tongue, and hard palate were visually examined; bars of the mandible were also palpated. Points were assigned to every lesion and then added together, such that each horse got an acute lesion score. Based on the score, the horses were divided into four groups (A—D) as follows: Group A, no lesions; B, mild lesions; C, moderate lesions; D, severe lesions. Of all the horses examined, 84% (219/261) had acute lesions in the bit area. In total, 21% (55/261) had mild lesions, 43% (113/261) had moderate lesions, and 20% (51/261) had severe lesions. Visible bleeding outside the mouth was observed in 2% (6/261) of the horses. Further, 5% of the horses (13/261) had blood on the bit when it was removed from the mouth, even though no blood was visible outside the mouth. In conclusion, soft tissue lesions in the bit area were common in the Finnish trotters examined. Moreover, the absence of blood outside the mouth does not rule out serious injuries inside the mouth. The scoring system presented can be used for evaluating the severity of oral lesions in different equestrian disciplines and populations to allow for comparable data across studies.

Keywords: animal welfare, bit, harness racing, horse, oral lesion, trotter

INTRODUCTION

Bit-related oral lesions cause pain, and are a commonly reported welfare problem for horses (1–4). Odelros and Wattle (5) reported acute soft tissue injuries in the rostral mouth in 88% (127/144) of Standardbred trotters examined in Sweden. Previous studies have also reported oral lesions in other equestrian disciplines, but dissimilar scoring systems make comparisons between studies challenging. In a study of Icelandic horses at competitions in Iceland, Björnsdottir et al. (1) reported 36% of horses with mild (up to 1 cm) lesions, and 8% with lesions that were more severe (over 1 cm) before the competition. Of these 424 horses, 77 were re-examined after the race. Bit-related lesions were found in 60%. Notably, if the horse had more than one lesion, only the most severe one was included in their data. In a study of polo and racehorses (n = 100) in England, Mata et al. (4) used a grading system from 0 to 5 to evaluate lip commissure and bar injuries, and another grading system to evaluate tongue injuries. In Denmark, Uldahl and Clayton (6) examined 3,143 horses from various disciplines after a competition performance (show jumping, dressage, eventing, and endurance). In total, 9.2% of the horses had lesions or visible bleeding from the mouth. However, only the corners of the mouth were examined, not the oral cavity. Lacerations of the skin and mucosa, as well as the presence of blood on the skin and mucosa were reported separately, but the four outcomes were combined into a single category for analysis.

Tell et al. (7) concluded that riding a horse with a bit and bridle can cause lesions to the oral cavity. However, they noted that oral lesions were also present in broodmares that were not regularly ridden with a bit, although to a lesser extent compared to those ridden with a bit. In this study, ulcers more than 0.5 cm in diameter were considered as large.

There have been various methods for lesion examination. After competition, Icelandic horses, polo horses, and racehorses have been examined without sedation or a mouth gag. Sedation was also not used when examining trotters in Sweden after competition, however a mouth gag and a light source was used, along with flushing the mouth with water (1, 4, 5). Tell et al. (7) performed the examination on sedated horses with a mouth gag and a light source. This examination was not related to competitions.

According to the Finnish racing guidelines, official race track veterinarians should only examine the horses after a competition if they show bleeding from the mouth. However, there is no information about the oral health of horses that do not show bleeding from the mouth after a race.

The lesion grading systems used in earlier studies are all unique to each study, and none of them account for the number, depth, and size of the lesions. We thus believe that a quick oral examination, which can be performed in the field environment and a simple, practical, and objective scoring system that includes both the number and severity of the lesions is needed to allow for more accurate comparisons among studies. Our aim was to create such a scoring system, and apply it to determine the occurrence, location, type (bruise or wound), size, depth (superficial or deep), and age (old or acute injury) of oral lesions in the bit area in a sample of trotters racing in Finland.

MATERIALS AND METHODS

Horses

The Finnish Trotting and Breeding Association (Suomen Hippos ry) is responsible for licensing trainers, drivers, and officials, as well as creating and monitoring the racing rules. Since this study was part of the association's welfare program for trotters, the oral examination performed after the race was compulsory. The horses (n = 261) were privately owned trotters that participated in 10 separate harness racing events (115 races) at four race tracks in Western Finland (Pori, Tampere, Forssa, and Turku). Standardbred trotters (n = 151), Finnhorses (n = 78), and ponies (n = 32) ranging in age from 3 to 15 years old were included in the study. Six of the Finnhorses participated to the monté race and all other horses participated into ordinary harness races.

Initially, the horses were randomly selected from the starting lists, however practical constraints were taken into account in order to maximize the number of horses examined in the limited time after finishing the race performance. The horses evaluated in previous races were excluded so that none was evaluated more than once. The horses which were resisting the examination were excluded from the study. We later checked whether the horses competed again within 2 weeks.

Oral Examination

The horses were examined 5–20 min after the race at their outdoor harnessing booth in the warm–up area. The rostral part of the oral cavity was evaluated by the first author of this study, who is a veterinarian experienced in oral examination of horses. The examination, which was modified from the one used in Icelandic horses (1), was carried out without sedation or a mouth gag; the horse was without the bridle, and wearing only its own halter. During the examination, the veterinarian wore disposable nitrile gloves and a Lumonite Navigator 3000 headlamp set at 420–1,300 lumens. The examination began with the examiner standing on the left side of the horse. The tongue was externally guided to the left side, allowing evaluation of the buccal mucosa near the second upper premolar tooth (106) and the mucosa at the inside of the lip commissure, on the contralateral (right) side. The tongue and palate were examined visually. If a sharp hook in 106 or 206 teeth was noticed while examining the buccal area near those teeth, it was recorded and the trainer was informed, but otherwise we could not palpate and examine sharp enamel points without mouth gag. Finally, the left bar area was palpated, and the left external commissure of the lips (the outside skin area) was examined. The same procedure was repeated on the right side of the horse (**Video 1** in Supplementary Material). Video recordings of some of the typical lesions were taken with a digital camera (Panasonic DMC-GX7). An assistant recorded the findings of the oral examination and the bit type on a data sheet, which was a modified version of a former Vet Form 2 from the International Federation of Icelandic Horse Associations (**Data Sheet 1** in Supplementary Material).

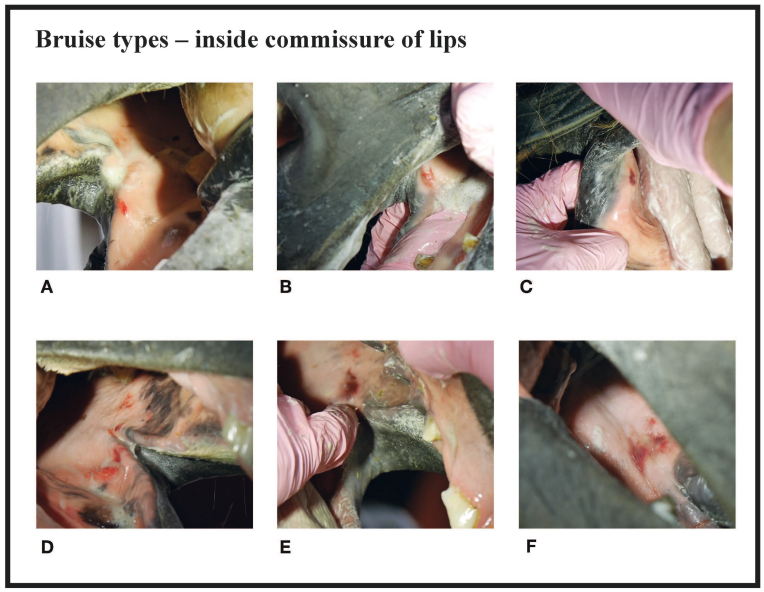


FIGURE 1 | Bruise types and their points at the inside commissure of the lips. **(A)** 1 point, **(B)** 2 points, **(C)** 2 points, **(D)** 3 points, **(E)** 4 points, **(F)** 4 points.

Lesion Scoring

Since many horses had several lesions, we established a score that considered all lesions in each horse. Points were given for every acute lesion that was detected, then added up to form a total score for the horse. This acute lesion score combines the number, size, quality (bruise or wound), and depth (superficial or deep) of acute lesions. Old lesions were recorded separately. A bruise (syn. contusion, hematoma) was determined as a discoloration of a superficially intact mucosa. Bruises were given points from 1 to 4 according their size (maximum width) as follows: <0.5 cm = 1 point; 0.5−1 cm = 2 points; >1 cm but <3 cm = 3 points; 3 cm or larger = 4 points. A lesion was determined as a wound if the mucosal surface was damaged. Wounds were visually classified as deep if there was extensive damage to the submucosal tissue, or superficial if the damage was less extensive. Wounds were given points from 2 to 8 according to their size as follows: <0.5 cm = 2 points; 0.5−1 cm = 4 points; >1 cm but <3 cm = 6 points; 3 cm or larger = 8 points (**Figures 1–4**). An additional two points were added for deep wounds. Points for each lesion were added together to form the acute lesion score (**Figure 5**).

Many of the lesions were assessed as mixed-type. These lesions were graded according to the most severe lesion type present. For example, if a bruise and a wound were present in the same lesion, the lesion was graded as a wound (**Figure 2C**). If an old and an acute lesion were present in the same lesion, the lesion was graded as acute. If the wound borders were depigmentated (**Figures 3B,C**) or wound margins were thickened (**Figure 2B**)—both signs of an old and chronic lesion—but if the wound was red or pink and not fully healed, the lesion was graded as an acute lesion. In some cases, a wound at the bars of the mandible was accompanied by swelling (**Figures 4B,C**). We did not systematically record redness and swelling at the bars, but we noted both in some horses without bruises or wounds.

The horses were divided into four groups (A—D) according to their acute lesion score as follows: Group A (no acute lesions) = horses with 0 points; Group B (mild lesions) = horses with 1–2 points; Group C (moderate lesions) = horses with 3–11 points (although this excluded horses with eight points for a single lesion); Group D (severe lesions) = horses with 12 or more points (including horses with eight points for a single lesion).

Old Lesions

The number and type (depigmentation, old wound, old bruise or scar) of old lesions were recorded, but not included in the acute lesion score. The size of old lesions was not recorded. A bruise was evaluated as old if the red color was faded. Depigmentation (acquired leukoderma or hypopigmentation) of the outside commissures of the lips was recorded. This lack of dark pigment at the lip commissures is caused by previous inflammation or prolonged pressure from the bit (8, 9) (**Figure 6**).

Bleeding

Visible blood outside the mouth, on the wound, or on the bit was recorded, but not included in the acute lesion score.

Photographs

Early in the study, we noticed that it is difficult to take oral photographs of horses when they are out of breath. Therefore,

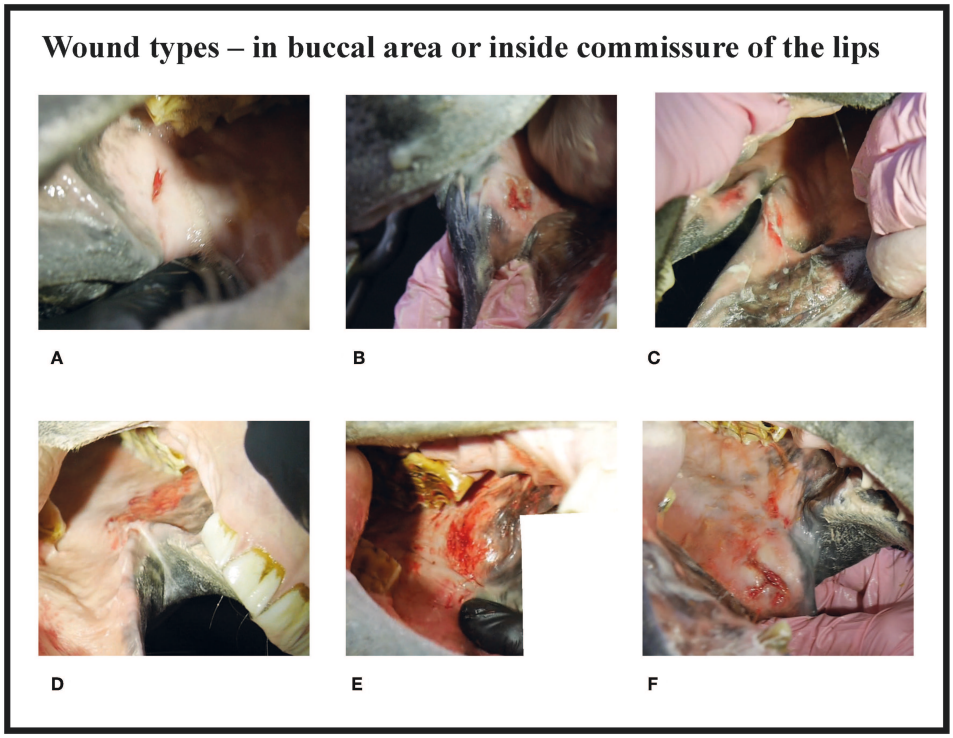


FIGURE 2 | Wound types and their points in buccal area or inside commissure of the lips. **(A)** 4 points, **(B)** 6 points, **(C)** 6 points, **(D)** 8 points, **(E)** 10 points, **(F)** 10 points.

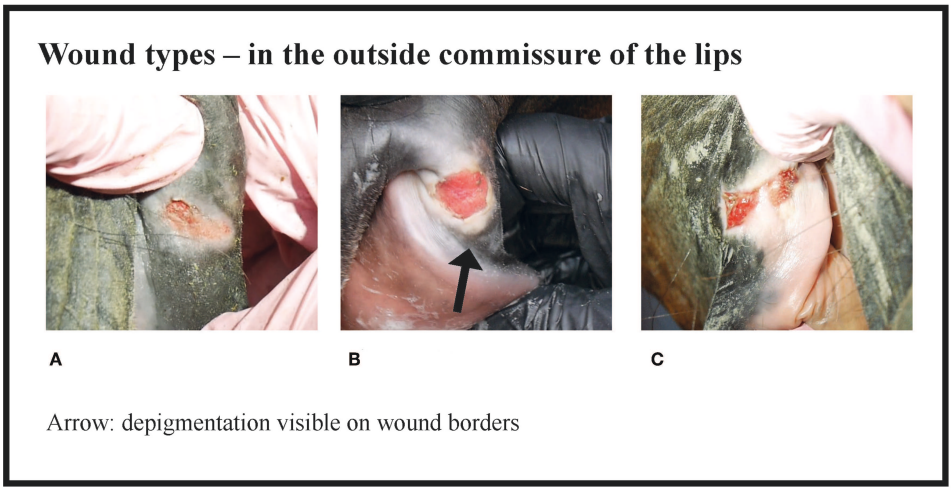


FIGURE 3 | Wound types and their points in the outside commissure of the lips. **(A)** 6 points, **(B)** 6 points, **(C)** 8 points.

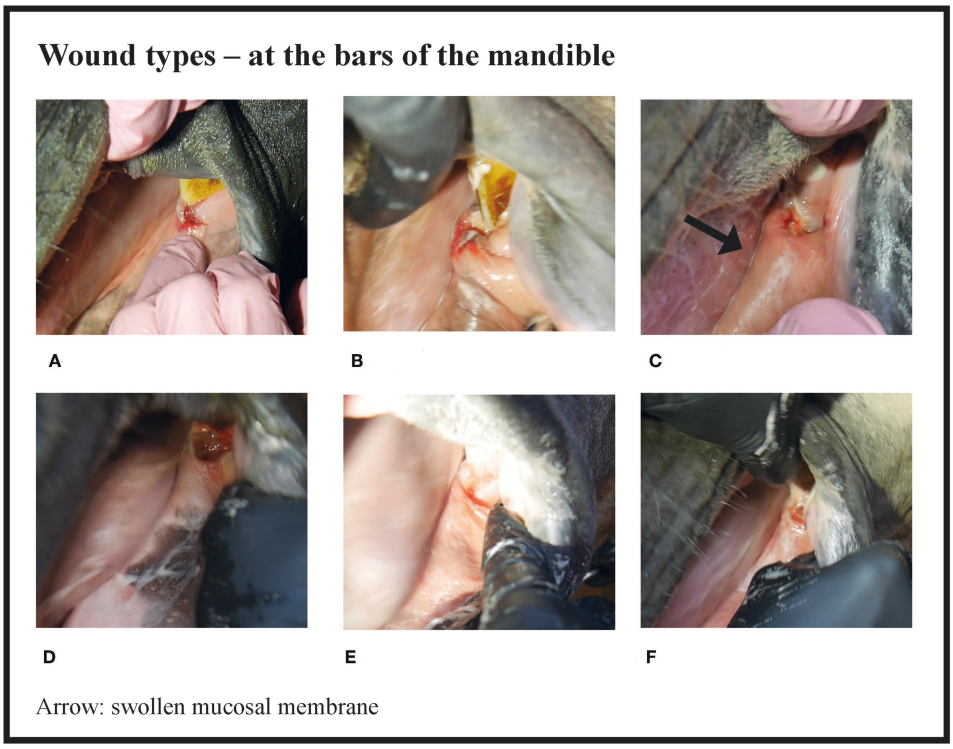


FIGURE 4 | Wound types and their points at the bars of the mandible. **(A)** 4 points, **(B)** 6 points, **(C)** 8 points, **(D)** 8 points, **(E)** 8 points, **(F)** 8 points.

video recordings (Panasonic DMC-GX7; lens H-FS14140, 14–140; settings: STD, MP4, 1,920 × 1,080 50 p 28 Mbps, recording mode: M (movie), exposure: P, light metering method: multiple, automatic focusing ON, optical zoom only) of the typical lesions were taken for lesion severity scale documentation purposes. From the video files, a focused frame was saved as a JPG image file using a video editing software (Adobe Premiere Pro CC 2017).

