Universität Zürich UZH
Universität Bern

Klinik für Bildgebende Verfahren / Departement für Pferde / Vetsuisse-Fakultät Zürich

Back health of Swiss riding horses

Association of diagnostic imaging findings in the cervical spine with epidemiologic factors and clinical findings

Masterthesis
Chantal Blättler

under supervision of
Prof. Dr. med. vet. Stefanie Ohlerth
Prof. Dr. med. vet. Michael Weishaupt
Dr. sc. Marie Dittmann
Dr. med. vet. José Suárez Sánchez-Andrade
Dr. med. vet. Selma Latif
Samuel Arpagaus

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ACCREDITED BY EAEVE / FVE
Universität Bern | Universität Zürich
vetsuisse-fakultät

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1 Abstract

Diagnostic imaging plays a major role in the evaluation of back and neck problems in horses. Radiography of the cervical spine allows identification of bony changes of the vertebral body (new bone formation, fractures, developmental disorders, malformations) and the articular process joints (osteoarthritis, developmental disorders). Ultrasonography is used for the assessment of soft tissue disorders (musculature, ligaments), but is also commonly applied to diagnose synovitis of the articular process joints in the back and neck. Imaging findings, prevalence and potential clinical symptoms of osteoarthritis of the articular process joints in the equine neck have been reported previously. However, the prevalence and significance of radiographic changes of the articular process joints has not been determined in horses, which are in normal use, i.e. riding sound horses. Moreover, the relevance of epidemiological factors and orthopaedic findings in the equine neck has not been investigated in detail in riding sound horses. Such data may reveal important information about the normal or subclinical variations in radiographic and ultrasonographic findings.

The purpose of the present study was therefore to investigate the health status of the cervical spine in riding sound Swiss riding horses, i.e. to determine the prevalence of radiographic and ultrasonographic changes, and to associate these findings with epidemiological factors and orthopaedic findings.

In a field study, 237 riding sound horses underwent a clinical orthopaedic and an orthopaedic examination. Thereof, 71 horses were randomly selected to be radiographically and ultrasonographically examined at the University of Zurich. Imaging findings (radiographic and ultrasonographic osteoarthritis scores) were correlated with epidemiologic and clinical data.

The majority of the 237 riding sound horses included in this study showed gait asymmetries above grade 1 and one third of the owners had noticed stiffness in their horses. In the subgroup of 71 horses, osteoarthritis was mainly seen in the caudal region of the cervical spine, with the most severe osteoarthritis scores occurring in the joints between the 6^{th} and 7^{th} cervical vertebrae, both on radiographic and ultrasonographic evaluation. Positive correlations between osteoarthritis scores and asymmetrically restricted active lateral flexion of the neck in the clinical examination were found. Some associations were found between osteoarthritis scores and epidemiological factors, such as age, withers height, weight and breed. Ultrasonography appeared more sensitive for the detection of clinically relevant osteoarthritis of the articular process joints in the neck. the imaging findings and epidemiological factors, such as age, withers height, weight and breed.

These results suggest that there is only a limited association between clinical and imaging findings when it comes to osteoarthritis of the equine cervical spine. This implies that radiographically and ultrasonographically visible defects or changes do not always lead to clinical signs.

2 Zusammenfassung

Bildgebende Verfahren spielen bei der Aufarbeitung von Rücken- und Halsproblemen beim Pferd eine wesentliche Rolle. Die Röntgenuntersuchung der Halswirbelsäule ermöglicht die Darstellung von knöchernen Veränderungen der Wirbelkörper (Zubildungen, Frakturen, Entwicklungsstörungen, Missbildungen) und der kleinen Wirbelgelenke (Osteoarthritis, Entwicklungsstörungen). Für die Untersuchung der Weichteile des Rückens (Muskulatur, Bänder) und des Randbereichs der kleinen Wirbelgelenke wird häufig die Ultraschalluntersuchung eingesetzt. Befunde aus der Bildgebung, Prävalenz und potentielle klinische Symptome von Osteoarthritis der kleinen Wirbelgelenke bei Pferden wurden bereits beschrieben. Jedoch wurden die Prävalenz und Bedeutung von radiografischen und ultrasonographischen Veränderungen der kleinen Wirbelgelenke in Pferden, welche von ihren Reitern als leistungsfähig eingeschätzt werden (also Reiter-gesunde Pferde), noch nicht ermittelt. Ausserdem wurde die Relevanz von epidemiologischen Faktoren und klinischen Befunden des Halses von Reiter-gesunden Pferden noch nicht detailliert untersucht. Dies könnte wichtige Informationen über die normalen oder subklinischen Variationen von radiographischen und ultrasonographischen Befunden offenlegen.

Das Ziel der vorliegenden Studie war daher, den Gesundheitsstatus der Halswirbelsäule von Schweizer Reitpferden, die in Bezug auf ihre Nutzung und ihren Einsatz von ihren Reitern als gesund eingeschätzt wurden (Reiter-gesund), sowie die Prävalenz von radiographischen und ultrasonographischen Veränderungen, zu ermitteln. Zudem sollten diese Befunde mit epidemiologischen Faktoren und klinischen Befunden assoziiert werden.

In einer Feldstudie wurden 237 reiter-gesunde Pferde einer klinisch-orthopädischen Untersuchung unterzogen. Davon wurden bei 71 Pferden die Halswirbelsäule an der Universität Zürich radiologisch und ultrasonographisch untersucht. Daten der bildgebenden Untersuchung (radiographic and ultrasonographic osteoarthritis scores) wurden mit Daten der orthopädischen Untersuchung (z.B. eingeschränkte Lateroflexion des Halses, Lahmheit) auf Korrelationen untersucht.