Statistical Analysis

Statistical analyses (mean, min, max, standard deviation) were performed with Stata IC version 15 (Stata Corporation, Texas, Usa) and Microsoft Office Excel 2007.

RESULTS

Only 12% (32/261) of all the horses examined had no acute or old mucosal lesions in the bit area, while 84% (219/261) had acute lesions in the bit area and 4% (10/261) had only old lesions. Among the 261 horses, 147 (56%) had more than one lesion (**Figure 7**). The highest number of acute lesions observed in an individual horse was six. The most common number of lesions was two. In total, 528 lesions were recorded, 452 of which were graded as acute in the bit area. During the race, single-jointed bits were the most common bit type (75%, 195/261 horses), followed by a straight bit type (18%, 48/261) and a double-jointed bit type (7%, 18/2019). The number of horses examined in this study represents 3.6% of all the trotters ($n = 7{,}261$) that competed in 2017 in Finland (10).

There were no acute lesions in 16% (42/261) of the horses (Group A). We found that 21% (55/261) of the horses had mild lesions (Group B), which meant they either had a 1 cm bruise or two bruises <0.5 cm (**Figures 1A–C**). 43% (113/261) had moderate lesions (Group C), and 20% (51/261) had severe lesions (Group D) (**Figure 8**). Group D included, for example, a horse with a single 3 cm or larger superficial wound (**Figure 2D**), a horse with a single deep wound larger than 1 cm (**Figure 4D**), and a horse with a single 1 cm bruise, a single 3 cm bruise and a single wound larger than 1 cm (**Figures 1C,E, 3A**). Acute lesion scores ranged from 0 to 36 (**Figure 9**). Among all horses, the mean acute lesion score was 5.6 (SD 5.6).

Lesion Types

Bruises and Wounds

In the bit area, 70% (182/261) of the horses had bruises, and 40% (104/261) had wounds (**Figure 10**). The wounds had different

Scoring of oral lesions

1. Estimate size of lesion
2. Estimate type of lesion
3. See score at intersection
4. Estimate depth of wound

SIZE OF LESION in mm	chart code	TYPE OF LESION: Bruise	Wound	Wound: superficial or deep?
		B	W	DEEP
< 5 mm	1	1	2	if deep, add +2 to W points
≤ 1 cm	2	2	4	
< 3 cm	3	3	6	
≥ 3 cm	4	4	8	

SCORING OF THE LESION BASED ON SIZE AND TYPE

FIGURE 5 | Scoring of oral lesions. Points for each acute lesion are added together to form the acute lesion score.

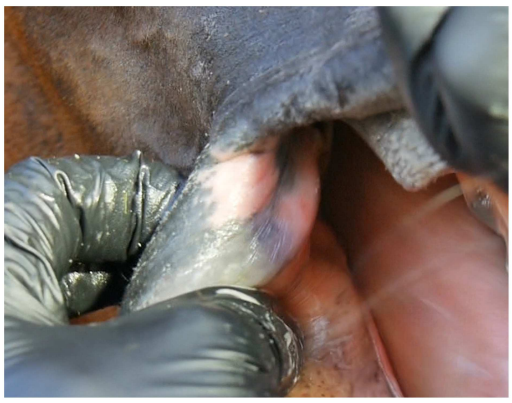


FIGURE 6 | Depigmentation in the outside commissure of the lips. Plain depigmentation without scarring and thickening of the skin.

appearances. The most common type was *abrasion*, a superficial injury to the mucosa (**Figure 2D**). Other types were *laceration*, a full thickness injury to the mucosa characterized by tearing of the tissue (**Figure 4D**), and *incision*, a clean cut wound longer than its width (**Figure 2A**). Deep wounds had a crater-like appearance (**Figures 4B–F**) or extensive damage to the submucosal tissue (**Figures 2E,F**).

Old Lesions

We found old lesions in 16% (41/261) of the horses, which were characterized by depigmentation on the outside commissures of the lips, scars, old wounds, or old bruises (**Figure 10**). Ten horses (4%) had only old lesions and 31 horses (12%) had old lesions together with acute lesions. The number of old lesions in any single horse ranged from 0 to 3 (**Figure 11**).

Location of Acute Lesions

The most common place for a lesion was the inside commissure of the lips, where 64% of all horses had lesions. The location of lesions is presented in **Figure 12**. In some cases, the lesion extended from the inside commissure of the lips to the buccal area (**Figures 2D–F**). The location of such lesions was recorded as inside commissure of the lips.

Tongue and Hard Palate Lesions

Nine horses had tongue lesions. Four had bitten their tongue (1.5%), three had bruises under the tongue (1.1%), and two

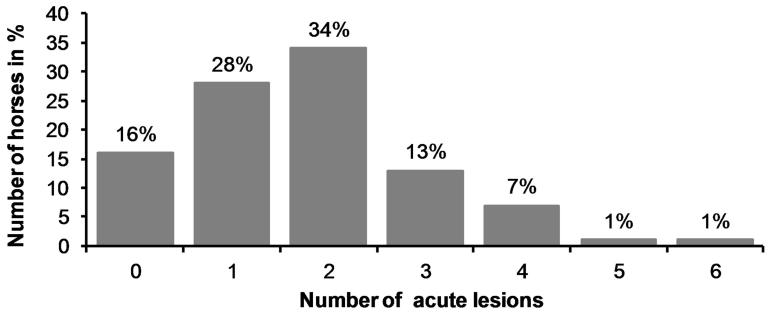


FIGURE 7 | Number of acute lesions in all horses.

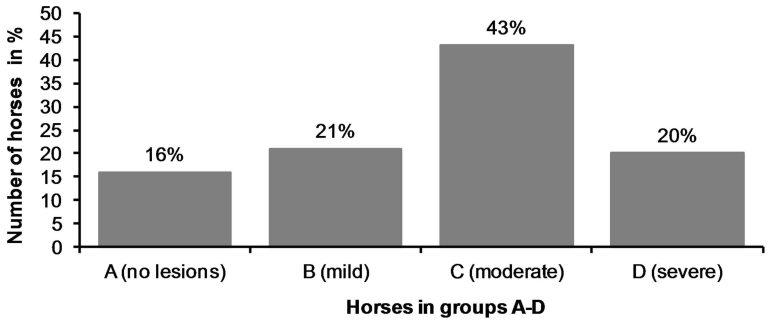


FIGURE 8 | The horses ($n = 261$) were divided in four different groups (A—D) according to their acute lesion score.

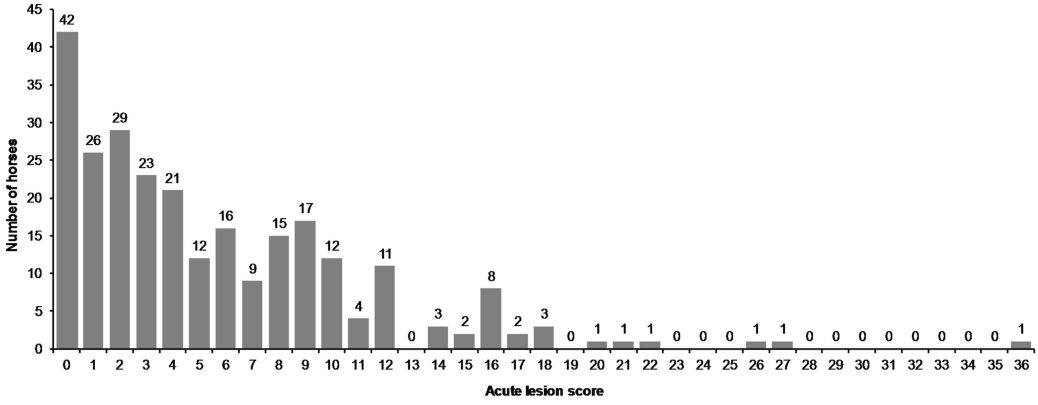


FIGURE 9 | Acute lesion scores in all horses.

had bruises at the sides of the tongue (0.8%). Only one horse (0.4%) had a small lesion in the hard palate. Tongue and hard palate lesions ($n = 10$) were not included in the acute lesion score in this study because these lesions were located so that they were not probably related to the bit.

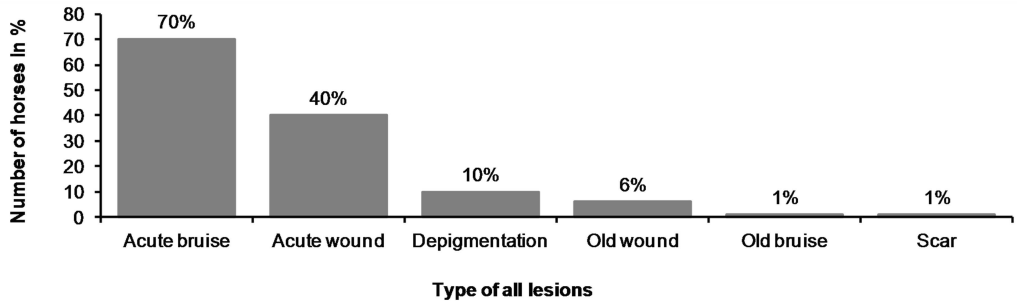


FIGURE 10 | Type of the lesions in horses.

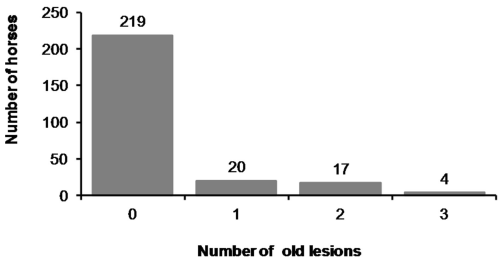


FIGURE 11 | Number of old lesions.

Teeth

Ten horses (3.8%) had a sharp beak in 106 or 206 teeth and in five of the horses the beak may have caused worsening of the lesion (**Figure 2E**). In the five other horses the lesion was not adjacent to the beak.

Bleeding

Blood was visible outside the mouth in 2% (6/261) of the horses. One of these horses had bitten its tongue. In 5% (14/261) of the horses, blood was visible on the bit once removed from the mouth, but blood was not visible on the outside of the mouth. Blood was visible on the wound in the mouth in 5% (13/261) of the horses, but not on the bit nor outside the mouth. Two of the three horses excluded from the study had blood on the bit. For those horses with blood on the outside of the mouth, the mean acute lesion score was 15.2 (min 10, max 21, SD 4.4), and for those with blood on the bit, the mean score was 12.7 (min 6, max 26, SD 5.8). Among all the horses, the mean lesion score was 5.6 (min 0, max 36, SD 5.6). Of the 14 horses with blood on the bit, 10 had severe lesions (Group D), and four had moderate lesions (Group C). Of the six horses with blood outside the mouth, five had severe lesions (Group D) and one had moderate lesions (Group C). The horse with the moderate lesions had bitten the tip of its tongue, which caused the bleeding. The three horses that got highest points (22, 27, and 36) did not have blood anywhere.

Timing of the Next Race Performance

In total, 20% of the horses (51/261) had severe lesions (Group D). Of those, 65% (33/51) competed again within 2 weeks, 13 competed within 1 week, and two competed again the following day.

DISCUSSION

We found a high occurrence of oral lesions in Finnish trotters examined. Over half of the horses (56%) had more than one acute lesion in the bit area. In fact, many had three to four lesions, and in some cases, as many as five or six. This scoring system enables an accurate evaluation of overall damage to the oral structures in the bitting area. In this respect, our method differs from previous studies on Icelandic horses, where the score was based only on the most severe lesion detected (1).

The horses were divided into four groups on the basis of their acute lesion score. Group A included horses with depigmentation of the corners of the lips, and/or an old scar or bruise, but without acute lesions considered to cause acute pain. Group B included horses with mild lesions that might potentially cause discomfort or pain, but would likely heal quickly, and therefore have minor significance for the welfare of the animal. In contrast, Group D included horses with either multiple lesions or large and deep lesions that likely cause considerable pain and heal slowly. The cut-off value for Group D was selected to include the horses with the most severe and potentially most painful damage. Group C included moderately affected horses. However, some horses with potentially painful injuries fell into Group C, such as the horse in **Figure 3B**. In the study of Icelandic horses, a lesion was graded as severe if it was an ulcer larger than 1 cm in diameter, with inflammation and/or soreness of the mucosa, or prominent thickening of the bars (1). In our study, some of the horses with superficial wounds larger than 1 cm fell into the moderate group (Group C), but if the horse had a deep 1 cm wound or multiple moderate lesions it fell into the severe group (Group D).

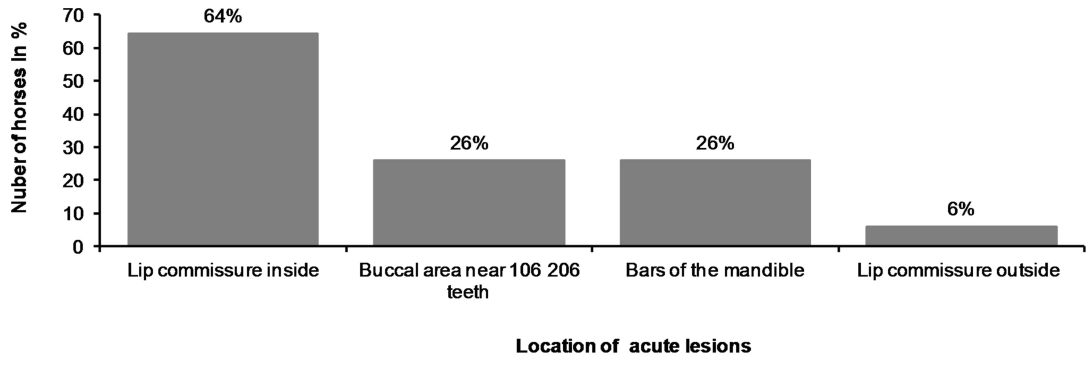


FIGURE 12 | Location of acute lesions in all horses.

Thus, in our study, both Groups C and D include horses with potential welfare problems, but the most severe cases are reflected in Group D.

Our examination method is not a substitute for a full oral or dental examination where sedation, mouth gag, and mirror are essential. Nevertheless, this quick and practical technique allows information to be acquired regarding the rostral part of the oral cavity that is potentially affected by the bit. During the examination, the horses experienced a slight and brief inconvenience while their tongue was being held. In the study by Odelros and Wattle (5), the mouth was similarly evaluated without sedation, but with a mouth gag. They flushed the mouth with tap water before the examination, which can improve visibility if the horse has a lot of mucus or food in the mouth.

In our study, 84% of the horses had acute lesions in the bit area after the race performance. This result is similar to a study of Swedish trotters, which reported lesions in 88% of horses (5). In Icelandic horses, 60% had lesions after a competition in 2012. A follow-up study reported 33% in 2014, and 43% in 2016 (1, 2). In our study, 20% of the horses had severe lesions, which is more than in Icelandic horses (8%). However, direct comparison of the results is difficult due to the different grading systems (1).

Of the trotters examined in our study, 6% had acute lesions in the outside commissures of the lips. This result is similar to the 9.2% of riding horses reported in a Danish study (6). Broodmares ($n = 20$) not using a bit did not have lesions in the lip commissures (7), indicating that this type of lesion is likely due to the use of bits. In the study by Mata et al. (4), polo ponies ($n = 50$), and racehorses ($n = 50$) had 15 and 53 commissure ulcerations, respectively. The racehorses had a significantly higher prevalence of commissure damage and a higher severity grading when compared to the polo ponies. Assuming that a horse can have a maximum of two commissure ulcers (one per side), the number of racehorses affected by this type of lesions would have been at least 25%, which is much higher than in our study. We cannot, however, directly compare our results to the Mata et al. (4) study because different grading systems were used and because the prevalence of lesion per horse was not reported and the result may contain both inside and outside commissure lesions.

We found that 26% of the trotters had lesions in the bars of the mandible. This is comparable to the 31% of Icelandic horses that had lesions after a competition (1). On the other hand, in the study by Tell et al. (7) of riding horses and broodmares, no horses had ulceration at the bars ($n = 113$). We found that it was important to examine and palpate carefully the area near the second lower premolar (306, 406), since we noticed that lesions in that area were hard to detect. We did not observe bone spurs or swellings of the bone at the bars of the mandible, but the possibility of these lesion types should be kept in mind when examining the rostral part of the oral cavity (4, 11). In the study by Mata et al. (4), polo ponies ($n = 50$) and racehorses ($n = 50$) had 28 and 30 bone spurs, respectively, in the mandible bars. No other lesions in the bars were mentioned. In future studies, lesion score points could be given for obvious swelling of the mucosa or the bone on the mandible bars.

In our study, 26% of the horses had acute lesions in the buccal area near the maxillary 06 teeth, which is more than in broodmares (5%), but less than regularly ridden horses in Sweden (56%) (7). Some of the buccal lesions and lesions extending from the inner lip commissure to the buccal area may be related to sharp enamel points of 106 and 206 teeth, if present (**Figures 2A,E**). A driver pulling at the reins may cause the mucous membrane to glide over these teeth with increased pressure. However, the majority of the lesions in our study were not near these potentially sharp enamel points, and therefore likely to be related to the bit rather than pressure from sharp enamel points. Doherty et al. (12) have studied noseband tightness in other equestrian sports and they found that only 7% of the horses had a noseband in the two fingers classification, which is the general recommendation. It is possible that sometimes noseband or other trotters' equipment's might press mucosal membranes against the teeth and contribute to lesions, but it has not been studied.

The oral mucosa consists of stratified squamous epithelium (mucosal epithelium) and an underlying connective tissue, called the *lamina propria* (13). Since the mouth is the gateway to the alimentary and respiratory tract, the oral mucosa is densely innervated in order to monitor all entering substances. Free nerve

endings are found in the mucosal epithelium and *lamina propria*. The sensation of pain is initiated by a noxious stimulus, such as a mechanical force causing tissue damage (13, 14). It is thus likely that lesions in the oral mucosa cause pain to the horse. Pain acts as an important protective warning system to minimize tissue damage (14–16). The horse is a flight animal, and its reaction to noxious stimuli is to escape the source (17). After experiencing a painful event, the horse can try to alter its behavior by learning to avoid potentially painful stimuli (16). Many trainers were surprised to learn that their horse had severe lesions. Signs of pain in horses are not always well-recognized, even though pain affects the horses' behavior and facial expressions (18–21). When the signs are frequently witnessed, such as head tossing, mouth opening or tongue lolling, people might begin to regard such abnormal behavior as normal (20). If tissue damage is not prevented, the injured tissue causes inflammatory pain. In this state, sensitivity is increased such that stimuli that would not normally cause pain will cause it. If not treated, inflammatory pain can cause allodynia (reduced threshold to pain) or hyperalgesia (increased response to pain) (14, 15). In this study, we did not evaluate soreness or pain to palpation, since it would have been difficult to evaluate on horses with a high sympathetic tone after a race performance. Interestingly, the two horses with the highest acute lesion scores (27 and 36) were extremely difficult to examine. The horse that received 27 points appeared to have "electric shocks" when its muzzle was touched. Two of the three horses that were too difficult to examine and were excluded from the study, had blood on the bit. We suggest that these difficulties during examination and extraordinary behavior were related to oral pain. Cook and Kibler (3) compared the behavior of 66 horses with and without a bit. The study was based on a questionnaire to riders, who had switched from a bitted to a bit-free bridle. From the answers, 69 pain signals were evaluated, and they noticed a 43−100% reduction in pain signals in 65 horses when ridden without the bit. Minimizing injuries and pain by rapid diagnosis and treatment are a part of the Five Domains of animal welfare (22, 23). Even slight discomfort can cause the horse to focus on the pain rather than on performance (16, 24).

Persistence of the inflammatory response delays wound healing (13). Foreign material in the wound, such as dirt, debris, and sutures can cause an intense inflammatory reaction that interferes with normal wound healing. A bit can be considered as a "foreign material" in the mouth, potentially preventing wound healing (25). On the other hand, profuse blood supply and the moist environment in the mouth enhance wound healing, compared to skin. The time required to replace all the cells in the epithelium has been estimated to be 52−75 days in the skin, 41−57 days in the gingiva, and 25 days in the buccal mucosa (13, 25). Healing of the lesions on the skin on the external lip commissures may therefore take more time. Collagen is deposited rapidly in the wound within 5–20 days, thus increasing tissue tensile strength, although as many as 150 days may be required to regain normal tissue strength (13, 25). In our study, 33 horses with severe lesions competed again within 2 weeks, and it is thus not likely that their lesions were healed completely before the next race. We thus suggest that when lesions, especially severe ones, are recorded, there is a need for careful evaluation of when the horse can be deemed fit for competition again.

The presence of a veterinarian in harness racing events in Finland is regulated by the Animal Welfare Act (26). According to the regulations in place during the preparation of this manuscript (2019), the veterinarian may remove a horse from the race or order an oral examination and a health certificate examination before it is allowed to compete again, if it is noticed that the equipment has damaged the horse (27). However, as we have shown in this study, the absence of blood on the outside of the mouth does not rule out severe lesions inside the mouth. Moreover, it is often suggested that bleeding from the mouth is due to the horse biting its tongue. However, we found that four horses had bitten their tongue and only one horse bled from the tongue.

One explanation for the high occurrence of lesions in harness racing may be the nature of the competition. Typically, 12−16 horses run together for a distance of 1,600−2,600 m. The horses are highly aroused, and the drivers control the horses via reins and bits. Since it is not desirable for the horses to fatigue during warm-up or early in the race, drivers might hold the reins with greater tension. The horses that have been trained to respond to stronger aids may have more oral injuries than horses given lighter aids (4, 28). We did not study the amount of force applied to the reins, but it is recommended in future studies.

One limitation of our study is that the horses were not examined before the race, since we did not want to disturb the competitors. Björnsdottir et al. (1) examined 77 horses before and after the competition. Of these, 43% horses had lesions already before, and 60% after the competition. Specifically in the bar region, however, there was a clear increase (8–31%) of lesions after the competition (1). Based on the acute clinical appearance of the lesions in our study, many were likely to have been acquired during the racing event, either during the warm-up or the actual race. Alternatively, the racing event may have worsened pre-existing lesions.

CONCLUSIONS

In conclusion, soft tissue lesions in the bit area were a common finding after a race performance in Finnish trotters examined. Lesions are easily left unnoticed, since they are inside the mouth and usually do not bleed. Importantly, while blood on the bit is a strong indication that the horse has severe lesions inside the mouth, the absence of blood on the bit and especially outside the mouth does not rule out severe injuries inside the mouth. The scoring system described here is practical, fast, and well-tolerated by the horses, and can be used to evaluate the severity of lesions at the race track. This study paves the way for future work in oral health of trotters.

DATA AVAILABILITY

The datasets for this manuscript are not publicly available because the data was collected during a welfare program for trotters, conducted by The Finnish Trotting and Breeding Association (Suomen Hippos ry).

Requests to access the datasets should be directed to kati.tuomola@helsinki.fi.

ETHICS STATEMENT

The study did not include procedures to animals of a type that requires formal approval from an animal ethics committee. The study was, however, considered ethically acceptable by the University of Helsinki Viikki Campus Research Ethics Committee (Statement 8/2018). The study information was published as an announcement in the national newspaper for trainers (Hevosurheilu) and on the internet page of The Finnish Trotting and Breeding Association (www.hippos.fi) prior to the study. Anonymity of the trainers and drivers was maintained. During the examination, the horses experienced a slight inconvenience when the tongue was held, which lasted no more than 1–2 min. In general, the horses tolerated the examination well. The examination was ceased and the horse was excluded from the study if it was difficult to examine (three out of 264 horses).

AUTHOR CONTRIBUTIONS

KT contributed to the study design, performed the oral examinations, data collection and analysis, and preparation of the manuscript. NM-K recorded all findings, contributed to data collection and analysis, video recordings, and preparation of the manuscript. MK-W, AM, and AV contributed to interpreting the results and preparation of the manuscript. All authors read and approved the final manuscript.

FUNDING

The study was partly funded by Suomen Hippos ry.

ACKNOWLEDGMENTS

The authors would like to thank Suomen Hippos ry and Katja Hautala and Reija Junkkari for making this study possible. We would also like to thank the horse owners and trainers for their interest and positive attitude toward the study, Pirkko Valmari for the advice on the scoring system, Mirjami Miettinen for advice on the oral examination form, Jarno Mäenpää, and Riitta-Mari Tulamo for their assistance.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fvets.2019.00206/full#supplementary-material

Video 1 | Oral examination. An educational video on how the horse owners and trainers could examine the rostral part of the mouth for lesion prevention or early detection.

Data Sheet 1 | Oral examination form. A modified version of a former Vet Form 2 from the International Federation of Icelandic Horse Associations.

REFERENCES

1. Björnsdóttir S, Frey R, Kristjansson T, Lundström T. Bit-related lesions in Icelandic competition horses. *Acta Vet Scand.* (2014) 56:40. doi: 10.1186/s13028-014-0040-8
2. Björnsdóttir S, Frey R, Kristjansson T, Lundström T. Welfare indicator for competition horses. Bit-related lesions. In: *Poster Presentation, Nordic Equine Veterinary Congress.* Norway (2018).
3. Cook WR, Kibler M. Behavioural assessment of pain in 66 horses, with and without a bit. *Equine Vet Educ.* (2018) in press. doi: 10.1111/eve.12916
4. Mata F, Johnson C, Bisho C. A cross-sectional epidemiological study of prevalence and severity of bit-induced oral trauma in polo ponies and race horses. *J Aplied Anim Welf Sci.* (2015) 18:259–68. doi: 10.1080/10888705.2015.1004407
5. Odelros E, Wattle O. Influence of racing on oral health in Standardbred trotters. In: *Poster Presentation, Nordic Equine Veterinary Congress.* Norway (2018).
6. Uldahl M, Clayton H. Lesions associated with the use of bits, nosebands, spurs and whips in Danish competition horses. *Equine Vet Educ.* (2018) 51:154–62. doi: 10.1111/evj.12827
7. Tell A, Egenvall A, Lundström T, Wattle O. The prevalence of oral ulceration in Swedish horses when ridden with bit and bridle and when unridden. *Vet J.* (2008) 178:405–10. doi: 10.1016/j.tvjl.2008.09.020
8. Knottenbelt DC. Iatrogenic and idiopathic disorders. In: *Pascoe's Principles and Practice of Equine Dermatology.* London: Saunders Elsevier (2009). p. 335–338.
9. Scott DW, Miller WH. Pigmentary Abnormalities. In: *Equine Dermatology.* St. Louis, MO: Saunders, Elsevier Science (2003). p. 591–5.
10. The National Equine Competence Assocation of Finland. *Hevostalous lukuina (The Horse Industry by The Numbers).* Ypäjä: Hippolis (2017). Available online at: http://www.hippolis.fi/UserFiles/hippolis/File/Hevostalouslukuina2017_lopullinen.pdf
11. Cook WR. Damage by the bit to the equine interdental space and second lower premolar. *Equine Vet Educ.* (2011) 23:355–60. doi: 10.1111/j.2042-3292.2010.00167.x
12. Doherty O, Casey V, McGreevy P, Arkins S. Noseband use in Equestrian sports–an International study. *PLoS ONE.* (2017) 12:e0169060. doi: 10.1371/journal.pone.0169060
13. Nanci A, Wazen R. Repair and regeneration of oral tissues. In: Nanci A, editor. *Ten Cates's Oral Histology. Development, Stucture and Function.* St. Louis, MO: Elsevier; Mosby Inc. (2013). p. 278–340.
14. Woolf CJ. Pain:moving from symptom control toward mechanism-specific pharmacologic management. *Ann Intern Med.* (2004) 140:441–451. doi: 10.7326/0003-4819-140-8-200404200-00010
15. Muir WW. Anaesthesia and pain management in horses. *Equine Vet Educ.* (1998) 10:335–40. doi: 10.1111/j.2042-3292.1998.tb00905.x
16. Sneddon LU, Elwood RW, Adamo SA, Leach MC. Defining and assessing animal pain. *Anim Behav.* (2014) 97:201–12. doi: 10.1016/j.anbehav.2014.09.007
17. Taylor PM, Pascoe PJ, Mama KR. Diagnosing and treating pain in the horse: where are we today? *Vet Clin North Am Equine Pract.* (2002) 18:1–19. doi: 10.1016/S0749-0739(02)00009-3
18. Pehkonen J, Karma L, Raekallio M. Behavioral signs associated with equine periapical infection in cheek teeth. *J Equine Vet Sci.* (2019) 77:144–50. doi: 10.1016/J.JEVS.2019.03.005
19. Gleerup K, Forkman B, Lindegaard C, H Andersen P. An equine pain face. *Vet Anaesth Analg.* (2014) 42:103–14. doi: 10.1111/vaa.12212
20. Lesimple C, Hausberger M. How accurate are we at assessing others' well-being? The example of welfare assessment in horses. *Front Psychol.* (2014) 5:21. doi: 10.3389/fpsyg.2014.00021

21. Dalla Costa E, Minero M, Lebelt D, Stucke D, Canali E, Leach MC. Development of the Horse Grimace Scale (HGS) as a pain assessment tool in horses undergoing routine castration. *PLoS ONE*. (2014) 9:doi: 10.1371/journal.pone.0092281
22. Mellor DJ. Moving beyond the "Five Freedoms" by Updating the "Five Provisions" and Introducing Aligned "Animal Welfare Aims." *Animals*. (2016) 6:59. doi: 10.3390/ani6100059
23. Mellor DJ. Operational details of the five domains model and its key applications to the assessment and management of animal welfare. *Anim*. (2017) 7:60. doi: 10.3390/ani7080060
24. Scoggins RD. Bits, Bitting and Dentistry. In: *Proceedings of the Annual Convention of the AAEP*. San Diego, CA (2001). p. 138–151.
25. Fossum TW, Hedlund CS, Hulse DA, Johnson AL, Howard HB, Willard MD, Caroll GL. Surgery of the Integumentary System. In: *Small Animal Surgery*. Mosby Inc (2002). p. 136.
26. Animal Welfare Act 247/1996 16 §. Finland (1996).
27. The Finnish trotting and breeding association. Ravikilpailusäännöt (Rules of Racing) 2019 47§. Finland (2019).
28. Clayton H, Singleton WH, Lanovaz J, Cloud GL. Measurement of rein tension during horseback riding using strain gage transducers. *Exp Tech*. (2003) 27:34–6. doi: 10.1111/j.1747-1567.2003.tb00112.x

Conflict of Interest Statement: The authors declare that this study received funding from Suomen Hippos ry. The data was collected during a welfare program for trotters, conducted by Suomen Hippos ry. The funder informed the trainers of the study on their website and in their newspaper. The funder approved the proposed data collection method but had no further role in the study design, collection, analysis or interpretation of the data or preparation of the manuscript. The decision to submit the report for publication is made by the authors, and approved by the funder. KT works as a veterinarian in races at Porin Ravit Oy, which is one of the tracks, where horses were examined, but she was not on duty during the research period. The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

ORAL EXAMINATION FORM AFTER A RACE **No._____**

Trot Track_____ **Date**_____**Breed**_____

Race_____/_____**Horse**_____**Sex**_____ **Age**_____

Area	Lesion	Size	Depth	Bleed.	Points
Right buccal mucosa	bruise / fresh wound / old wound/ scar	1 / 2 / 3 / 4	superficial / deep	B	
Right lip corner inside	bruise / fresh wound / old wound/ scar	1 / 2 / 3 / 4	superficial / deep	B	
Right bar	bruise / fresh wound / old wound/ scar	1 / 2 / 3 / 4	superficial / deep	B	
Right lip corner outside	bruise / fresh wound / old wound/ scar/depigmentation	1 / 2 / 3 / 4	superficial / deep	B	
Left buccal mucosa	bruise / fresh wound / old wound/ scar	1 / 2 / 3 / 4	superficial / deep	B	
Left lip corner inside	bruise / fresh wound / old wound/ scar	1 / 2 / 3 / 4	superficial / deep	B	
Left bar	bruise / fresh wound / old wound/ scar/depigmentation	1 / 2 / 3 / 4	superficial / deep	B	
Left lip corner outside	bruise / fresh wound / old wound/ scar	1 / 2 / 3 / 4	superficial / deep	B	
Sides of the tongue	bruise / fresh wound / old wound/ scar	1 / 2 / 3 / 4	superficial / deep	B	
Tip of the tongue	bruise / fresh wound / old wound/ scar	1 / 2 / 3 / 4	superficial / deep	B	
Palate	bruise / fresh wound / old wound/ scar	1 / 2 / 3 / 4	superficial / deep	B	

Other observations:_____

Depigmentation: lack of dark pigment at the outside corners of the mouth

Size
Size 1: less than 5mm
Size 2: max 1cm
Size 3: larger than 1 cm
Size 4: 3 cm or larger

Acute lesion score_____
Bruise points = size of the bruise
Wound points = size x 2
Deep wound = plus 2 points

Equipment

Bit type and material_____

Is the bit ”right or wrong way” in the mouth?_____

Bit thickness measured near the bitring_____mm

Checkbit Yes No Type_____

Jawstrap Yes No Material_____

Overcheck Yes No Front-part_____back-part_____

Tonguetie Yes No Material_____

Other equipment Yes No _____

II

Received: 23 April 2020 | Accepted: 11 December 2020

DOI: 10.1111/evj.13401

GENERAL ARTICLE

Equine Veterinary Journal WILEY

Risk factors for bit-related lesions in Finnish trotting horses

Kati Tuomola[1] | Nina Mäki-Kihniä[2] | Anna Valros[1] | Anna Mykkänen[3] | Minna Kujala-Wirth[4]

[1]Research Centre for Animal Welfare, Department of Production Animal Medicine, University of Helsinki, Helsinki, Finland

[2]Independent Researcher, Pori, Finland

[3]Department of Equine and Small Animal Medicine, Faculty of Veterinary Medicine, University of Helsinki, Helsinki, Finland

[4]Department of Production Animal Medicine, Faculty of Veterinary Medicine, University of Helsinki, Helsinki, Finland

Correspondence
Kati Tuomola, Research Centre for Animal Welfare, Department of Production Animal Medicine, University of Helsinki, Helsinki, Finland.
Email: kati.tuomola@helsinki.fi

Funding information
The study was funded by Suomen Hippos ry, The Finnish Foundation of Veterinary Research, Orion Research Foundation, The Finnish Veterinary Foundation (Mercedes Zachariassen Foundation), Juliana von Wendt Foundation and the Doctoral School in Health Sciences, University of Helsinki.

Abstract

Background: Bit-related lesions in competition horses have been documented, but little evidence exists concerning their potential risk factors.

Objectives: To explore potential risk factors for oral lesions in Finnish trotters.

Study design: Cross-sectional study.

Methods: The rostral part of the mouth of 261 horses (151 Standardbreds, 78 Finnhorses and 32 ponies) was examined after a harness race. Information on bit type, equipment and race performance was collected.