Die Mehrheit der vorgestellten Reiter-gesunden Pferde wiesen eine Gangasymmetrie von mindestens Grad 1 auf und ein Drittel der Besitzer gab an, dass ihr Pferd Anzeichen von Steifheit zeigte. In der Bildgebung wurden Veränderungen besonders in der caudalen Region der Halswirbelsäule gefunden, und die höchsten Scores wurden für das Gelenk zwischen sechstem und siebtem Halswirbel, auf dem Röntgen und im Ultraschall, vergeben. Positive Korrelationen wurden zwischen den Befunden der bildgebenden Verfahren und asymmetrischer Einschränkung der Lateroflexion des Halses gefunden. Zudem gab es statistische Zusammenhänge, zwischen Befunden aus den bildgebenden Verfahren und epidemiologischen Faktoren, wie Alter, Widerristhöhe, Gewicht und Rasse.

Diese Resultate zeigen, dass in der Halswirbelsäule des Pferdes nur in begrenztem Ausmass Zusammenhänge zwischen klinischen Befunden und Befunden aus bildgebenden Verfahren gibt und dass Defekte und Veränderungen, welche auf Röntgenbildern oder im Ultraschall sichtbar sind, nicht immer symptomatisch sind.

3 Introduction

3.1 Anatomy of the equine cervical spine

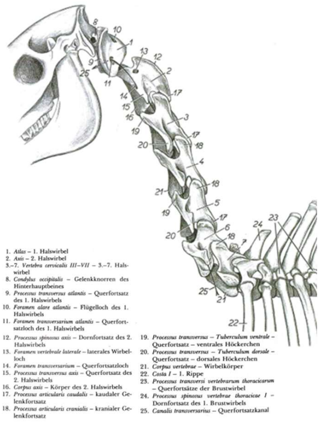

Figure 1: Skeleton of the equine neck, view from the left [Popesko, 7th edition, image 153]

The seven cervical vertebrae of the equine spine are located in the ventral part of the neck, just above the jugular furrow. The first cervical vertebra (C1), the atlas, is a ring-shaped bone consisting of a dorsal and ventral arch that meet laterally to form the wings of the atlas. The second cervical vertebra (C2), the axis, features a prominent, dorsally convex spinous process and a strong, odontoid peg, called the dens axis [001]. The remaining five cervical vertebrae (C3 - C7) are more uniform in morphology. They consist of a ventral body and a dorsal arch with two lateral transverse processes (each with a ventral and dorsal tubercle), two cranial and caudal articular processes and one spinous process (more prominent in the more caudal vertebrae). The caudal articular processes point ventro-laterally and articulate with the cranial articular processes (pointing dorso-medially) of the following vertebra. The ventral tubercle of C6 is elongated into a ventral lamina. All vertebrae together form the vertebral canal surrounding the spinal cord. The spinal nerves exit the canal through the intervertebral foraminae between two neighbouring vertebrae [002].

The atlantooccipital joint is composed of the convex occipital condyles (lateral to the foramen magnum) and the cranial articular cavities of the atlas. The atlantoaxial joint is formed by the dens axis protruding into the atlas and articulating with the fovea dentis. The remaining cervical vertebrae are connected by an articular process joint (APJ) on each side and an intervertebral disc (IVD) located between the vertebral bodies [001]. The APJs are situated directly dorsally to the intervertebral foramina and represent oval shaped synovial joints, formed by the cranial and caudal articular processes of C2 to C7 [003]. The opposing articular surfaces are relatively flat and covered by articular cartilage, that is substantially less stiff under compression than in other joints, probably because APJs are under less compressive loads than other joints [004]. The dense fibrous joint capsule features four (cranial, caudal, lateral and medial) outpouches, which follow the contours of the vertebrae [003]. From cranial to caudal the size and angulation of the APJs increase correspondingly to a more vertical orientation of the articular processes, thereby enabling a higher degree of joint movement [003, 005]. The IVDs consist of an outer, shiny and white annulus fibrosus (consisting of lamellar collagen) and an inner, gelatinous and semi-translucent nucleus pulposus (consisting of intracellular matrix and proteoglycan-rich cartilage) [006]. The anatomy of equine IVDs has been unclear, with some researchers still believing the nucleus pulposus to be missing [007, 008].

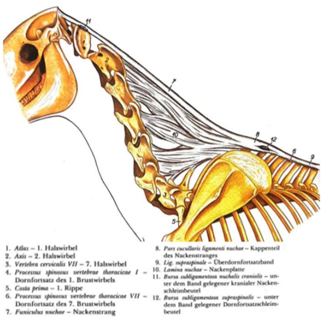

Figure 2: neck, view from the left [Popesko, 7th edition, image 185]

The bony structures of the spine are supported by numerous ligaments and muscles. The nuchal ligament consists of a funicular part, spanning from the occiput to dorsal spinous processes of the first thoracic vertebrae, and a lamellar part, connecting the funicular part with the 2nd to the 5th cervical vertebrae. Caudal to its attachment at the withers it continues as the supraspinous ligament all the way to the sacrum. The ligamenta flava run between the arches of neighbouring vertebrae, the ligamenta interspinalia between their spinous processes [001]. The dorsal and ventral longitudinal ligament run on the ventral side of the vertebral canal and the ventral contour of the vertebrae, respectively, and also attach to the IVDs [009].

Different anatomical variations in the number and shape of vertebrae are described, although there is a high degree of conservation for the number of seven cervical vertebrae in mammals [010].

3.2 Biomechanics and kinematics of the equine cervical spine

The equine head and neck account for up to 10% of the horse's body weight [011]. This mass is situated at a large distance from the body's centre of gravity, creating a cantilever beam that is only attached at one end [012]. This not only creates great forces between the APJs (especially in the caudal section of the neck) [013], but also has a considerable effect on the craniocaudal and lateral balance [014], the movement of the entire horse [011], and the cervical spinal cord with the emerging spinal nerves [001].