Results: A multivariable logistic regression model of Standardbreds and Finnhorses showed a higher risk of moderate or severe oral lesion status associated with horses wearing a Crescendo bit (n = 38, OR 3.6, CI 1.4–8.9), a mullen mouth regulator bit (n = 25, OR 9.9, CI 2.2-45) or a straight plastic bit (n = 14, OR 13.7, CI 1.75-110) compared with horses wearing a snaffle trotting bit (n = 98, $P = .002$). Bar lesions (67 horses) were more common in horses wearing unjointed bits than in horses wearing jointed bits (Fisher's exact test $P < .001$). Lesions in the buccal area and the inner lip commissures were not associated with bit type. Using a tongue-tie or an overcheck, galloping, placement in the top three or money earned in the race were not associated with lesion risk.

Main limitations: The sample size for certain bit types was insufficient for statistical analysis.

Conclusions: Moderate and severe oral lesion status was more common in horses wearing a Crescendo bit, a mullen mouth regulator bit or a straight plastic bit than in horses wearing a single-jointed snaffle trotting bit. However, lesions were observed regardless of bit type. Further studies on rein tension, the interaction between bit type and rein tension and prevention of mouth lesions in trotters are warranted.

KEYWORDS
horse, animal welfare, bit, harness racing, oral lesion, trotter

The abstract is available in Portuguese in the Supporting Information section of the online version of this article

1 | INTRODUCTION

Bit-related lesions, causing pain and diminishing equine welfare, are common in competition horses.[1–7] In Nordic countries, an 84%-88% occurrence of oral lesions in the bit area after racing has been reported.[1,5] Only few studies have described bit types as a risk factor; in Icelandic horses, a curb bit with a port was associated with a higher risk of lesions in the bars of the mandible compared with a snaffle bit or a traditional Icelandic curb bit,[3] and a snaffle bit was associated with a higher risk for buccal lesions compared with the various curb bits.[3] Snaffle-bitted racehorses had more lesions than did gag-bitted polo ponies,[2] and 11-mm Myler-bitted ridden horses were less stressed and expressed less head-tossing than horses ridden with a traditional 18-mm snaffle bit.[8] Unridden horses on a treadmill independently applied higher rein tension with a double-jointed bit compared with an unjointed but curved mullen mouth snaffle bit.[9]

Horses can be controlled without a bit during exercise,[10] but bitting is considered an obligatory safety measure in harness racing. Successful bit use is based on the principles of negative reinforcement, and problematic behavioural consequences of erroneously applied pressure or pain are common and well described elsewhere (see eg 11,12). Scientific literature is still scarce on identifying the risks posed by bits and tack in a competition setting, yet developing means to minimise work-related lesions is necessary for welfare and ethical reasons.[13–15] The aim of this study was to investigate whether mouth lesions in a mixed population of Finnish trotting horses were associated with certain bits, trotter's equipment or race performance.

2 | MATERIALS AND METHODS

2.1 | Horses and oral examination

The data were collected from horses as previously reported,[1] as part of a welfare programme for trotters conducted by The Finnish Trotting and Breeding Association (Suomen Hippos ry) in 2017. A total of 261 horses were evaluated. These were privately owned trotters participating in 10 separate harness racing events on four racetracks in western Finland. As described previously,[1] the horses were initially selected at random from the starting lists. Priority was occasionally given to first arrivers at the harnessing booths to ensure collection of an adequate sample size in the limited timeframe between races.

The rostral part of the oral cavity was examined systematically.[1] Lesion location was identified as inner lip commissures, outer lip commissures, bars of the mandible, buccal area near the second premolar tooth (106, 206), tongue or hard palate.[1] Points were given for each acute lesion. Bruises (submucosal bleeding) were given points according to their size as follows: <0.5 cm = 1 point; 0.5–1 cm = 2 points; >1 cm but <3 cm = 3 points; ≥3 cm = 4 points. Wounds (mucosal surface damaged) were given points as follows: <0.5 cm = 2 points; 0.5–1 cm = 4 points; >1 cm but <3 cm = 6 points; ≥3 cm = 8 points. For deep wounds, additional two points were added.[1] For each horse, points were summed up to obtain a total lesion score, which determined the severity category as follows: A (no acute lesions), horses with 0 points; B (mild lesion status), horses with 1-2 points; C (moderate lesion status), horses with 3-11 points, but excluding horses with eight points from one single lesion; and D (severe lesion status), horses with 12 or more points and horses with eight points from one single lesion.[1] For statistical analysis, lesion severity categories A-D were merged into two categories: AB (no lesions or mild lesion status) and CD (moderate or severe lesion status). From a clinical point of view, the most severe case in the combined AB group was a horse with two points (eg a horse with one bruise not exceeding 1 cm). Horses with more severe lesions fell into the combined CD group, where the lower cut-off limit was three points (eg a horse with one bruise exceeding 1 cm) and in this data set, the maximum case was 36 points (a horse with two wounds exceeding 1 cm, one wound equal or exceeding 3 cm, one deep wound exceeding 1 cm and two wounds not exceeding 1 cm in different locations). Additionally, the presence or absence of blood inside the mouth was recorded.[1] Old lesions (scars, depigmentation of outer lip commissures, old bruises and old wounds) were recorded separately and excluded from the analysis.

2.2 | Data collection

The breed, age and sex of the horse were recorded along with bit type, mouthpiece material and bit thickness, which was measured adjacent to the bit ring with a vernier caliper. Additional variables recorded were overcheck (yes/no), check bit (yes/no), check bit type, jaw strap (yes/no), tongue-tie (yes/no) and tongue-tie material. The following variables were obtained from Heppa database (Suomen Hippos ry's online database for information on horses and racing): start type (auto start or volt start), race distance (1100 m (Shetland ponies only), 1600 m, 2100 m or 2600 m), whether the horse won money in the race (yes/no), was placed in the top three (yes/no) or galloped during the race (yes/no) and whether the horse had raced within the last 2 weeks (yes/no). Additionally, the driver, the trainer and their license types were recorded.

2.3 | Data analysis

Data were analysed statistically using Stata IC version 16 (Stata Corporation). Univariable analyses of the associations between all potential risk factors and outcome variable of interest (AB vs CD lesion status) were first computed using Chi-square tests (Table S1). Three age groups were formed (3-5, 6-9 and 10-15 years). For bit thickness, four categories were created: thin (12-13 mm), basic (14-17 mm), thick (18-22 mm) and extra thick (23-30 mm) bits.

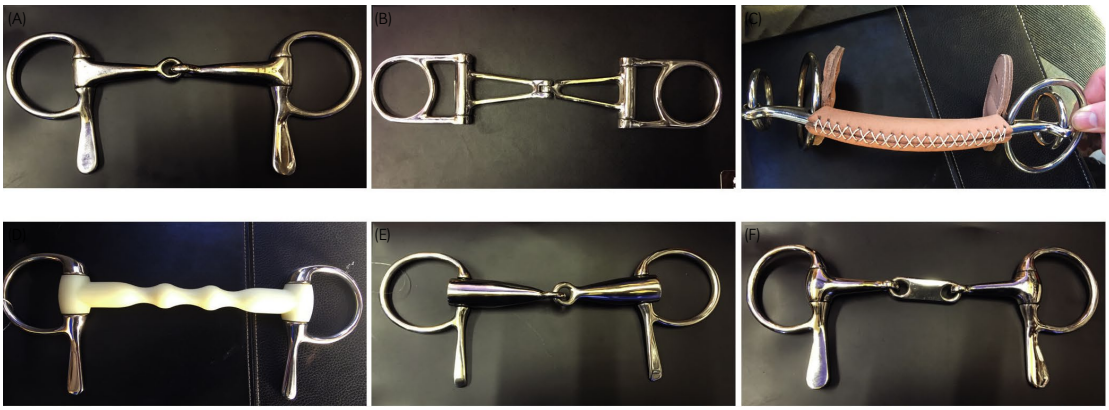
Relationships between potential risk factors were evaluated by examining pair-wise associations and were taken into consideration when building the logistic regression model. Associations were considered significant if $P < .05$. Bit type, but not bit thickness, was

included in the model as there was an association between them, with all unjointed bits being thick or extra thick, and bit type was our main variable of interest. Breed was associated with bit type. Compared with Standardbreds, Finnhorses were more often bitted with a Crescendo or a mullen mouth regulator bit. Parallel models were run with and without breed to ensure that the association between breed and bit type did not affect the results. The outcome of these models was very similar for all the other risk factors. Thus, as breed was considered biologically important, the model including breed is reported, despite this association. The driver license type was associated with the breed: most Standardbreds were driven by drivers with Licence A, and Finnhorses by drivers with Licence B or C.

Pony drivers are typically a minor with a pony licence. The reported pony results are descriptive only and excluded from statistical analysis due to small sample size, over-representation of the snaffle trotting bit (21 of 32) and the fundamental difference between betting and nonbetting races, in which ponies participate exclusively.

The six most common bit types and the group 'other bit' were included in the model (Figure 1). Nurmos bits (n = 10) and moisturiser bits (n = 2) were combined due to their similarity and collectively named the Nurmos bit group. All horses with a straight plastic bit (vernacular: happy mouth bit or apple bit, n = 14) had a CD lesion status. One of these horses received three points (one < 0.5 cm wound and one < 0.5 cm bruise at the bars) and was thus very close to the B lesion status cut-off limit. This horse was moved into the AB group to enable the logistic regression analysis. Manual stepwise backward and forward procedures were used to build the model, and explanatory variables, except breed, were eliminated until all remaining parameters had an association with a *P*-value of ≤.05. At each step, the removed variables were evaluated for confounding effects by checking whether the coefficients for the remaining variables changed substantially. All relevant interactions (eg sex × age, distance × breed, distance × age, bit type × bit thickness, bit type × tongue-tie and bit type × overcheck) were tested one by one, but no significant association with CD lesion status was detected.

The number of horses included in the model was 229. Horses were trained by 171 individual trainers and driven by 120 individual drivers. The majority of them trained or drove only one horse. The model was



Bit type	Material	Joints	Mean thickness (mm)	Thickness min max (mm)	Notes
(A) Snaffle trotting bit (119)	Metal	1	17	12-22	
(B) Crescendo bit (39)	Metal	1	30	25-30	Thickest bit
(C) Mullen mouth regulator bit (28)	Metal, leather	0	21	18-25	Shanks increase leverage
(D) Straight plastic bit, leather (3)	Metal, plastic	0	20	18-21	Formed mouthpiece
(E) Nurmos bit (12)	Metal	1	23	18-26	Hollow and thick
(F) Dr. Bristol bit (13)	Metal	2	13	12-18	Plate in the middle
(G) Other bit (35) various bit types	Metal, plastic, rubber, leather, copper	0, 1,2	18	13-24	Single-jointed regulator bit (n=5); Snaffle trotting bit, loose ring (5); Snaffle trotting bit, plastic (4); Straight trotting bit, leather (3); Snaffle trotting bit, leather (3)

FIGURE 1 Six most common bits used on trotters in the study

TABLE 1 The results of multivariable logistic regression model. Risk factors for moderate or severe oral lesion status (CD) compared with no lesions or mild lesion status (AB). N = 229

Variable	Category	n	Horses in CD group (%)	OR	95% CI	*P*-value
Breed						.3
	Standardbred	151	92 (61)	Reference		
	Finnhorse	78	58 (74)	1.5	0.8-2.9	
Sex						.05
	Gelding	98	56 (57)	Reference		
	Mare	102	75 (74)	2.2	1.2-4.2	.01
	Stallion	29	19 (66)	1.3	0.5-3.4	.5
Bit type						.002
	Snaffle trotting	98	49 (50)	Reference		
	Crescendo	38	30 (79)	3.6	1.4-8.9	.007
	Mullen mouth regulator	25	23 (92)	9.9	2.2-45.2	.003
	Straight plastic	14	13 (93)	13.7	1.7-110	.01
	Nurmos	12	6 (50)	1.1	0.3-3.6	>.9
	Dr. Bristol	10	8 (80)	3.9	0.8-20	.1
	Other	32	20 (63)	1.7	0.7-3.9	.2

tested with the trainer or driver as a random factor and both proved nonsignificant. This was expected considering a large number of trainers and drivers. The final model, containing breed, sex and bit type, is presented as a simple multivariable logistic regression model. The model was evaluated by a sensitivity and specificity test, ROC curve inspection, the goodness of fit test and by evaluating the residuals per covariate pattern and influential data (leverage and delta-betas). Results of the final model, in Table 1, are maximum likelihood estimates and presented as odd ratios (OR) and 95% confidence interval (CI). The association between lesion location and blood detected with any given bit type was analysed with the Fisher's exact test. The association between blood in the mouth and breed was analysed with the Pearson Chi-square test. Significance was set at $P \leq .05$.

3 | RESULTS

3.1 | Logistic regression model

Of the 229 horses, 151 were Standardbreds and 78 were Finnhorses; 102 were mares, 98 were geldings and 29 were stallions and age ranged from 3 to 15 years (Mean 6.9, SD 2.6). Of the Standardbreds, 83% (125/151) had acute lesions; and their lesion status distribution was 17% (26/151) A status, 22% (33/151) B status, 43% (65/151) C status and 18% (27/151) D status. Of the Finnhorses, 90% (70/78) had acute lesions with a distribution of 10% (8/78) A status, 17% (13/78) B status, 44% (34/78) C status and 29% (23/78) D status.

The full model containing breed, sex and bit type was statistically significant (N = 229, χ^2 38.75, $P < .001$) indicating that the model was able to distinguish between AB and CD lesion status horses. The model's sensitivity was 83% and specificity was 42%. The model correctly classified 68% of the cases. The area under the ROC curve was 73% (CI 67%-80%, $P < .001$). The *P*-value for the Pearson χ^2 goodness of fit test was 0.4.

The snaffle trotting bit was the most common bit among all the breeds (Figure 2). The CD lesion status was recorded for 50% (49/98) of horses wearing the snaffle, but the risk of CD lesion status was higher for horses wearing a Crescendo bit 79% (30/38), a mullen mouth regulator bit 92% (23/25) or a straight plastic bit 100% (14/14) ($P = .002$) (Table 1). Bit thickness was not associated with CD lesion status. Sex was associated with CD lesion status ($P = .05$). Mares had a higher risk for CD lesion status than did geldings but stallions (only 29 horses) did not differentiate from geldings (Table 1, Figure 3). Breed, retained in the model, was not significant.

3.2 | Lesion location, blood and bit type

Unjointed bits were associated with the occurrence of bar lesions (67 horses). Bar lesions were found in 86% (12/14) of the horses wearing a straight plastic bit, in 64% (16/25) of the horses wearing a mullen mouth regulator bit and in 50% (6/12) of the horses wearing a Nurmos, but only in 20% (2/10) of the horses wearing a Dr. Bristol bit, in 19% (19/98) of the horses wearing a snaffle trotting bit and in 8% (3/38) of the horses wearing a Crescendo bit ($P < .001$). Bit type was associated neither with lesions in the buccal area (63 horses) ($P > .9$) nor the lesions in the inner lip commissures (145 horses) ($P = .2$). For the lesion location analysis, we only considered whether the horse had lesions in a particular location while disregarding the severity and number of lesions. The low number of lesions in the outer lip commissures (16 horses), the tongue (nine horses) and the hard palate (one horse) did not allow for analysis of their association with bit type. Blood in the mouth was present more often in

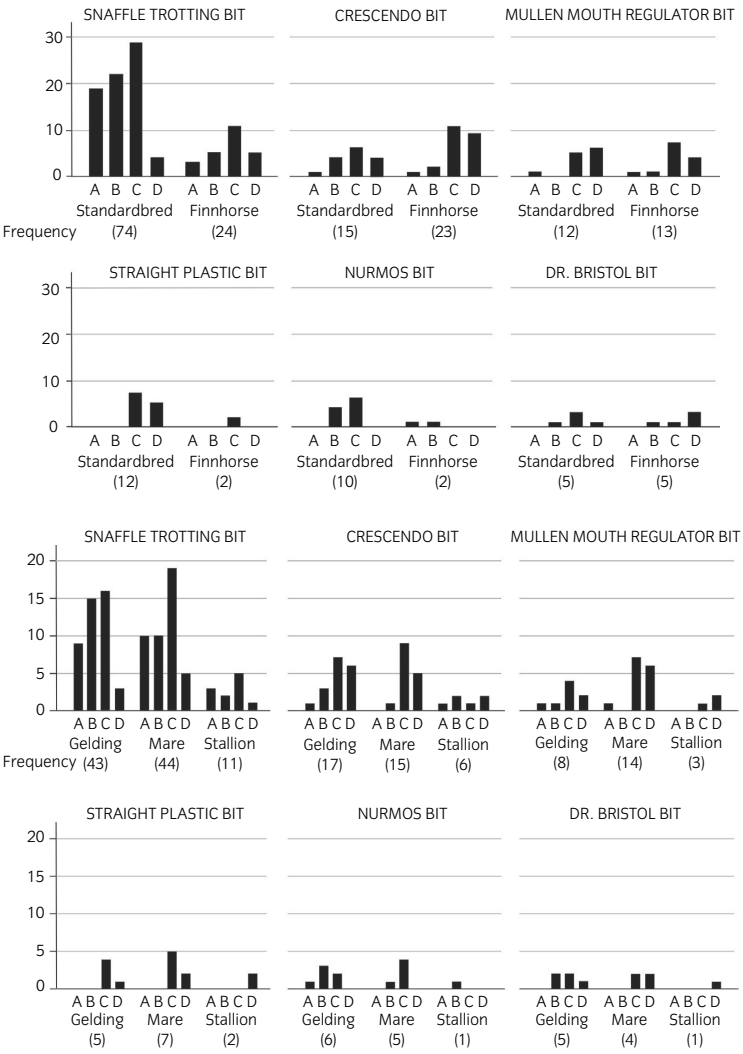


FIGURE 2 Standardbreds and Finnhorses according to bit type and lesion category. No lesions (A), mild (B), moderate (C) and severe (D) lesion status (N = 229)

FIGURE 3 Geldings, mares and stallions according to bit type and lesion category. No lesions (A), mild (B), moderate (C) and severe (D) lesion status (N = 229)

Finnhorses (21%, 16/78) than in Standardbreds (10%, 15/151, $P = .03$). Number of blood observations per bit type was as follows: Crescendo bit 10/38, straight a plastic bit 3/14, Dr. Bristol bit 2/10, mullen mouth regulator bit 4/25, other bit 4/32, snaffle trotting bit 8/98 and Nurmos bit 0/12.