Joints have three zones of movement (figure 3): a physiologic, a paraphysiologic and a pathologic zone. The physiologic zone is made up of an active and a passive range of motion and ends in an elastic barrier. The pathologic zone describes movement outside of the anatomical limits and with disruption of peri- and intraarticular structures. The paraphysiologic zone lies in between the elastic and anatomical barrier [015].

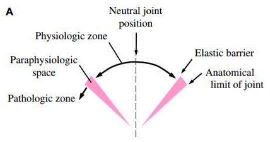

Figure 3: Joint mechanics [20]

The joints between two vertebral bodies together with all the associated soft tissues (including ligaments, muscles, blood vessels and nerves) make up a motion unit.

Generally, there are six different types of joint movements: dorsoventral flexion/extension, lateral bending, axial rotation, transverse shearing, longitudinal compression/tension and vertical shearing [005]. The atlantooccipital joint is a hinge joint, allowing mainly dorsoventral flexion and extension. The lateral bending is limited, especially in the flexed joint, due to impingement of the jugular process of the occiput on the lateral arch of the atlas. The atlantoaxial joint is a trochoid or pivot joint, enabling axial rotation. Extension, flexion and lateral bending are restricted by the dens axis [005]. In the joints between C3 and first thoracic vertebra (T1), the APJs of the caudal cervical vertebrae allow a high range of dorsoventral flexion/extension and lateral bending, as well as some axial rotation [005]. In those joints, lateral bending seems to be coupled with axial rotation [005]. During extension the compressive forces act more on the cranial aspects of the joints [001] and the size of the intervertebral foraminae decreases (with the potential to temporarily reduce nerve function) [016].

Muscles and ligaments are needed to counteract some of the forces caused by the mass of the head and neck [017] and to protect the joints and periarticular structures from single-impact and multiple-strain injuries [001]. The nuchal ligament is involved in the extension of the head and neck and stores elastic energy during locomotion (which limits the amount of oscillatory head movements) [013]. The neck muscles also play an important role in spinal stabilisation, especially during faster gaits [018]. This is achieved through simultaneous contraction of antagonistic muscle groups and deep muscles like the Mm. multifidi and M. longus colli. While walking or while standing still, these muscles are mainly involved in the execution of voluntary out-of-rhythm movements (e.g. looking around) [001].

The largest range of motion in the neck occurs in the cranial and caudal segments, whereas the mid-cervical region only shows small movements. The range of motion in lateral bending progressively increases from C2 to C7 [019, 020]. An extended neck, as is often seen in faster gaits [021], has a positive effect on balance [001] but also restricts the dorsoventral movement in the back [022]. A low carriage of head and neck creates more movement in the thoracolumbar vertebrae, which in turn may increase the breathing volume [001].

During ridden work, the biomechanics in the complete equine body change substantially. Initially, the weight of the rider (a vertical loading on the thoracolumbar spine) may lead to an extension of the vertebral column including the neck. This effect can be counteracted by the horse, if it has sufficient coordination and strength in the abdominal muscles and the muscles of the shoulder girdle. Additionally, the rider and his aids have considerable influence on the neck position and obtaining a certain neck position is widely considered a prerequisite for most uses of the horse [001]. The neck position has a significant effect on mass distribution [023], muscle group activation [024] and stride length [022].

3.3 Diseases of the equine cervical spine

Diseases of the neck are generally uncommon in horses, but can be a cause of lameness (without pain localised to the limb) and poor performance. Further clinical signs include abnormal neck positions, swelling, stiffness or painfulness of the neck on palpation [009]. Neurological symptoms originating from the neck are most often related to space-occupying lesions originating from the APJs, vertebral dorsal laminae and the ligamentum flavum [009, 025, 026], trauma or infections. In the following sections, the most common diseases of the cervical vertebrae, the APJs, IVDs, and the soft tissues are discussed.

Diseases of the joints in the cervical spine

As previously mentioned, there are three articular components between the cervical vertebrae. It is expected that a lesion in one of those structures negatively affects the other two [027]. Arthropathies in the APJs are very common: about 50% of horses show degenerative changes of the APJ at the level of C6-7 [028, 029]), whereas the equine IVD appears to be rarely affected.

Arthropathy of the articular process joints

Pathologies of the APJs most commonly appear in the caudal neck (C5-7) [030, 031] and can lead to a variety of clinical signs. *Local effects* caused by mechanical and inflammatory processes can cause neck pain, neck stiffness and muscle atrophy [032, 033]. *Peripheral effects* due to mechanical compression or chemical irritation of the emerging nerve roots include neck pain, local sweating, muscle atrophy, hypoaesthesia, reduced performance, stumbling and forelimb lameness [009, 034, 032, 035]. Lastly *central effects* are symptoms associated with a compression of the spinal cord such as ataxia, paresis and spasticity [003, 025, 026, 032, 036, 037]

The two main disorders of APJs in horses are osteoarthritis (OA) and osteochondrosis [036, 037]. These may be caused by widespread failure of bone and cartilage development and maturation or overuse and overloading; however, little is still known regarding the etiopathogenesis [029, 033, 034]. It is theorized that a primary cartilage lesion leads to damage of the articular surface [036] which in turn can cause a loss of joint function through progressive bone remodelling. This decreases the range of motion and may cause spinal cord compression and nerve root irritation and impingement [025, 026,

028, 037]. Thus, OA and osteochondrosis of APJs play a role in cervical malformation (CVM) [026, 032, 037]. Categorically CVM is split into cervical static stenosis (permanent compression of the spinal cord) and cervical vertebral instability (dynamic compression, usually in flexion) [026].
Treatment options for APJ arthropathies include rest, NSAIDs, peri-/intraarticular corticosteroid infiltration and possibly surgery [009, 028, 034]. Restoration of the articular surface through cartilage tissue engineering could limit the progressive bone remodelling and aid in regeneration [025, 033]. Due to the relatively low tensile properties of the facet cartilage in horses, a tissue engineering solution may be more readily achievable [004].
Arthropathies of the APJs are considered progressive diseases with a poor prognosis and pose a significant risk for usage in sport and breeding, as a hereditary component cannot be excluded [035].

Degeneration of the intervertebral discs
Equine IVDs are a relatively rare site for pathologies, especially in the cervical region; they typically occur between T11 and S1 [006].
Degeneration of the IVD is slightly more common with age and significantly more severe in the caudal cervical region [006], which could be explained by the higher mechanical load [007] and dorsoventral mobility in this area [038]. Typical symptoms include neck pain, forelimb lameness and ataxia [039, 040, 041]. The prognosis is guarded [009].

Diseases of the cervical vertebrae
Fractures of the cervical vertebrae are most often caused by trauma (e.g. falling backwards from rearing or fall after a jump). They can be associated with a low neck position, neck stiffness and painfulness (local or diffuse), soft tissue swelling, muscle guarding or muscle atrophy, ataxia or lameness and patchy sweating. Conservative treatment includes box rest and analgesia [009]. A surgical stabilisation is indicated when a compression of the spinal cord is likely due to instability, as it may minimise the formation of fracture callus and the development of a malalignment.
Subluxations in the equine cervical vertebrae appear usually at the level of C1-2, C5-6 or C6-7 [009]. They are likely related to trauma and damage to the supporting structure (e.g. fracture of the dens axis) [042, 043] or of congenital origin (i.e. malformation and malarticulation) [009]. A subluxation of C1-2 may cause stiffness of the neck, extension of the head and neck, a clicking noise and an abnormal movement between the vertebrae. It is rarely associated with neurological abnormalities. In contrast, a subluxation in the caudal segments of the cervical spine may lead to a forelimb lameness, lack of hindlimb strengths, poor performance and hindlimb ataxia [009].

Diseases of the soft tissues in the equine neck
Cervical muscle lesions can be caused by poorly fitting tack, an unbalanced rider or trauma (e.g. falling, pulling back when tied) and leads to muscle soreness and lameness. The latter is usually primary in nature but can appear secondary due to soreness of the M. brachiocephalicus. Suggested treatment includes NSAIDs, rest and physiotherapy with progressive remobilisation [009].
Insertional desmopathy of the nuchal ligament typically originates from trauma or excessive amounts of lunging with restricting side or draw reins [028, 044] The clinical signs are permanent resistance against reins, difficulty or unwillingness to lower and flex the neck, head shaking and rearing. Therapy consists of repeated corticosteroid-infiltration and rest, although movement training (such as encouraging flexion in the poll region) is considered to be an indispensable element in recovery and disease prevention [044]. Additionally, acupuncture, magnetic field therapy, laser therapy or ultrasound/shock wave therapy may be used [009].

Nuchal bursitis is a rare infectious or non-infectious disease, which can cause neck stiffness and pain, abnormal neck posture and localised tissue swelling. Surgical debridement is the treatment option of choice [009].

3.4 Risk factors for disease in the equine neck

Studies [045] have shown that male horses have significantly more bony changes in their cervical articular processes. This may be associated with their larger body mass [045].
Most studies agree that older horses are significantly more affected by cervical osteoarthrosis [001, 026] however some studies did not find a difference between young and old horses [030, 031]. Down and Henson [046] found significantly larger caudal APJs on older horses in their radiographic study, but they found no differences between male and female horses.
It is believed that taller and heavier horses show more bony changes in the cervical vertebrae due to the additional weight and length of the neck, which has a leverage effect [001].
The discipline seems to have no significant effect on either the size of APJs on radiographs [046] or their radiographic uptake in scintigraphy [047].
Little to no literature has been published regarding the effect of training (frequency, head-neck position, neck conformation) or stabling (pasture frequency and duration, height of feeding) on equine cervical diseases.

3.5 Diagnostic approach to the equine cervical spine

3.5.1 Clinical examination

The first step to a complete clinical examination should be the collection of a thorough medical history as well as a detailed discussion of the chief complaint(s) [015].

Next, the horse should be observed from a distance. The conformation, musculature and posture of the entire horse must be evaluated to correctly localize the source of the complaint [015]. If a cervical problem is suspected, special attention should be given to the conformation, shape and positioning of the neck and any asymmetries in this area should be noted. The development of the cervical muscle groups can further give insight into the condition, but also in which or for which body posture and head-neck position the horse was trained. Additionally, patchy sweating or changes in coat colour (associated with intermitted sweating) can be signs of local damage to a sympathetic nerve emerging from the spinal cord [009].
If possible, the gait should be analysed in terms of overall balance and fluidity of the movements, stride length, foot placement and signs of discomfort or pain [015].
It can also be helpful to evaluate the tack for correct fit and positioning, as well as the horse's response to being saddled, girthed or even ridden [009, 015].

A general physical examination should be conducted to exclude any systemic issues [015]. In this context the jugular veins should be checked for signs of thrombophlebitis, as this can also lead to stiffness in the neck [009].