3.3 | Equipment and race performance

Using a tongue-tie or overcheck was not associated with CD lesion status in univariable analysis, so they were not included in the logistic regression model (Table S1). A tongue-tie was fitted on 72% of the horses (166/229), with most common materials being an elastic leg bandage (111 horses), Vet Flex or Vet Wrap (28 horses) or stockings (15 horses). An overcheck was recorded for 83% of Standardbreds (125/151) and 96% of Finnhorses (75/78). Among these, a jaw strap was used on 44% of horses, a check bit on 44% of horses and both of them on 12% of horses. The most common check bit type was a straight basic check bit.

Galloping during the race, placement among the top three, money earned in the race, race distance, start type or racing previously no longer than 2 weeks ago were not lesion risk factors. License types, eight for trainers and three for drivers, were not associated with the occurrence of CD lesion status (Table S1).

3.4 | Trotting ponies

In total 32 ponies were examined, 18 Shetland ponies and 14 Gotland Russ ponies. Lesion status A was described for 25% (8/32), B status

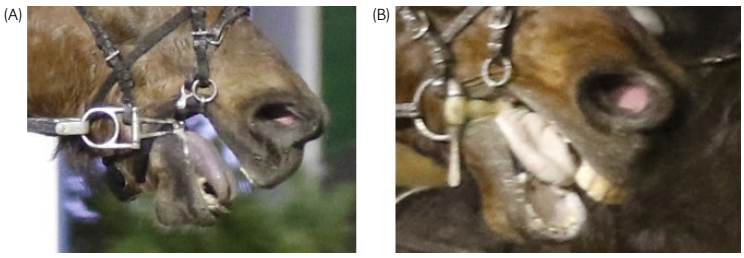


FIGURE 4 A, A horse racing with Crescendo bit. Rein tension is applied to the bit and the bit is compressing lip commissures and tongue. B, A horse racing with straight plastic bit. Rein tension is applied to the bit and the bit is compressing lip commissures and bars of the mandible (Copyrighted image).

for 28% (9/32), C status for 44% (14/32) and D status for 3% (1/32) of the ponies. Eight ponies (25%) had wounds and 23 (72%) had bruises. Blood was observed in the mouth of one pony. Twenty-one ponies wore a snaffle trotting bit, and less common bit types were the Crescendo (n = 1), straight plastic (n = 1), mullen mouth regulator (n = 1), Dr. Bristol (n = 3) and other bit (n = 3). Of all ponies, 9% (3/32) had a tongue-tie and 88% (28/32) raced with an overcheck.

4 | DISCUSSION

Bit type was a risk factor for CD oral lesion status, yet our model does not allow for determining any fractions of this total risk to a particular cause, such as rein tension, action mechanics or physical properties of the bit (such as material-specific friction or bit form) or their interaction. The Crescendo bit is commonly considered the most 'severe' bit of our sample with its thin metal rails presumably focusing pressure on a relatively small contact area in the mouth. Horses racing with this bit had an elevated risk of CD lesion status compared with horses racing with snaffle trotting bit. Compared with the Crescendo, the mullen mouth regulator and unjointed bits are often considered 'gentler', but horses bitted with these also carried an elevated risk of a CD lesion status. The leather covering and thickness of the mullen mouth regulator bit may contribute to a 'gentler' appearance, but the shanks may in fact amplify rein tension through their lever action.[16] The jointed snaffle bit is generally regarded as a 'gentle bit'.[17] However, CD lesion status occurred in half of the horses racing with the single-jointed snaffle trotting bit and the Nurmos bit. A minor finding in the current study—potentially affecting the mechanical action of the bit—was that, six bits were fitted on backwards accidentally (two trainers) and on purpose (four trainers) on the rationale that the bit would have a less severe effect. Harness racing guidelines in Finland state that all equipment should be correctly fitted but fail to describe the correct fit.[18]

In the current study, horses wearing unjointed bits had more bar lesions than horses wearing jointed bits. The bars, a thinly covered bony structure under the bit, are particularly vulnerable to trauma.[19] It seems that the potent action of an unjointed bit, in particular, may compress the mucous membrane causing ulceration adjacent to the first lower cheek teeth (Figure 4). Large and painful lesions adjacent to the first lower cheek teeth and even traumatised mandibular bone receding from the reserve crown have been found in a previous study of trotting horses.[20] Another study has documented bar lesions in half (51%) of competing Icelandic horses wearing curb bits with ports but the ratio between unjointed and jointed bits was not reported.[3]

Bit choice is mainly based on the subjective assessment by the trainer or driver.[19] It has been suggested that 'the multiplicity of bits now on the market strongly suggest that bit designs are used to overcome training and performance issues, many of which probably reflect some deficits in training or riding'.[16] Horses that do not respond to light rein signals are a common issue in equitation and are called 'pullers', 'heavy-mouthed' or 'hard-mouthed'.[12,20] In training, negative reinforcement is usually used to teach the horse to respond in a certain manner to rein signals, also called aids or cues, which usually involve applying pressure to the bit via rein tension.[21] It is possible that Crescendo, mullen mouth regulator and unjointed happy mouth bits are chosen for horses that are unresponsive to light rein signals for various reasons, including an evasion or flight response due to painful stimulus or anticipation of pain,[22,23] habituation to bit pressure due to inconsistent training not reinforcing the desired reaction to bit pressure[12,16] and multiple stressors present in the competition environment such as transportation, unfamiliar horses and novel situations.[24,25] Inability to respond to a light rein signal due to erroneous learning combined with high arousal (be that excitement, anxiety or fear) may increase the rein tension needed and predispose these horses to oral trauma. As there might be complicated interactions between factors such as horse behaviour and performance, and bit type and rein tension, it would be interesting to follow the same horses driven with different bits and different rein tensions.

Sex was unexpectedly associated with lesion risk, so that mares compared with geldings were at higher risk of CD lesion status. Horse handlers need to note this risk potential. This finding supports further studies on sex differences, as existing literature recognises sex-based attitudes potentially affecting horse handling, such as mares assumed more anxious and flighty than geldings and anthropomorphically gender-stereotyping mares as 'difficult'.[26,27]

Other variables did not prove significant risk factors for lesions. Of the horses, 26% galloped during the race. Once a horse gallops, the driver usually pulls on the reins to slow the horse down to a trot, but in contrast to our expectations, no association emerged between galloping and lesion severity.

Tongue-ties were used on the majority of horses. Use of a tongue-tie is allowed in racing in Finland, in contrast to Switzerland and parts of Germany, where its use is forbidden.[28] Finnish racing rules do not regulate tongue-tie width in contrast with Sweden, where the tongue-tie must be at least 10-mm wide.[18,29] In the current study, the tongue-tie was not associated with lesions.

Good performance does not guarantee good welfare, even though that still is a common belief.[30] Horses with a CD lesion status were placed in the top three or earned money in the race similarly to horses with a AB lesion status. Lesions, although potentially painful, do not necessarily manifest in concurrent poor performance, because pain sensation might be temporarily suppressed by stress-induced analgesia under stressful conditions.[31] Currently, it is not fully understood how negative experiences from lesions are linked to the horse's behaviour later on during their competition career nor is the safety risk for humans fully appreciated.[22,32] However, learning and mood are affected by all experiences[11,12] and pain or discomfort can elicit a fear reaction, acute stress response and, later, anticipatory stress in the competition environment.[11,25,32,33] 'Flightiness' is a trait that some might consider advantageous to a racehorse to a certain degree,[11] but it can constitute risk for accidents.

The current study has some limitations. Firstly, the number of certain bit types was too small for robust statistical results. The group using straight plastic bits comprised only 14 horses, so confirming the result requires further research in a larger horse population. Secondly, post-racing examination does not determine the exact moment of lesion occurrence. Only acute lesions were included in this analysis, but obviously some lesions might have been present before the race, for example, due to different bit used in training. However, if this was the case, it would only further emphasise the need for racing awareness on and control of the oral health of trotters. Thirdly, horses were selected at random but not randomly in a statistical sense, in order to maximise the number of horses examined in the limited timeframe between races. Among those not examined previously, priority was occasionally put on those horses first to arrive to their harnessing booth. First arrivers might be horses that did not finish or were disqualified, but only 34 horses (15%) were such cases in the current study. Finally, in a previous Danish study, noseband use has been associated with lip commissure lesions.[7] Noseband tightness was not measured in the current study due to limited data collection timeframe.

Only one study has evaluated rein tensions in trotters previously. Maximum rein tensions among trotting horses were twice as high as in riding horses.[34] Several studies on rein tension are available for ridden horses.[17,35–37] Horses are not voluntarily willing to tolerate great or prolonged rein tension in exchange for rewards, and rein tension has been correlated with expression of conflict behaviour, such as mouth gaping (Figure 4),[24,35,36,38] leading to reduced rideability or analogously reduced driveability.[36] It would be useful to assess the association of oral lesions, conflict behaviour and rein tension in trotters as well.

In conclusion, crescendo, mullen mouth regulator or straight plastic bitted trotters had a higher risk of moderate or severe oral lesion status after a race than horses racing with single-jointed snaffle trotting bits, but lesions occurred regardless of bit type. Horses racing with unjointed bits had more bar lesions than horses racing with jointed bits. Further studies on rein tension, the interaction between bit type and rein tension and prevention of mouth lesions in trotters are warranted.

ACKNOWLEDGEMENTS

The authors are grateful to Suomen Hippos ry, Finnish Pony Trotting Association, Katja Hautala and Reija Junkkari for making this study possible and to the horse owners and trainers for their interest and positive attitude towards the study and to Pauli Impola for the horse photos.

CONFLICT OF INTERESTS

The authors declare that this study received funding from Suomen Hippos ry. The data were collected during a welfare programme for trotters, conducted by Suomen Hippos ry. The funder approved the proposed data collection method but had no further role in the study design, collection, analysis or interpretation of the data or preparation of the manuscript. The decision to submit the report for publication was made by the authors and was approved by the funder. K. Tuomola works as a race veterinarian at Porin Ravit Oy, which is one of the tracks where horses were examined, but she was not on duty during the research period. All authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

K. Tuomola contributed to the study design, data collection and analyses and preparation of the manuscript. M. Kujala-Wirth performed the statistical analysis. N. Mäki-Kihniä contributed to data collection and analyses, and manuscript preparation. M. Kujala-Wirth, A. Valros and A. Mykkänen contributed to interpreting the results and manuscript preparation. K. Tuomola and M. Kujala-Wirth have had a full access to all data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. All authors have read and approved the final manuscript.

ETHICAL ANIMAL RESEARCH

The study was considered ethically acceptable by the University of Helsinki Viikki Campus Research Ethics Committee (Statement 8/2018).

INFORMED CONSENT

The oral examination was compulsory for participants in the harness racing events. Suomen Hippos ry informed the trainers of the study on their website (www.hippos.fi) and in their newspaper (Hevosurheilu) prior to the study.

DATA ACCESSIBILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Peer Review

The peer review history for this article is available at https://publons.com/publon/10.1111/evj.13401.

ORCID

Kati Tuomola https://orcid.org/0000-0002-2984-1458
Anna Valros https://orcid.org/0000-0002-4431-3346
Anna Mykkänen https://orcid.org/0000-0003-4248-8983
Minna Kujala-Wirth https://orcid.org/0000-0003-1449-7583

REFERENCES

1. Tuomola K, Mäki-Kihniä N, Kujala-Wirth M, Mykkänen A, Valros A. Oral lesions in the bit area in Finnish trotters after a race: lesion evaluation, scoring and occurrence. Front Vet Sci. 2019;6:1–12. https://doi.org/10.3389/fvets.2019.00206
2. Mata F, Johnson C, Bishop C. A cross-sectional epidemiological study of prevalence and severity of bit-induced oral trauma in polo ponies and race horses. J Appl Anim Welf Sci. 2015;18:259–68. https://doi.org/10.1080/10888705.2015.1004407
3. Björnsdóttir S, Frey R, Kristjansson T, Lundström T. Bit-related lesions in Icelandic competition horses. Acta Vet Scand. 2014;56. https://doi.org/10.1186/s13028-014-0040-8
4. Björnsdóttir S, Frey R, Kristjansson T, Lundström T.Welfare indicator for competition horses. Bit-related lesions. In: *Poster presentation, Nordic Equine Veterinary Congress*, 2018, Norway.
5. Odelros E, Wattle O.Influence of racing on oral health in Standardbred trotters. Abstract. In: *Poster presentation, Nordic Equine Veterinary Congress*, 2018, Norway.
6. Tell A, Egenvall A, Lundström T, Wattle O. The prevalence of oral ulceration in Swedish horses when ridden with bit and bridle and when unridden. Vet J. 2008;178:405–10. https://doi.org/10.1016/j.tvjl.2008.09.020
7. Uldahl M, Clayton H. Lesions associated with the use of bits, nosebands, spurs and whips in Danish competition horses. Equine Vet J. 2019;51:154–62. https://doi.org/10.1111/evj.12827
8. VanderHorst KJ, Rijksen L, Ariëns J, VanRiet A, Timmerman M, Schreuder M, *et al.* The effect of type of bit on welfare and performance of horses. J Vet Behav. 2013;8:e22. https://doi.org/10.1016/j.jveb.2012.12.050
9. Kau S, Potz IK, Pospisil K, Sellke L, Schramel JP, Peham C. Bit type exerts an influence on self-controlled rein tension in unridden horses. Sci. Rep. 2020;10:2420. https://doi.org/10.1038/s41598-020-59400-w
10. Cook WR, Kibler M. Behavioural assessment of pain in 66 horses, with and without a bit. Equine Vet. Educ. 2019;31:551–60. https://doi.org/10.1111/eve.12916
11. Mcbride SD, Mills DS. Psychological factors affecting equine performance. BMC Vet Res. 2012;8:1–11. https://doi.org/10.1186/1746-6148-8-180
12. McLean AN, Christensen JW. The application of learning theory in horse training. Appl Anim Behav Sci. 2017;190:18–27. https://doi.org/10.1016/j.applanim.2017.02.020
13. McGreevy P, McLean A, Buckley P, McConaghy F, McLean C. How riding may affect welfare: what the equine veterinarian needs to know. Equine Vet Educ. 2011;23:531–9. https://doi.org/10.1111/j.2042-3292.2010.00217.x
14. Campbell MLH. When does use become abuse in equestrian sport? Equine Vet. Educ. 2013;25:489–92. https://doi.org/10.1111/eve.12087
15. Lesimple C. Indicators of horse welfare: state-of-the-art. Animals. 2020;10:294. https://doi.org/10.3390/ani10020294
16. McGreevy P, Christensen JW, von Borstel Uta König, MA. Equitation Science, 2nd edn. Chichester, UK: Wiley-Blackwell; 2018.
17. Clayton HM, Singleton WH, Lanovaz JL, Cloud GL. Strain gauge measurement of rein tension during riding: a pilot study. Equine Comp Exerc Physiol. 2005;2:203–5. https://doi.org/10.1079/ecp200553
18. Ansio J, Ertola K, Hautala K, Junttila J, Lahtinen M. Varusteopas (Transl. Equipment regulations). Espoo: Suomen Hippos ry; 2015.
19. Manfredi J, Clayton H, Rosenstein D. Radiographic study of bit position within the horse's oral cavity. Equine Comp Exerc Physiol. 2005;2:195–201. https://doi.org/10.1079/ecp200564
20. Foster DL. The gold standard of dental care for the adult performance horse. Vet Clin North Am Equine Pract. 2013;29:505–19. https://doi.org/10.1016/j.cveq.2013.04.012
21. Clayton HM. A fluoroscopic study of the position and action of different bits in the horse's mouth. J Equine Vet Sci. 1985;5:68–72. https://doi.org/10.1016/S0737-0806(85)80050-2
22. Starling M, McLean A, McGreevy P. The contribution of equitation science to minimising horse-related risks to humans. Anim an open access J from MDPI. 2016;6:15. https://doi.org/10.3390/ani6030015
23. Doherty O, Mcgreevy PD, Pearson G. The importance of learning theory and equitation science to the veterinarian. Appl Anim Behav Sci. 2017;190:111–22. https://doi.org/10.1016/j.applanim.2017.02.012
24. König U, Visser EK, Hall C. Indicators of stress in equitation. Appl Anim Behav Sci. 2017;190:43–56. https://doi.org/10.1016/j.applanim.2017.02.018
25. Bohák Z, Harnos A, Joó K, Szenci O, Kovács L. Anticipatory response before competition in Standardbred racehorses. PLoS One. 2018;13(8). https://doi.org/10.1371/journal.pone.0201691
26. Fenner K, Caspar G, Hyde M, Henshall C, Dhand N, Probyn-Rapsey F, *et al.* It's all about the sex, or is it? Humans, horses and temperament. PLoS One. 2019;14(5): https://doi.org/10.1371/journal.pone.0216699
27. Duberstein KJ, Gilkeson JA. Determination of sex differences in personality and trainability of yearling horses utilizing a handler questionnaire. Appl Anim Behav Sci. 2010;128:57–63. https://doi.org/10.1016/j.applanim.2010.09.012
28. Union Européenne du Trot. Règlementation de l'UET relative au bien-être animal, Suisse. Règlementation l'UET Relat. au bien-être Anim. Suisse 21. https://www.uet-trot.eu/images/pdf-uet/fr/animal_welfare/suisse.pdf
29. Svensk Travsport.Utrustingsbestämmelser i Travlopp i Sverige, Bromma; 2019.
30. Heleski CR, Anthony R. Science alone is not always enough: The importance of ethical assessment for a more comprehensive view of equine welfare. J Vet Behav. 2012;7:169–78. https://doi.org/10.1016/J.JVEB.2011.08.003
31. Butler RK, Finn DP. Stress-induced analgesia. Prog Neurogibol. 2009;88:184–202. https://doi.org/10.1016/j.pneurobio.2009.04.003
32. McGreevy PD, Henshall C, Starling MJ, McLean AN, Boakes RA. The importance of safety signals in animal handling and training. J Vet Behav Clin Appl Res. 2013;9:382–7. https://doi.org/10.1016/j.jveb.2014.06.006
33. Vlaeyen JWS, Linton SJ. Fear-avoidance and its consequences in chronic musculoskeletal pain: A state of the art. Pain. 2000;85:317–32. https://doi.org/10.1016/S0304-3959(99)00242-0