Afterwards a thorough palpation of all tissue layers in the affected area is recommended. The epidermis and dermis are inspected for lesions like scabs, scrapes, insect bites or masses. The subcutaneous tissue is evaluated for the presence of oedema, cellulitis, masses or fat deposits. The superficial and deep fascia should be smooth and uniform in tonicity and should not show any signs of masses or scar tissues. When applicable, tendons and ligaments are palpated for swelling, pain, thickening, fibrosis or fibre disruption [015]. The musculature is checked for symmetry, shape (existence of swellings, depressions or masses), sensitivity (presence of pain, hyper- or hypoaesthesia), tension and fasciculations [009, 015]. Hypotonicity may be a sign of neuropathies or systemic illnesses, whereas hypertonicity often occurs due to excessive loading (e.g. usage of the brachiocephalic muscles for stabilisation) or with a neuropathy or myopathy. Fasciculations are associated with profound muscle weaknesses and fatigue, electrolyte imbalances or primary muscle pathologies [015]. Lastly the bones are evaluated for morphology, symmetry, alignment and possible crepitations [009, 015].
The active and passive joint movement should be assessed for symmetry, painfulness, coordination, range of motion, and the willingness of the horse to perform a specific movement. Painless restrictions in the range of motion are generally associated with soft-tissue contractures and adhesions, while painful restrictions may be caused by acute strains or intra-articular injuries with secondary muscle guarding. Painless hypermobility of a joint indicates a complete rupture of an intra- or periarticular structure, while painful hypermobility indicates a partial rupture [015].

Additionally, the local reflexes in the neck may be evaluated [009]. The cervicofacial reflex is triggered by stroking the skin over the brachiocephalic muscle with a closed hemostat from cranial to caudal. The expected response, a facial contraction and retraction of the commissure of the lip, is felt by placing a finger on the commissure of the lip. Interruptions of this reflex indicate a lesion in the facial nerve, cervical nerve roots or local cervical spinal cord segments [048, 049]. The thoracolaryngeal reflex, also known as the slap test, is performed by slapping one hemithorax and assessing the adduction of the muscular process of the contralateral arytenoid cartilage. The reflex is absent in horses with lesions of the ascending cervical spinal cord, CNS or the motor nerve supply to the larynx [050].

For a complete assessment of the horse a thorough orthopaedic and neurological examination may be added.

3.5.2 Diagnostic imaging of the equine neck

Radiography

Radiography represents the most common and readily available imaging technique used for the evaluation of the equine neck [051]. Sedation and a straight orientation of the spine with the head in a neutral position are mandatory for radiographs of diagnostic quality, i.e. images without rotation or positional scoliosis of the neck. Whereas the cranial region (C1-C5) may be imaged with commonly available portable x-ray generators and detectors, the most caudal cervical segments (C6-T1) require a more powerful generator [052].
Laterolateral and 45°-50°ventrolateral-dorsolateral oblique radiographs can be easily obtained in the standing horse. Oblique radiographs are better suited for the assessment of lateralised osseous abnormalities of the spine [052]. Ventrodorsal images are best obtained with the horse in dorsal recumbency under general anaesthesia and they are therefore not commonly available, except in small ponies and foals.

The complex anatomy, superimposition of symmetric structures and difficulty of obtaining orthogonal (ventrodorsal or dorsoventral) views are complicating factors when it comes to cervical radiology [052].

First, the direction of projection should be evaluated. Lateral radiographs need to be analysed on possible rotation; this can be done using the vertebral processes [046].

The vertebrae are assessed regarding size, shape, opacity, margination, and alignment.

On lateraolateral radiographs (figure 4-7) the atlas is depicted as a short and blocky vertebra without a spinous process. The axis is the longest cervical vertebra. It features a prominent spinous process and its dens is protruding into the atlas. In this context it is important to note that during development the dens axis possesses two separate centres of ossification, which may be misinterpreted as fractures. In the mid-cervical region (C3-5) the vertebrae are very similar in terms of size and shape. In comparison to the neighbouring vertebrae, C6 has a flatter ventral silhouette and longer transverse processes fusing with the more prominent ventral lamina. The shorter C7 sometimes features a small dorsal spinous process [052].

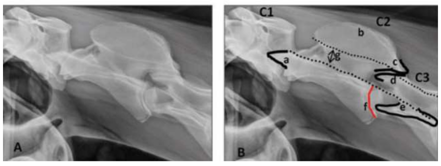

Figure 4 [052]: lateral radiograph of cervical vertebrae 1-3 (C1, C2, C3): a = dens axis, b = spinous process of C2, c = caudal articular process of C2, d = cranial articular process of C3, e = transverse process of C3, f = IVD space, g= vertebral canal

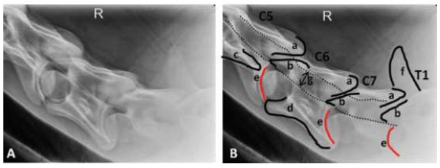

Figure 5 [052]: lateral radiograph of caudal cervical vertebrae (C5, C6, C7, T1): a = caudal articular processes, b = cranial articular processes, c = transverse process of C5, d = transverse process of C6, e = IVD space, f = dorsal spinous process of T1, g = vertebral canal

The APJs are assessed for shape, size, and alignment of the articular processes, orientation, width and regularity of the joint space, defects and fragments in association with the subchondral bone, and articular and peri-articular remodelling [052].

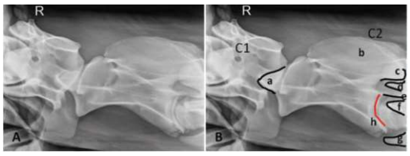

Figure 3 [052]: left lateral-45-50°-dorsal to right lateral-ventral oblique of cervical vertebrae 1 and 2: a = dens axis, b = spinous process of C2, c = right caudal articular process of C2, d = right cranial articular process of C3, e = left caudal articular process of C2, f= left cranial articular process of C3, g = left transverse process of C3, h = IVD space

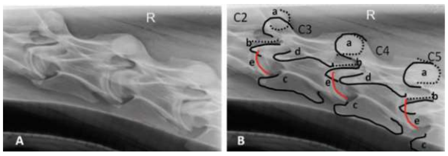

Figure 7 [052]: oblique radiograph (left lateral 45-50° dorsal to right lateral-ventral oblique) of cervical vertebrae 3 and 4: a = right APJs (dashed line = caudal articular processes, solid line = cranial articular processes), b = left APJs (dashed line = caudal articular processes, solid line = cranial articular processes), c = left transverse processes, d = right transverse processes, e = IVD space

Different studies [035, 053] suggest measuring cervical vertebral structures (e.g. height and length of the vertebral corpus, height and length of the articular processes) to facilitate interpretation. However, differences in the measured ratios were larger between observers than between healthy and diseased horses [035, 054]. Additionally, the size of the APJs was underestimated on oblique radiographs [054]. An objective grading system for the caudal cervical APJs was established by Down and Henson in 2009 [046]. It is based on evaluating the APJs for enlargement in relation to the vertebral canal width, new bone formation dorsally and ventrally and size of the intervertebral foramina [046].