34. Preuschoft H, Witte H, Recknagel S, Bär H, Lesch C, Wüthrich M. Über die Wirkung gebräuchlicher Zäumungen auf das Pferd. Dtsch. Tieratzliche Wochenschrift. 1999;106:167–75.
35. Piccolo L, Kienapfel K. Voluntary rein tension in horses when moving unridden in a dressage frame compared with ridden tests of the same horses—a pilot study. Animals. 2019;9: https://doi.org/10.3390/ani9060321
36. König von Borstel U, Glißman C. Alternatives to conventional evaluation of rideability in horse performance tests: suitability of rein tension and behavioural parameters. PLoS One. 2014;9. https://doi.org/10.1371/journal.pone.0087285
37. Dumbell L, Lemon C, Williams J. A systematic literature review to evaluate the tools and methods used to measure rein tension. J Vet Behav. 2019;29:77–87. https://doi.org/10.1016/j.jveb.2018.04.003
38. Christensen JW, Zharkikh TL, Antoine A, Malmkvist J. Rein tension acceptance in young horses in a voluntary test situation. Equine Vet J. 2011;43:223–8. https://doi.org/10.1111/j.2042-3306.2010.00151.x

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

How to cite this article: Tuomola K, Mäki-Kihniä N, Valros A, Mykkänen A, Kujala-Wirth M. Risk factors for bit-related lesions in Finnish trotting horses. *Equine Vet J*. 2021;53:1132–1140. https://doi.org/10.1111/evj.13401

Equine Veterinary Journal BEVA

Table S1: The results of the univariable analysis (Chi-square test and Fisher's exact test in bit type) in Standardbreds and Finnhorses. Summary of trotter's explanatory variables and their association with an outcome; moderate or severe oral lesion status (CD) vs. no lesions or mild oral lesion status (AB). From all Standardbreds and Finnhorses 66% (150/229) had CD lesion status. P-value < 0.05 was considered significant (N = 229).

Variable	Category	n	Horses in CD group	(%)	P-value
Breed					0.04
	Finnhorse	78	58	(74)	
	Standardbred	151	92	(61)	
Sex					0.05
	Mare	102	75	(74)	
	Stallion	29	19	(66)	
	Gelding	98	56	(57)	
Age (years)					0.4
	3–6	119	82	(69)	
	7–9	74	44	(59)	
	10–15	36	24	(67)	
Overcheck					0.2
	Yes	200	134	(67)	
	No	29	16	(55)	
Check bit					0.7
	Yes	110	71	(65)	
	No	117	78	(67)	
Jaw strap					0.3
	Yes	112	77	(69)	
	No	116	72	(62)	
Check bit and jaw strap					> 0.9
	Yes	23	15	(65)	
	No	204	134	(66)	
Tongue-tie					0.8
	Yes	166	110	(66)	
	No	62	40	(65)	
Bit type					< 0.001
	Snaffle trotting	98	49	(50)	
	Crescendo	38	30	(79)	
	Mullen mouth regulator	25	23	(92)	
	Straight plastic	14	14	(100)	
	Nurmos	12	6	(50)	
	Dr. Bristol	10	8	(80)	
	Other	32	20	(63)	
Bit thickness (mm)					0.5
	10–13	14	9	(64)	
	14–17	60	35	(58)	
	18–22	104	69	(66)	
	23–30	51	37	(73)	
Galloping during the race					0.7
	Yes	59	40	(68)	
	No	170	110	(65)	
Placement in the top three					0.2
	Yes	60	35	(58)	
	No	169	115	(68)	
Money earned in the race					0.3
	Yes	124	85	(69)	
	No	105	65	(62)	
Start type					0.3
	Auto	150	95	(63)	
	Volt	79	55	(70)	
Race distance (m)					0.2
	1600	63	44	(70)	
	2100	156	102	(65)	
	2600	10	4	(40)	
Competed in last 14 days					0.8
	Yes	107	69	(64)	
	No	122	81	(66)	
Driver's license type					0.2
	A (the most experienced)	185	116	(63)	
	B	22	16	(73)	
	C	22	18	(82)	
Trainer's license type					0.7
	Professional license	92	59	(64)	
	Other license	137	91	(66)	

III

frontiers in Veterinary Science

ORIGINAL RESEARCH
published: 31 March 2021
doi: 10.3389/fvets.2021.651160

Bit-Related Lesions in Event Horses After a Cross-Country Test

Kati Tuomola[1], Nina Mäki-Kihniä[2], Anna Valros[1], Anna Mykkänen[3] and Minna Kujala-Wirth[4]*

[1] Department of Production Animal Medicine, Research Centre for Animal Welfare, University of Helsinki, Helsinki, Finland, [2] Independent Researcher, Pori, Finland, [3] Department of Equine and Small Animal Medicine, Faculty of Veterinary Medicine, University of Helsinki, Helsinki, Finland, [4] Department of Production Animal Medicine, Faculty of Veterinary Medicine, University of Helsinki, Helsinki, Finland

Bit-related oral lesions are common and may impair horse welfare. The aim of this study was to investigate the prevalence of oral lesions and their risk factors in a sample of Finnish event horses. The rostral part of the oral cavity (the bit area) of 208 event horses (127 warmbloods, 52 coldbloods, and 29 ponies) was examined in a voluntary inspection after the last competition phase, i.e., the cross-country test. Acute lesions were observed in 52% (109/208) of the horses. The lesion status was graded as no acute lesions for 48% (99/208), mild for 22% (45/208), moderate for 26% (55/208) and severe for 4% (9/208) of the horses. The inner lip commissure was the most common lesion location observed in 39% (81/208) of the horses. A multivariable logistic regression model with data of 174 horses was applied to risk factor analysis. Horses wearing thin (10–13 mm) (OR 3.5, CI 1.4–8.7) or thick (18–22 mm) (OR 3.4, CI 1.4–8.0) bits had a higher risk of moderate/severe lesion status than horses wearing middle-sized (14–17 mm) bits ($P = 0.003$). Breed was associated with moderate/severe lesion status ($P = 0.02$). The risk was higher for warmbloods (reference group) and coldbloods (OR 2.0, CI 0.88–4.7) compared with ponies (OR 0.2, CI 0.04–0.87). Mares were at higher risk of moderate/severe lesion status (OR 2.2, CI 1.1–4.5) than geldings (reference group) ($P = 0.03$). Bar lesions were more common in horses with unjointed bits (40%, 8/20) than with basic double-jointed (10%, 5/52), formed double-jointed (8%, 6/78) or single-jointed bits (5%, 2/40) (Fisher's exact test, $P = 0.002$). The results of this study suggest that thin and thick bits and mare sex should be considered risk factors for mouth lesions. In addition, in this sample ponies had smaller risk for lesions than other horse breeds. We encourage adopting bit area monitoring as a new routine by horse handlers and as a welfare measure by competition organizers for randomly drawn horses.

Keywords: animal welfare, eventing, Ulcer, BIT, horse

OPEN ACCESS

Edited by:
Tamara Alejandra Tadich, University of Chile, Chile

Reviewed by:
Hedie A. Bustamante, Austral University of Chile, Chile
Hilde M. N. Vervaecke, University College Odisee, Belgium
Mariano Hernandez-Gil, UNAM Facultad de Medicina Veterinaria y Zootecnia, Mexico

****Correspondence:***
Kati Tuomola
kati.tuomola@helsinki.fi

Specialty section:
This article was submitted to Animal Behavior and Welfare, a section of the journal Frontiers in Veterinary Science

Received: *08 January 2021*
Accepted: *06 March 2021*
Published: *31 March 2021*

Citation:
Tuomola K, Mäki-Kihniä N, Valros A, Mykkänen A and Kujala-Wirth M (2021) Bit-Related Lesions in Event Horses After a Cross-Country Test. Front. Vet. Sci. 8:651160. doi: 10.3389/fvets.2021.651160

INTRODUCTION

Horse welfare in competitive equestrian sports is under increasing scrutiny (1, 2), with attention being directed among others to bit-related lesions, which affect horse welfare by potentially causing anxiety, fear, and pain (3). Oral tissues have a strong somatosensory innervation (4, 5). The function of the nociceptive system is to detect potentially noxious mechanical, chemical, or thermal stimuli (4, 5). From animal welfare point of view it is essential to minimize such negative experiences by

preventing or at least rapidly diagnosing and treating injuries and ensuring conditions which avoid suffering (6–8). Bit-related lesions in equestrian competitions have previously been examined in Icelandic horses, polo ponies, racehorses, riding horses and trotters (9–14). Curb bits with ports in Icelandic horses and Crescendo bits, unjointed regulator mullen mouth bits and straight plastic bits in trotters have been associated with higher lesion risk (9, 15). Thoroughbred racehorses with snaffle bits had multiple and more severe lesions than polo ponies wearing gag bits (12). Harness racing increased mucosal injuries in the rostral oral cavity compared to training (14). One study investigated event horses after a competition, but only the mouth corners were examined to detect lesions, because the rules of the governing equestrian federation did not allow for a full intraoral examination (13). Mouth corner lesions were present in six (7.5%) out of 80 event horses and in one (3%) out of 33 event ponies (13).

Although oral lesions are a commonly reported problem (9–12, 16–19) and of long-established citizen and veterinary concern (8, 19, 20), the underlying risk factors are not adequately described in scientific literature. The aim of this study was to analyze the occurrence of oral lesions in a sample of Finnish event horses and the potential association of lesions with equipment, such as noseband, bit type and bit thickness or other factors such as breed, age, sex, competition level or competition performance.

MATERIALS AND METHODS

Horses and Oral Examination

Examinations of rostral mouth area were carried out in eight competition events at three locations in western Finland during the summers of 2018 and 2019. Apart from one international event all were national level competition events. The study was executed in collaboration with The Equestrian Federation of Finland (Suomen Ratsastajainliitto, SRL). The examination was voluntary. Information regarding the study was provided to participants when they registered online for the competition and in an information leaflet distributed on the 1st day when checking in at the competition office. All competitions were 2-day events. Dressage and show jumping phases were held on the 1st day. Examination was carried out on the 2nd day, after competitors had completed the cross-country test and approached the horse trailer area. An invitation to participate was extended to as many competitors as possible to maximize the sample size but horses examined in previous competitions were excluded. The majority of those approached (215/227, 95%) agreed to participate, and 97% of their horses (208/215) were successfully examined, with seven horses excluded due to obvious avoidance behavior during examination. Examination was performed from the left and right sides of the horse without sedation or mouth speculum, and with disposable nitrile gloves and an efficient headlamp (Lumonite Navigator 3,000 headlamp set at 420–1,300 lumens) (11) by a single veterinarian experienced in the oral examinations of horses. Lesions were assessed visually, and bars of the mandible, the area mesial to second lower premolar teeth, were also palpated. An assistant verified and recorded all the findings on an examination form. Examples of lesions were documented with a digital camera (Panasonic DMC-GX7; lens H-FS14140, 14–140) with the rider's permission.

According to Finnish riding competition rules, horses must be bridled in the competition venue for safety reasons, so the majority of horses were examined with their bridle on. A good view and a reliable examination result was achieved when the noseband and curb chain, if present, were unlatched, allowing the examiner to open the horse's mouth. Fingers were used to lift the bit to achieve better visibility (**Figures 1A,C,F**, **2A–D**). In other regards, the examination was similar to that conducted on Finnish trotters in a previous study and described in Tuomola et al. (11).

Data Collection

The following data were collected on oral lesions. *Lesion location* was identified as inner lip commissure, outer lip commissure, bars of the mandible, buccal area near second upper premolar, tongue, or palate. *Lesion type* was recorded as a bruise (submucosal bleeding, but with the mucosa visually intact) (**Figures 1A–D**, **2A–C**) or a wound (mucosal injury) (**Figures 1E–I**, **2D–F**, **3A–F**) (11). We did not collect information on periostitis (bone spurs) in the bars (16, 21) or bit-induced second lower premolar abrasion (16). For each acute lesion, points from 1 to 10 were given based on lesion type, size and depth as described in detail in Tuomola et al. (11). Points were added together to form a lesion score determining the lesion severity status of each horse: A (no acute lesions) 0 points, B (mild lesion status) 1–2 points, C (moderate lesion status) 3–11 points, except horses with 8 points from one single lesion, or D (severe lesion status) over 11 points and horses with 8 points from one single lesion (11) (**Supplementary Material 1**). Wounds with signs of chronicity were graded as acute if the lesion was visibly red and incompletely healed (**Figures 1E,F**, **3C,E,F**). *Old lesions* were recorded separately as scars, old wounds, old bruises, or depigmentation of the outer lip commissures (**Figures 4A–C**).

Other recorded variables were breed (warmblood, coldblood, or pony), sex and age of the horse, and competition level described as jump height in centimeters. The name of the rider (anonymized for the data analysis) and performance at the current event (placing, no placing, or no final result because the horse did not finish the cross-country test) were verified from the SRL online show management database (KIPA).

Variables related to bit were bit type (basic double-jointed, formed double-jointed, single-jointed, unjointed, Myler type, Waterford or other), bit thickness in millimeters (mm), and bit leverage effect (yes/no). For example Baucher, Gag, and Olympia bits were considered to have a leverage effect. Any double-jointed bit with a distinctive design was considered to be formed. Bit names with distinctive designs or leverage effect are presented in **Supplementary Material 2**. Due to practical field constraints, bit thickness was measured adjacent to the bit ring with a vernier caliper for only 186 of the examined horses.

Variables related to noseband were noseband type (Cavesson, Cavesson with flash, Mexican, Micklem-type, Drop, or PS of Sweden High Jump or similar) and the presence of a lower noseband (yes/no). Other noseband types apart from Cavesson were considered to have a lower noseband.

FIGURE 1 | Bit-related inner lip commissure lesions; **(A)** bruise 2 points **(B)** bruise 2 points **(C)** bruise 2 points **(D)** bruise 3 points **(E)** wound 4 points **(F)** wound 6 points **(G)** wound 6 points **(H)** wound 6 points **(I)** wound 6 points.

Data Analysis

Data were analyzed statistically using Stata IC version 16 (Stata Corporation, Texas, US). For risk factor analysis, lesion severity categories A–D were merged into two categories: AB (no lesions or mild lesion status) (0–2 points) and CD (moderate or severe lesion status) (over 2 points). Three horse age categories (4–7, 8–12, or 13–19 years), three bit thickness categories (thin bits 10–13 mm, middle-sized bits 14–17 mm, or thick bits 18–22 mm), and three competition level categories (60–80, 90–95, or 100–120 cm) were created. Only ten horses competed at the international level (CCN2* or CCN3* with jump height 115 or 120 cm), and they were merged with the competition level category 110–120 cm. For logistic regression analysis, Myler type bits ($n = 8$) and Waterford bits ($n = 7$) were included in the group "other bit," as were Bombers 2½ cable bits ($n = 1$), Bombers single-jointed lock-up bits ($n = 1$), and bits without a type category ($n = 1$).

Univariable analyses of the associations between all potential risk factors and the outcome variable of interest (no lesions/mild lesion status vs. moderate/severe lesion status) were first evaluated using Pearson Chi-square or Fisher's exact tests (bit type) (**Table 1**). Relationships between potential risk factors (multicollinearity) were evaluated by pairwise associations. Breed or sex were not associated with bit type or bit thickness. Bit type and bit thickness were associated ($P < 0.001$), and only bit thickness was entered into the model as it was significantly associated with moderate/severe lesion status (**Table 1**). Breed and sex were associated so that the majority of stallions (11/13) were coldbloods. Stallions were therefore excluded from the logistic regression analysis. Bit thickness was not measured

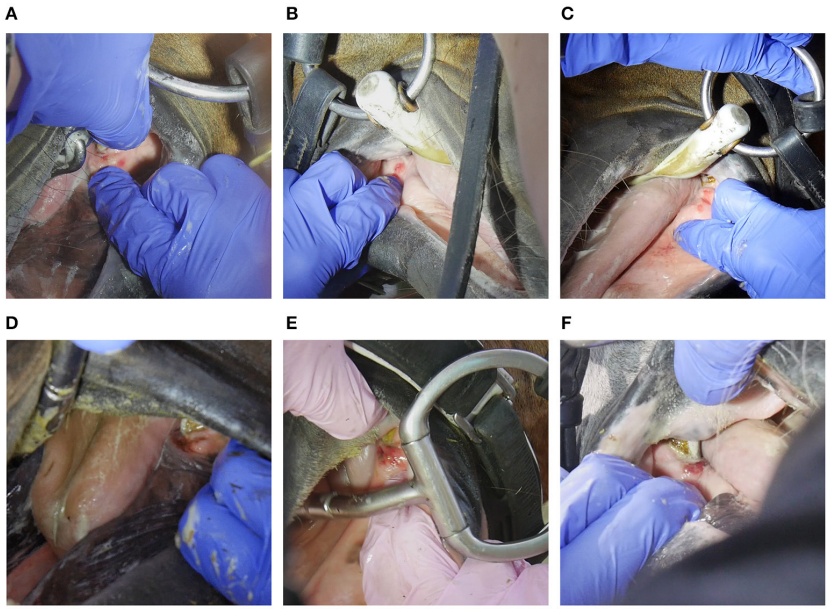


FIGURE 2 | Bit-related bar lesions; **(A)** bruise 1 point **(B)** bruise 2 points **(C)** bruise 3 points **(D)** wound 4 points **(E)** wound 6 points **(F)** wound 6 points.