Osteoarthritis of APJs may be characterised by enlargement of the articular processes, changes in joint space width (widening due to joint effusion, narrowing due to degeneration of articular cartilage), new bone formation, sclerosis, subchondral cysts, vascular channel formation, obliteration of the intervertebral foramina, extension of the dorsal laminae between the vertebrae and sometimes fractures dorsal to a joint [009, 034, 046]. If the OA is caused by osteochondrosis, a chip may be visible radiographically. However, the normal size of APJs increases in more caudal cervical segments possibly due to the higher degree of movement and with age of the horse [054, 046]. Therefore, an enlarged APJ may not always represent a pathological condition and may not correlate with the degree of clinical or neurological signs [054].

Ultrasonography

Ultrasonography (US) of the neck is used for diagnostic evaluation as well as therapeutical applications (i.e. intra-articular injections of corticosteroids) [034]. This modality has the advantage of being a quick and non-invasive diagnostic method that enables dynamic assessment of soft tissues, joints and bony contours [055]. Ultrasonography is routinely used for the examination of the APJs.

For an ultrasonographic examination of the APJs a linear or convex 5.0-7.5MHz transducer may be used [056]. The APJs are identified via palpation [055] and imaged using one of the following approaches. In the dorsal approach the transducer is oriented perpendicular, in the cranial approach parallel to the long-axis of the neck [057]. The craniodorsal approach, holding the transducer at an approximately 45° angle to the long-axis of the neck [057], is used to image the joint space between the cranial and caudal facet [056].

The images are evaluated layer by layer (figure 8). Cutaneous and subcutaneous tissue appear as a hyperechoic zone enclosed by more hyperechoic fat. Muscles are depicted as heterogenous texture made up of hypoechoic fibers, hyperechoic fat and hyperechoic collagenous fibers and are surrounded by hyperechoic fascia. The contours of the vertebrae appear as hyperechoic borders with shadowing underneath. The articular processes, transverse process, vertebral arch and spinous process of each vertebrae can be addressed. It is important to note that the articular processes naturally possess an irregular outline (due to the insertion of epaxial muscles), which may complicate the identification of osteophytes [055]. The articular cartilage can only be identified if it is projected perpendicularly, as the transition between cartilage, synovial fluid and bone creates a distinct hypoechoic zone bordered by an outer and inner hyperechoic line [058]. The joint space is readily recognised as an anechoic discontinuity, but its size can vary with no association with the actual anatomical or pathological findings [055].

Osteoarthritis and osteochondrosis of APJs most commonly lead to synovial effusion, capsular fibrosis/hypertrophy and periarticular new bone formation, which may be identified ultrasonographically [026, 037].

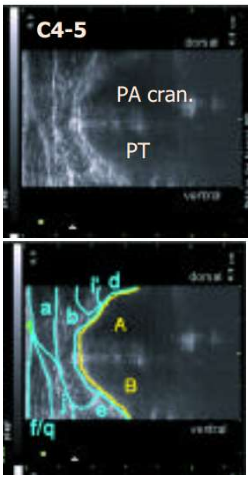

Figure 8: Identifiable structures on ultrasound images at the level of C4-C5. A = Proc. articularis caud., B = Proc. articularis cran., a = M. splenius, b = M. longissimus atlantis, d = Mm. multifidii cervicii, e = Mm. inter-transversarii cervicii, f = M. brachio-cephalicus, i = M. semispinalis capitis [055]

Advanced diagnostic imaging

Additional imaging modalities, such as computed tomography (CT) or scintigraphy, may be used in the diagnostic workup of cervical diseases. However, these modalities are less readily available and more expensive than radiography and ultrasonography.

Computed tomography creates cross-sectional radiographic images by rotating an x-ray generator around the area of interest. These cross-sections may be reconstructed to form a 3-dimensional image. This allows the assessment of complex anatomical structures (such as the APJs, the vertebral canal, the spinal cord with its nerve roots, the IVDs and ligaments [003]) in much greater detail than radiography [059].

The head to midneck can be imaged in the sedated and standing horse. A relatively profound sedation is needed to ensure cooperation of the horse and minimise motion artefacts [059].

CT-images are evaluated according to the same criteria as radiographs. The vertebrae are assessed regarding size, shape, opacity, margination and alignment. The APJs are evaluated for shape, size, and alignment of the articular processes, orientation, width, and regularity of the joint space, defects and fragments in association with the subchondral bone, and articular and peri-articular remodelling.

However, CT is superior to plain radiographs because the joint space is seen without superimposition, and the presence and degree of narrowing of the intervertebral foramen and the vertebral canal may be assessed. In a recent CT study of 102 horses with clinical signs related to the neck [060] a narrowing of the intervertebral foramen was the most common finding (79.4%), followed by degenerative changes of the APJs (73.5%). However, it is likely that clinically normal horses also show a wide spectrum of anatomical differences [059], which may complicate the interpretation of such CT-images.

In contrast to anatomical imaging modalities (radiography, ultrasonography and CT), which depict only changes in morphology or physical characteristics of tissue, skeletal scintigraphy allows identification of changes in bone metabolism [059, 061]. This permits identification of a problem or disease before the occurrence of morphologic changes, as well as evaluation of the clinical relevance of radiologic findings (such APJ-remodelling in radiographs) [059, 061].

A radiopharmaceutic agent (typically Tc^{99m}-labelled methylene diphosphonate) is injected intra-venously, ideally through an indwelling catheter to minimise the risk of perivascular injection, which would cause superimpositions over the cervical vertebrae [059]. It subsequently distributes within the body in three distinguishable phases: the vascular phase (immediately after injection), the soft tissue phase (2-10 min after injection) and the bone phase (2-3h after injection) [059, 061]. The uptake of the radiopharmaceutical by any region largely depends on the metabolic activity and blood flow of said tissue [061]. It is measured in the form of radiation with a gamma-camera and displayed as an image after a computer processes the raw data [059, 061]. Lateral images of the cervical spine should be acquired from both sides to identify uni- or bilateral injuries and may be complemented with a ventrodorsal view [047, 059]. For the acquisition of said images the horse needs to be sedated and have its head placed on a head rest to minimise motion artefacts, especially when taking a series of images (= dynamic acquisition) [059, 061].

Images are evaluated based on the distribution of detected radiation, which depends on the uptake of the radiopharmaceutic agent and the degree of attenuation by overlying tissue. The radiologist must have an understanding of normal variations based on the physiologic state of the patient (body type, age, etc.) in order to correctly interpret the findings [059]. An increased uptake may represent physiological (joints, open growth plates, higher exercise level) or pathological conditions (increased bone turnover due to a bone injury like OA, fractures, tumours or infections) [059, 061]. A decreased uptake may occur in association with necrotic osteomyelitis, a sequestrum or silent cyst like lesions [062].

Thermography

Thermography is similar to scintigraphy in that it provides information about physiological processes rather than anatomical morphology [063]. It creates an image representing the surface temperature of the animal [064, 065], which is dependent on tissue metabolism (generally constant) and local circulation [066], but also environmental factors such as sunlight (thus standardised conditions are needed to minimise artefacts).

Injured tissue shows a change in local circulation [065] either in the form of an increase (localised inflammation [064, 065]) or decrease (swelling or ischemia [065]). Thus, thermography can be used to localise areas with abnormal blood flow, which may then be examined more closely with anatomical imaging (such as radiography or ultrasound) [063]. In certain cases, thermography may help identify injuries up to two weeks before clinical changes are first seen [063].
Lateral images of the neck (from both sides) may be used to identify injuries to ligaments, muscles and joints as well as luxations, subluxations and fractures of the cervical vertebrae. Linear increases in temperature following the nerve roots from the spinal cord can signify irritation to the local sympathetic nerves [063].

3.6 Aim of the study

As summarized above, imaging findings, prevalence and potential clinical symptoms of OA of the APJs in the equine neck have been reported previously. So far, the prevalence and significance of radiographic and ultrasonographic changes of the APJs has not been determined in normally performing horses though. Moreover, the relevance of epidemiologic factors and findings in the equine neck has not been investigated in detail in normally performing horses which may reveal important information about the normal or subclinical variations in radiographic and ultrasonographic findings. The purpose of the present study was therefore to investigate the health status of the cervical spine in normally performing Swiss riding horses, i.e. to determine the prevalence of radiographic and ultrasonographic changes, and second to associate these findings with epidemiologic factors and clinical findings.

4 Materials and Methods

4.1 Animals

For the present study, horses were selected randomly out of a preceding field study. For that purpose, the study was published in the Swiss equitation press and announced to Swiss horse stable owners with the aim to investigate the riding soundness of riding horses i.e. their back health in relation to the athletic health of their riders. Interested riders applied to the Section of Sports Medicine at the Equine Department, University of Zurich via an online questionnaire. Riders and their horses were included in the field study if the age of the rider was > 18 years, horses were between 5 and 18 years old, horses were exercised 2 hours per week at minimum and riders as well as horses provided a good physical health status. Riders had to confirm that they were riding their horse themselves two-thirds of the time at minimum. Additionally, horses were only included if a lameness grade ≤ 2 was diagnosed at the subsequent lameness examination on hard ground. All riders and horses were only allowed to participate in the study once.

Riders provided detailed general information via a standardised online questionnaire 10 days prior to the clinical examination of the horses and subsequent tests [067]. Out of the collected data, the following variables were used for the present study: age, breed, gender, body weight, withers height, use of the horse (show jumping, dressage, western style, endurance, leisure), pasturing, elevated feeding (no, yes) and frequency of training. Riders also described subjectively the horse's neck conformation (pronounced underneck muscles, neutral conformation, pronounced dorsal muscles and fat tissue). Further, unspecific riding problems such as stiffness during riding (no, yes) were addressed individually but also summarized in a ridability score (0 to 11 scores) including behaviour during riding (unwillingness to work, stiffness, gait irregularities, stumbling, bucking) and aversive reactions to saddling or mounting (biting, kicking, tail swishing, back pinning of ears, grinding teeth, head shaking, dorsoventral extension of the back, unwillingness to stand still).

In the field study, 237 rider-horse pairs were included finally and invited to 8 defined equestrian clubs, which were unknown to all riders and horses. Both riders and horses underwent specific clinical and athletical tests as described previously [067].

After completion of all examinations and tests, 71 horses were randomly selected for a 1-day work-up at the university of Zurich after a mean of 130 days (SD, 58; range, 5-266 days). They underwent a clinical examination, a second lameness examination on hard ground at the walk and trot, subsequently radiography and ultrasonography, and finally a gait analysis on the treadmill.