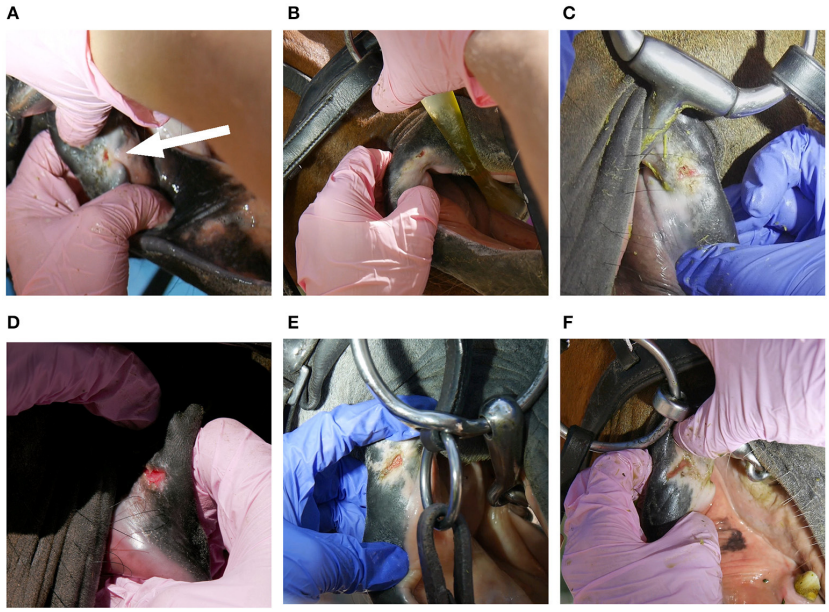


FIGURE 3 | Bit-related outer lip commissures lesions; **(A)** wound 4 points, Arrow: abnormal appearance of lip commissure due to old bit-related lesion. **(B)** Wound 4 points **(C)** wound 4 points **(D)** wound 6 points **(E)** wound 6 points **(F)** wound 6 points.

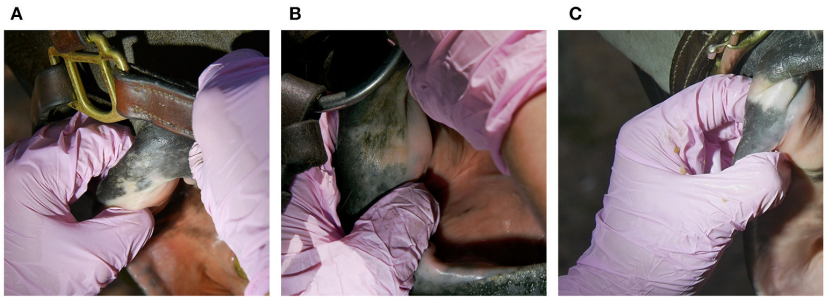


FIGURE 4 | Various degrees of pigment loss on outer lip commissures **(A–C)**. Prolonged bit pressure or previous inflammation may inhibit melanocyte function and cause depigmentation on areas that should normally be pigmented (22, 23).

for all horses ($n = 22$) so the logistic regression analysis was performed with 174 horses. These horses were ridden by 159 individual riders, thus the rider effect could not be reliably analyzed. Biologically relevant interactions were tested and none were found.

The logistic regression model (Model I) was built with manual stepwise backward and forward procedures and explanatory variables were eliminated until all remaining variables had an association with moderate/severe lesion status with a $P \leq 0.05$. At each step, the removed variables were evaluated for confounding effects by checking whether the coefficients for the remaining variables changed substantially. The Model I containing breed, sex, and bit thickness was evaluated using tests for sensitivity, specificity, ROC curve (Receiver Operating Characteristic) and goodness of fit and visually from the graphs of the residuals, leverage, and delta-betas per covariate pattern.

Because bit thickness was associated with bit type, we wanted to analyze horses wearing the same bit type and as a consequence double-jointed bitted horses ($n = 110$) were analyzed in a separate model (Model II) including breed, sex and bit thickness. The model building process and evaluation were performed as in Model I

Associations between lesion location and bit type were analyzed with Fisher's exact test. A $P < 0.05$ was considered statistically significant in all analyses.

RESULTS

The study included 208 horses: 127 warmbloods (predominantly part-breds), 52 coldblooded riding horses (49 of which were Finnhorses), and 29 ponies of various breeds. Sex distribution was 120 geldings, 75 mares, and 13 stallions. Ages ranged from 4 to 19 years (Median 10, Mean 10.7, SD 3.5). The majority of the horses competed at jump height level 60–80 cm (**Table 1**).

Oral Lesions

Of all horses, 52% (CI 45–59%) (109/208) had acute oral lesions in the bit area. Lesion status was no lesions for 48% (CI 41–55%) (99/208), mild for 22% (CI 16–28%) (45/208), moderate for 26% (CI 20–32%) (55/208), and severe for 4% (CI 1–7%) (9/208) of the horses. The results of the univariable analysis are presented in **Table 1**.

Bruises were found in 39% of all horses (82/208) and wounds in 19% (40/208). None of the wounds were graded as deep. If lesions were present, there was typically only one. The highest number of acute lesions observed in an individual horse was five (**Figure 5**). One horse had blood inside the mouth. This horse also had the highest lesion score (total points) 22 (**Figure 6**).

Old lesions were not included in logistic regression analysis, but it is worth noting that depigmentation of the outer lip commissures was observed in 52% (108/208) (**Figures 4A–C**), old wounds in 10% (20/208), old bruises in 5% (10/208), and old scars in 3% (6/208) of the horses.

Lesion location and Bit Type

The inner lip commissure was the most common lesion location, with 39% (81/208) of horses having lesions in this area (**Figures 1A–I**). Of all horses, 12% (24/208) had lesions in the bars (**Figures 2A–F**), 9% (18/208) in the outer lip commissures (**Figures 3A–F**) and 6% (12/208) in the buccal area near the first upper cheek teeth. Only two horses had tongue lesions, located at the lateral edges. No lesions were present on the palate. The double-jointed bit was the most common bit type, present in 65% of the horses. Bar lesions were more common in horses with unjointed bits (40%, 8/20) than with basic double-jointed (10%, 5/52), formed double-jointed (8%, 6/78) or single-jointed bits (5%, 2/40) (Fisher's exact test, $P = 0.002$). Six unjointed bits had ports, and three horses wearing ported unjointed bits had bar lesions. Three of the Myler-type bitted horses (3/8) and none of the Waterford bitted horses (0/7) had bar lesions, but such a small subsample size does not allow for definitive conclusions. Bit type was unassociated with outer lip (Fisher's exact test, $P = 0.5$) or inner lip commissure lesions (Fisher's exact test, $P = 0.8$).

Logistic Regression Model

Model I containing breed, sex, and bit thickness was statistically significant ($N = 174$, χ^2 26.0, $P < 0.001$) indicating that the model was able to distinguish between lesion status AB and CD. Results of the Model I, in **Table 2**, are presented as odd ratios (OR) and with a 95% confidence interval (CI). Model sensitivity

TABLE 1 | Event horses ($N = 208$) and their risk factors for moderate or severe oral lesion status.

Variable	Category	*n*	Moderate/ severe lesion status horses	% (95% CI)	*P*-value
Breed					0.003
	Warmblood	127	37	29 (21–37)	
	Coldblood	52	24	46 (32–60)	
	Pony	29	3	10 (0–21)	
Sex					0.01
	Mare	75	29	39 (28–50)	
	Stallion	13	7	54 (27–81)	
	Gelding	120	28	23 (15–31)	
Age (years)					0.7
	4–7	39	10	26 (12–40)	
	8–12	106	34	32 (23–41)	
	13–19	63	20	32 (20–44)	
Noseband type					0.4
	Cavesson	33	10	30 (14–46)	
	Cavesson with flash	63	19	30 (19–41)	
	Micklem	32	6	19 (5–33)	
	Mexican	43	17	40 (25–55)	
	Drop	16	5	31 (19–43)	
	PS of Sweden high jump	15	7	47 (22–72)	
	Missing value	6			
Lower noseband					> 0.9
	Yes	169	54	32 (25–39)	
	No	33	10	30 (14–36)	
	Missing value	6			
Bit type					0.2
	Double-jointed basic	78	17	22 (13–31)	
	Double-jointed formed	52	17	33 (20–46)	
	Single-jointed	40	16	40 (25–35)	
	Unjointed	20	9	45 (23–67)	
	Myler type	8	3	38 (4–72)	
	Waterford	7	2	29 (0–63)	
	Other	3	0	0	
Bit thickness (mm)					0.007
	10–13	38	16	42 (26–58)	
	14–17	107	23	22 (14–30)	
	18–22	41	18	44 (29–59)	
	Missing value	22			
Leverage					0.9
	Yes	57	18	32 (20–40)	
	No	150	46	31 (24–38)	
	Missing value	1			
Competition level (cm)					0.9
	60–80	103	30	29 (20–38)	
	90–95	62	20	32 (20–44)	
	100–120	43	14	33 (19–47)	
Placement					0.8
	Placement	65	18	28 (17–39)	
	No placement	122	39	32 (24–40)	
	No result	21	7	33 (13–53)	

The results of the univariable analysis in Pearson Chi-square test. Bit type was tested with Fisher's exact test. All predictors were tested against the outcome: no lesions or mild lesion status vs. moderate or severe lesion status. Thirty-one percent of all horses had moderate/severe lesion status.

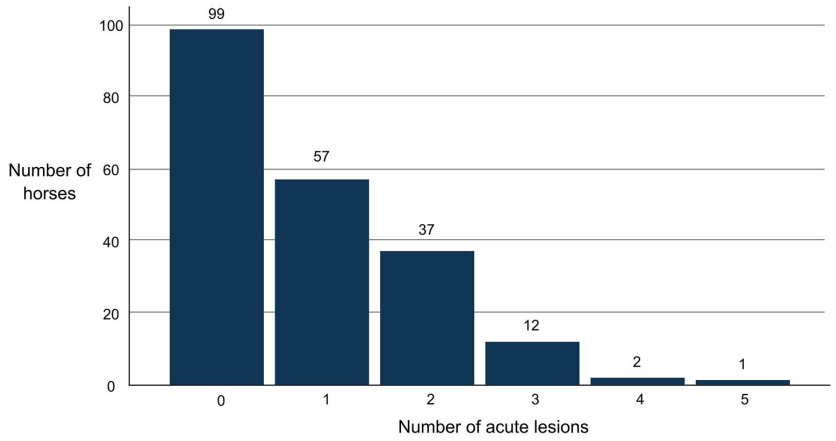


FIGURE 5 | Number of acute bit-related lesions on event horses ($N = 208$) after a cross-country test.

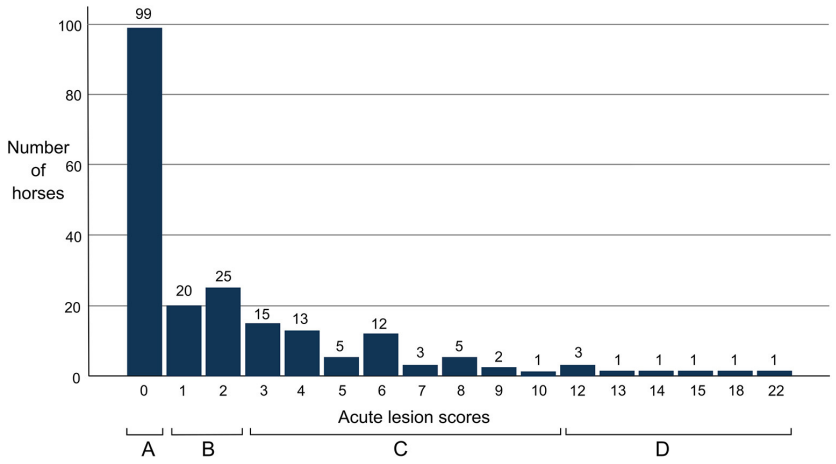


FIGURE 6 | Acute lesion scores (total lesion points) and lesion severity status for event horses ($N = 208$) after a cross-country test.

was 37% and specificity was 85%. The model correctly classified 71% of the cases. The area under the ROC curve was 73% (CI 65–80%, $P < 0.001$). Pearson's goodness of fit test supported the model (χ^2 10.4, $P = 0.5$).

Horses wearing thin (OR 3.5, CI 1.4–8.7) or thick (OR 3.4, CI 1.4–8.0) bits had a higher risk of moderate/severe lesion status than horses wearing middle-sized bits (reference group) ($P = 0.003$). However, bit thickness was associated with bit type so that double-jointed bits were mostly middle-sized and unjointed bits were mostly thick ($P < 0.001$) (**Table 3**). Moderate/severe lesion status was observed less in horses wearing basic double-jointed bits, but the result was statistically non-significant.

Breed was associated with moderate/severe lesion status ($P = 0.02$). The risk of moderate/severe lesion status was lower for ponies (OR 0.2, CI 0.04–0.87) than warmbloods (reference group) and coldbloods (OR 2.0, CI 0.88–4.7). The difference between coldbloods and warmbloods was not statistically significant. Mares were at higher risk (OR 2.2, CI 1.1–4.5) than geldings (reference group) ($P = 0.03$) (**Table 2**).

In Model II, only horses wearing various double-jointed bits ($n = 110$) were analyzed. Horses wearing either thin ($n = 13$, OR 4.3, CI 1.3–14) or thick ($n = 17$, OR 4.5, CI 1.2–17) bits had a higher risk of moderate/severe lesion status than horses wearing middle-sized (14–17 mm) bits ($n = 80$) ($P = 0.01$). In Model II sex ($P = 0.2$) and breed

TABLE 2 | Event horses ($N = 174$) and their risk factors for moderate or severe (CD) oral lesion status vs. no lesion or mild lesion (AB) status in the bit area.

Variable	Category	*n*	Moderate/ severe lesion status horses (%)	OR	95% CI	*P*-value
Breed						0.02
	Warmblood	109	34 (31)	Reference		
	Coldblood	39	15 (39)	2.0	0.88–4.7	0.1
	Pony	26	2 (8)	0.2	0.04–0.87	0.03
Sex						0.03
	Gelding	106	25 (24)	Reference		
	Mare	68	26 (38)	2.2	1.1–4.5	
Bit thickness (mm)						0.003
	14–17	102	20 (20)	Reference		
	10–13	34	14 (41)	3.5	1.4–8.7	0.007
	18–22	38	17 (45)	3.4	1.5–8.0	0.004

The results of the logistic regression analysis for the Model I containing breed, sex, and bit thickness. Thirty-one percent of all horses in the study had moderate/severe lesion status.

TABLE 3 | Bit type and bit thickness were associated ($P < 0.001$).

Bit type	*n*	10–13 mm (%)	14–17 mm (%)	18–22 mm (%)
Double-jointed basic	66	11 (17)	45 (68)	10 (15)
Double-jointed formed	49	6 (12)	38 (78)	5 (10)
Single-jointed	37	9 (24)	16 (43)	12 (32)
Unjointed	17	3 (18)	2 (12)	12 (71)
Other	17	9 (53)	6 (35)	2 (12)

Some bit types are only available in certain thicknesses. Double-jointed bits were mostly middle-sized and unjointed bits were mostly thick (n = 186).

($P = 0.09$) were not significantly associated with moderate/severe lesion status.

Horse Age, Noseband, Bit Leverage, Competition Level and Performance

All horses wore a noseband, and 84% (169/202) of horses wore an additional lower noseband. Noseband type, presence of lower noseband, bit leverage, horse age, competition level or competition performance (placement, no placement, or no result) were not associated with moderate/severe lesion status (**Table 1**).

DISCUSSION

Acute lesions in the bit area were observed in 52% of the event horses after a cross-country test. Lesion status was moderate for 26% of the horses, severe for 4% of the horses. Horses wearing thin or thick bits, mares, and horse breeds were at higher risk of moderate or severe oral lesion status in the bit area. Horses wearing unjointed bits were at higher risk of bar lesions than horses wearing jointed bits.

This study has certain limitations. First, we did not have control over the bit types as the study was executed on a competition setting where the bit selection is made by the participants. The examination was voluntary. Nevertheless, the participation rate for the study (95%) was very high, and the sample represents 25% (208/831) of the Finnish event horses competing in 2018–2019. Second, the horses had competed in dressage and show jumping the day before. If some lesions had occurred during those performances or from earlier training and were still exhibiting as acute lesions, they could have been unrelated to but possibly aggravated by the bit type worn during the cross-country phase. Third, noseband tightness was not measured to minimize inconvenience to the competitors. Noseband tightness has been previously linked with outer lip commissure lesions (13). However, noseband type and the presence of a lower noseband were recorded and we did not find evidence of an association between noseband and moderate/severe lesion status. Finally, the small sample size of coldbloods and other than double-jointed bits may prevent detection of their potential risk regarding moderate/severe lesion status (type II error).

Even though a high occurrence of oral lesions were found in this post-competition sample of Finnish event horses, the occurrence was lower than in trotters in Finland (84%) and Sweden (88%) (11, 14). The current study results are in accordance with bit-related lesions observed in Icelandic horses in 2012 (60%) and 2016 (43%) (9, 10) but differ from results from 2014 when lesion prevalence was 33% (10). The proportion of horses with severe lesion status was smaller in event horses (4%) than in trotters (20%) (11). Likewise, moderate lesion status was less common in event horses (26%) than among trotters (43%), but mild lesion status was as common in event horses (22%) as in trotters (21%) (11). Severe lesions were reported in 8% of Icelandic horses, but this result cannot be compared to the present study due to different grading systems (9). In the Icelandic study a mucosal ulcer larger than 1 cm was graded as severe (9) in contrast to the present study where an ulcer of that size was graded as moderate if it was not deep and not reaching 3 cm in diameter. In the present study, no bleeding was observed outside the mouth, and blood was observed inside the mouth in one horse (0.5%), which was less than in trotters (12%) (11).

These differences in lesion severity status and blood occurrence might be explained by differences between the two sports. For example in Finland, 16 horses may compete simultaneously in harness racing, in contrast to eventing, where the horse is performing alone. Close proximity of unfamiliar horses in harness racing may increase anxiety in horses (24). Furthermore, the driver is able to lean fully backwards in the sulky while supporting the feet against the footrests. Sudden forceful or high rein tension due to the above mentioned reasons may predispose trotters to oral trauma.

Bruises were more common than wounds. The inner lip commissure was the most common lesion location, corresponding to findings in a previous study of trotters (11). In the present study no association was found between inner lip commissure or buccal lesions and bit type in contrast to the study where Icelandic horses competing with snaffle bits ($n = 26$) had higher risk of buccal lesions (62%) (buccal lesions in that study included inner lip commisure lesions) than horses competing with curb bits with a port ($n = 45$) 13% (9). Outer lip commissure lesions were observed in 9% of the horses. This finding is similar to studies of Danish riding horses (9%, $N = 3{,}143$) and Finnish trotters (6%, $N = 264$) (11, 13). Various degrees of depigmentation, indicating prolonged bit pressure or previous inflammation (22, 23), was more common in event horses (52%) than in trotters (10%) (11).

Bar lesions were observed in 12% of the horses. Horses wearing unjointed bits had more bar lesions mesial to second lower premolar teeth than did other horses, which aligns with observations concerning trotters (15). When pressure is applied to the bit, mucosal tissue may get pressed and pinched or lacerated between the bit and the mesial surface of the second lower premolar (25). In Icelandic horses ($n = 77$), bar lesions increased from 8 to 31% during competition and were associated with using curb bits (unjointed and jointed) with ports (9). In trotters, bar lesions were observed in 26% after a race (11). In a study of ridden and non-ridden horses (70 riding horses and ponies, 23 riding horses examined after 5 weeks of rest and after 7 weeks of work, and 20 broodmares), none had bar ulcerations (17). Therefore, it is possible that, in addition to unjointed bit types, factors relating to competitions or comparable training sessions increase the occurrence of bar lesions.

Horses competing with bits categorized as either thin or thick were at higher risk of moderate and severe lesions. Several mechanisms can explain this finding. First, thin bits may cause increased pressure on a relatively small area. One aspect of the mouthpiece's severity is its inverse relation to its diameter (26) as pressure is the amount of force applied to a certain area ($P = \mathrm{F/A}$) (27). Second, the distance between the maxilla and the mandible varies individually, ranging between 25 and 43 mm in horses and 25 and 39 mm in ponies (28). This distance was not measured in the current study, making it difficult to estimate whether the recorded bit was too thick to fit the individual. It has been suggested that thick bits may cause more discomfort in horses with small oral cavities (29). Third, double-jointed bits were overrepresented in the middle-sized bit category, while the thin and thick bit categories included relatively more single-jointed and unjointed bits meaning that thickness is a feature of a particular bit type. However, performing a more narrow analysis of horses with various double-jointed bits showed that middle-sized bits were still associated with a lower moderate/severe lesion status risk. Finally, according to the authors' perceptions, 14–17-mm double-jointed bits are commonly used for riding in Finland. It is plausible that riders revert to other bit types or sizes than the commonly used 14–17-mm double-jointed bit when their horses show conflict behavior or reduced rideability, which may be related to increased rein tension (30–32). The way that bit thickness was associated with lesion severity was surprising and needs further verification in a larger sample of horses.

Horse breed and sex were associated with moderate/severe lesion status risk. The risk was lower for ponies than for warmbloods and coldbloods. In previous studies, ponies have exhibited less oral lesions in riding disciplines and harness racing (13, 15, 17). Mares were at higher risk of moderate/severe lesion status than geldings. This finding is in line with that of trotters (15). Different rein tension resulting from differences in horse handling (17, 33), education level (34), pain sensation (35), anxiousness (36, 37), or excitability (37) is a possible mechanism behind these results for mares and ponies. Ponies are typically ridden by children, who have less physical strength to apply to rein tension than adults (17). As for mares, literature suggests that sex-based stereotypes may compromise mare welfare if their behavior is interpreted arising from gendered beliefs or if pain-related behaviors are ignored (33). For both subgroups, differences in mucosal wound susceptibility or healing capacity cannot yet be ruled out, as wound healing is faster in ponies than in horses (38) and, in humans, oral mucosal wound healing capacity is slower in women than in men (39).

Other variables were unassociated with moderate/severe lesion status. Most event horses in our present study competed nationally at a low difficulty level (60–80 cm). Oral lesions were unconnected to competition level, in contrast to a Danish study where the number of commissure lesions increased with competition level (13).

Good performance is still often held as an indicator of good welfare (40). Evidence of association between lesion status and competition placement was not found in the present study and a previous study (15) also showed no association with race performance. Therefore, well performing horses are not necessarily free from welfare concerns.

CONCLUSIONS

If the size of the horse's oral cavity is not known, it is advisable to choose a middle-sized jointed bit and pay attention to handling of mares and warmblooded and coldblooded horses since this study suggests that horses wearing thin or thick bits as well as mares, warmblooded and coldblooded horses had an elevated risk of moderate or severe oral lesion status compared with horses wearing middle-sized bits, geldings, and ponies. Furthermore, horses wearing unjointed bits were at higher risk to get bar lesions than horses wearing jointed bits.

We encourage adopting bit area monitoring as a new routine by horse handlers and as a welfare measure by competition

organizers for randomly drawn horses since oral lesions in the bit area were common after a competition even though no external bleeding was observed. In riding horses bit-related lesions can be monitored in competition environment with systematic oral examination by using a headlamp, unlatching nosebands and possible curb chain, and lifting the bit while examining the bars of the mandible.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The animal study was reviewed and approved by University of Helsinki Viikki Campus Research Ethics Committee. Written informed consent for participation was not obtained from the owners because The participants received information concerning the study upon online registration for competitions and from an information leaflet pertaining to the study handed out on the 1st day when they checked in at the competition office. The examination was voluntary for the participants. Consent for the examination was asked orally due to field conditions in competitions. Anonymity of the riders was maintained.

AUTHOR CONTRIBUTIONS

KT contributed to the study design, performed the oral examinations, data collection and analyses, and preparation of the manuscript. MK–W and KT performed the statistical analysis, have had full access to all data in the study and take responsibility for the integrity of the data, and the accuracy of the data analysis. NM–K recorded all the findings, contributed to data collection, and manuscript preparation. MK–W, AV, and AM contributed to interpreting the results and manuscript preparation. All authors have read and approved the final manuscript.

FUNDING

The study was funded by the Finnish Cultural Foundation (Pirkanmaa Regional Fund), Orion Research Foundation, The Finnish Foundation of Veterinary Research, The Finnish Veterinary Foundation (Mercedes Zachariassen Foundation), Juliana von Wendt Foundation, SEY Animal Welfare Finland (Heli Castrén grant), and the Doctoral School in Health Sciences, University of Helsinki.

ACKNOWLEDGMENTS

The authors are grateful to The Equestrian Federation of Finland (SRL), competition organizers and to horse owners and riders for their positive attitude and interest shown toward the study. We thank Kirsi Norkio and Tuula Tuomola for assistance at the competition venue.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fvets.2021.651160/full#supplementary-material

Supplementary Material 1 | Scoring of oral lesions. Estimate lesion size and type. See points at intersection and estimate depth of wound. From each lesion count the points together to form lesion score for the horse. Lesion score determines the severity category of the oral lesion status A (no acute lesions), horses with 0 points; B (mild lesion status), horses with 1–2 points; C (moderate lesion status), horses with 3–11 points, but excluding horses with eight points from one single lesion; and D (severe lesion status), horses with 12 or more points and horses with eight points from one single lesion (11).

Supplementary Material 2 | Bit names with distinctive designs or leverage effect.

REFERENCES

1. McLean AN, McGreevy PD. Horse-training techniques that may defy the principles of learning theory and compromise welfare. *J Vet Behav Clin Appl Res.* (2010) 5:187–95. doi: 10.1016/j.jveb.2010.04.002
2. Campbell MLH. Freedoms and frameworks: How we think about the welfare of competition horses. *Equine Vet J.* (2016) 48:540–2. doi: 10.1111/evj.12598
3. Mellor DJ. Mouth pain in horses: physiological foundations, behavioural indices, welfare implications, and a suggested solution. *Animals.* (2020) 10:572. doi: 10.3390/ani10040572
4. Haggard P, de Boer L. Oral somatosensory awareness. *Neurosci Biobehav Rev.* (2014) 47:469–84. doi: 10.1016/j.neubiorev.2014.09.015
5. Nanci A, Wazen R. Repair regeneration of oral tissues. In: Nanci A, editor. Ten *Cate's Oral Histology. Development, Stucture Function.* St. Louis, MO: Elsevier, Mosby Inc (2013). p. 278–340.
6. Mellor DJ. Updating animal welfare thinking: moving beyond the five freedoms towards a life worth living. *Animals.* (2016) 6:21. doi: 10.3390/ani6030021
7. Farm Animal Welfare Council. *Report on Priorities for Animal Welfare Research and Development*. Tolworth Tower: Ministry of Agriculture, Fisheries and Food (1993).
8. Easley J. Applied bitting to dental disease. In: *Proceedigs of the AAEP Focus Meeting on Dentistry*. Albuquerque, NM: American Association of Equine Practitioners (2011). p. 209–212.
9. Björnsdóttir S, Frey R, Kristjansson T, Lundström T. Bit-related lesions in Icelandic competition horses. *Acta Vet Scand.* (2014) 56:40. doi: 10.1186/s13028-014-0040-8
10. Björnsdóttir S, Frey R, Kristjansson T, Lundström T. *Welfare Indicator for Competition Horses. Bit-Related Lesions in Poster Presentation.* Bergen: Nordic Equine Veterinary Congress (2018).
11. Tuomola K, Mäki-Kihniä N, Kujala-Wirth M, Mykkänen A, Valros A. Oral lesions in the bit area in finnish trotters after a race: lesion evaluation, scoring and occurrence. *Front Vet Sci.* (2019) 6:206. doi: 10.3389/fvets.2019.00206
12. Mata F, Johnson C, Bishop C. A cross-sectional epidemiological study of prevalence and severity of bit-induced oral trauma in polo ponies and race horses. *J Appl Anim Welf Sci.* (2015) 18:259–68. doi: 10.1080/10888705.2015.1004407
13. Uldahl M, Clayton H. Lesions associated with the use of bits, nosebands, spurs and whips in Danish competition horses. *Equine Vet J.* (2019) 51:154–62. doi: 10.1111/evj.12827
14. Odelros E, Wattle O. *Influence of Racing on Oral Health in Standardbred Trotters. Abstract in Poster Presentation.* Bergen: Nordic Equine Veterinary Congress. (2018).

15. Tuomola K, Mäki-Kihniä N, Valros A, Mykkänen A, Kujala-Wirth M. Risk factors for bit-related lesions in Finnish trotting horses. *Equine Vet J.* (2021) 1–9. doi: 10.1111/evj.13401
16. Cook WR. Damage by the bit to the equine interdental space and second lower premolar. *Equine Vet Educ.* (2011) 23:355–60. doi: 10.1111/j.2042-3292.2010.00167.x
17. Tell A, Egenvall A, Lundström T, Wattle O. The prevalence of oral ulceration in Swedish horses when ridden with bit and bridle and when unridden. *Vet J.* (2008) 178:405–10. doi: 10.1016/j.tvjl.2008.09.020
18. Foster DL. The gold standard of dental care for the adult performance horse. *Vet Clin North Am Equine Pract.* (2013) 29:505–19. doi: 10.1016/j.cveq.2013.04.012
19. Mayhew E. *The Illustrated Horse Doctor*. Philadelphia, PA: J. B Lippincott & Co. (1862).
20. Russell M. How "pullers" are made- a study of methods of bitting the colt. *San Fr Call.* (1893) 75:15.
21. van Lancker S, van den Broeck W, Simoens P. Incidence and morphology of bone irregularities of the equine interdental spaces (bars of the mouth). *Equine Vet Educ.* (2007) 19:103–6. doi: 10.2746/095777307X179882
22. Scott DW, Miller WH. Pigmentary abnormalities. In: Kersey R, editor. *Equine Dermatology*. St. Louis, MO: Saunders, Elsevier Science (2003). p. 591–5.
23. Knottenbelt DC. Iatrogenic and idiopathic disorders. In: *Pascoe's Principles and Practice of Equine Dermatology*. London: Saunders Elsevier (2009). p. 335–8.
24. König U, Visser EK, Hall C. Indicators of stress in equitation. *Appl Anim Behav Sci.* (2017) 190:43–56. doi: 10.1016/j.applanim.2017.02.018
25. Scoggins RD. Bits, bitting and dentistry. In: *Proceedings of the Annual Convention of the AAEP*. San Diego, CA (2001). p. 138–51.
26. Bennett DG. An overview of bits and bitting. In: *AAEP Focus Meeting*. Indianapolis, IN (2006).
27. International review. *Pressure Ulcer Prevention: Pressure, Shear, Friction and Microclimate in Context. A Consensus Document*. London: Wounds International (2010).
28. Engelke E, Gasse H. An anatomical study of the rostral part of the equine oral cavity with respect to position and size of a snaffle bit. *Equine Vet Educ.* (2003) 15:158–63. doi: 10.1111/j.2042-3292.2003.tb00235.x
29. Clayton HM, Lee R. A fluoroscopic study of the position and action of the jointed snaffle bit in the horse's mouth. *J Equine Vet Sci.* (1984) 4:193–6. doi: 10.1016/S0737-0806(84)80141-0
30. Fenner K, Mclean AN, Mcgreevy PD. Cutting to the chase: how round-pen, lunging, and high-speed liberty work may compromise horse welfare. *J Vet Behav.* (2019) 29:88–94. doi: 10.1016/j.jveb.2018.05.003
31. Christensen JW, Zharkikh TL, Antoine A, Malmkvist J. Rein tension acceptance in young horses in a voluntary test situation. *Equine Vet J.* (2011) 43:223–8. doi: 10.1111/j.2042-3306.2010.00151.x
32. König von Borstel U, Glißman C. Alternatives to conventional evaluation of rideability in horse performance tests: suitability of rein tension and behavioural parameters. *PLoS ONE.* (2014) 9:e87285. doi: 10.1371/journal.pone.0087285
33. Fenner K, Caspar G, Hyde M, Henshall C, Dhand N, Probyn-Rapsey F, et al. It's all about the sex, or is it? Humans, horses and temperament. *PLoS ONE.* (2019) 14:e216699. doi: 10.1371/journal.pone.0216699
34. McLean AN, Christensen JW. The application of learning theory in horse training. *Appl Anim Behav Sci.* (2017) 190:18–27. doi: 10.1016/j.applanim.2017.02.020
35. Frot M, Feine JS, Bushnell MC. Sex differences in pain perception and anxiety. A psychophysical study with topical capsaicin. *Pain.* (2004) 108:230–6. doi: 10.1016/j.pain.2003.11.017
36. Duberstein KJ, Gilkeson JA. Determination of sex differences in personality and trainability of yearling horses utilizing a handler questionnaire. *Appl Anim Behav Sci.* (2010) 128:57–63. doi: 10.1016/j.applanim.2010.09.012
37. Lloyd AS, Martin JE, Bornett-Gauci HLI, Wilkinson RG. Horse personality: variation between breeds. *Appl Anim Behav Sci.* (2008) 112:369–83. doi: 10.1016/j.applanim.2007.08.010
38. Wilmink JM, Stolk PWT, Weeren PR, Barneveld A. Differences in second-intention wound healing between horses and ponies: macroscopic aspects. *Equine Vet J.* (1999) 31:53–60. doi: 10.1111/j.2042-3306.1999.tb03791.x
39. Engeland CG, Bosch JA, Cacioppo JT, Marucha PT. Mucosal wound healing: the roles of age and sex. *Arch Surg.* (2006) 141:1193–7. doi: 10.1001/archsurg.141.12.1193
40. Heleski CR, Anthony R. Science alone is not always enough: the importance of ethical assessment for a more comprehensive view of equine welfare. *J Vet Behav.* (2012) 7:169–78. doi: 10.1016/J.JVEB.2011.08.003

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

ISBN 978-951-51-8033-9 (PRINT)
ISBN 978-951-51-8034-6 (ONLINE)
ISSN 2342-3161 (PRINT)
ISSN 2342-317X (ONLINE)
http://ethesis.helsinki.fi

HELSINKI 2022