4.2 Clinical and orthopaedic examination

Body posture (neutral = normal, extension) was assessed in the relaxed, standing horse (figure 9 and 10). During clinical examination of the neck, active lateral flexion (normal, moderately to severely restricted) and asymmetric active lateral flexion to the left or right (no, yes) as well as restricted dorsoventral flexion at the withers (no, yes) were evaluated. Moderate to severe hypertrophy of the brachiocephalic muscle was also noted (no, yes). Active lateral flexion of the neck was assessed by encouraging the horse to follow a treat to the level of the thoracic wall (figure 11). Restricted dorsoventral flexion at the withers

Figure 4: an example of a horse with the body posture «in extension» [photo S. Latif]

Figure 10: an example of a horse in a neutral body posture [photo M. Dittmann]

was tested by encouraging the horse to lift its trunk and lower its neck in relation to its front limbs by applying gentle pressure to the sternum (figure 12).

Figure 5: testing active lateral flexion

Figure 12: testing dorsoventral mobility

Subsequently, a standard lameness examination was performed at the walk and trot on hard ground. Then, horses underwent a radiographic and ultrasonographic examination of the neck. After a rest of 2 hours minimum, a second lameness examination was performed on the treadmill at the walk and trot. A lameness grade of 0 to 5 was given for each examination. Grade 0 was defined as no lameness at the walk or trot, whereas a normal walk and a slight irregularity not visible at every stride at the trot, or, present at every stride at the trot, represented a lameness grade 1 or 2, respectively. Slight irregularity at the walk and moderate lameness at the trot was given a grade 3. Horses showing moderate lameness at the walk and severe lameness at the trot were scored with a grade 4, whereas a grade 5 was given if no weight bearing on the affected limb was seen. If both, the lameness grade on hard ground and on the treadmill, were not identical and differed by one grade, then the mean was noted as the final lameness grade. For the statistical analyses, the lameness grade was converted into binary variables: left or right front lameness and left or right hind lameness, respectively (0 = no lameness, 1 = lameness grade ≥ 1).

4.3 Radiographic examination

Three laterolateral radiographs of the cervical spine were acquired in the standing and sedated horse: from the occiput to the cranial part of C3, from C3 to C5 and from C5 to C7 or the first thoracic vertebra (T1). A high power generator (Optimus 65, Philips Medical System, Switzerland) in combination with a digital radiography system (FDR D-EVO I, Fujifilm (Switzerland) AG) was used.

The APJs of C2-T1 were evaluated each for osteo-arthritic changes (radiographic OA grade) based on four criteria: joint size, orientation and shape of the joint space, bone opacity and periarticular bone remodelling. A grade from 0 to 4 (0 = normal, 1 = mild, 2 = moderate, 3 = marked, 4 = severe changes) was allotted to each joint (table 1). Due to superimposition of the left and right APJ on laterolateral radiographs, the total grade referred to the most severe changes of each segment i.e. both APJs.

Grade	Enlargement of articular processes	Joint space: shape and orientation	Bone opacity	Periarticular new bone formation
1	mild	normal	normal	few
2	moderate	mildly changed	mildly changed	some (dorsal)
3	moderate	changed	altered (increased or decreased)	dorsal +/- ventral
4	severe	altered	irregularities and lysis	present dorsal and ventral

Table 1: Radiographic grading of osteoarthritis in the equine neck

4.4 Ultrasonographic examination

Ultrasonographic examination (macroconvex probe, 2-6 MHz, Aloka ProSound Alpha 7, Hitachi, Switzerland) of the left and right APJs of C5-T1 were performed in the sedated horse premedicated with a spasmolyticum given intravenously. First, the most caudal APJ i.e. C7-T1 was identified based on the location of the vertebral artery and then the more cranial joints were examined. Video loops were recorded for each APJ while sweeping in short axis over the joint. All videos were reviewed at the end of the study for osteoarthritic changes (ultrasonographic OA grade) based on 4 criteria: presence of osteophytes/enthesophytes, synovial effusion, echogenic spots in the synovial fluid, and visibility of the joint space. Similar to radiography, a grade ranging from 0 (normal) to 4 (severe changes) was allotted to each joint (table 2).

Grade	Articular processes	Synovial effusion	Presence of echogenic spots
1	irregular margins	none	none
2	NBF	mild	few
3	abnormal shape, NBF	mild	moderate
4	marked dysplasia, NBF	moderate, dorsal fluid hernia	severe

Table 2: Ultrasonographic grading of OA in the equine neck (NBF = new bone formation)

4.5 Statistics

Descriptive statistics were calculated for age, breed, gender, body weight, withers height, use of the horse, pasturing, elevated feeding, frequency of training, neck conformation, stiffness, body posture, ridability score, active lateral flexion, asymmetric flexion, restricted dorsoventral flexion at the withers, hypertrophy of the brachiocephalic muscle, left and right front lameness, left and right hind lameness, radiographic OA grade for each segment C2-T1 and ultrasonographic OA grade for each left and right APJ of each segment C5-T1.

For the calculation of associations with independent variables, the radiographic OA grades for each segment were modified and additional variables were calculated: sum of the radiographic OA grades of all segments C2-C7 (total radiographic OA score C2-C7), sum of the radiographic OA grades of all segments C2-T1 (total radiographic OA score C2-T1), and sum of the radiographic OA grades of C2-C5 and C5-C7, respectively (cranial and caudal radiographic OA score). The variable binary radiographic OA grade referred to the grade of the most severely affected joint in the whole neck of a horse (normal = grades 0, 1; diseased = grades 2, 3, and 4).

Similarly, more ultrasonographic variables were calculated: sum of the ultrasonographic OA grades of all left APJs (total left ultrasonographic OA score), sum of the ultrasonographic OA grades of all right APJs (total right ultrasonographic OA score), and sum of the ultrasonographic OA grades of both, all left and right APJs (total bilateral ultrasonographic OA score). For each segment, the ultrasonographic OA grade of the left and right APJ were also added (bilateral OA score C5-6, C6-7, and C7-T1). The variable binary ultrasonographic OA referred to the grade of the most severely affected joint in the neck of a horse (normal = grades 0, 1; diseased = grades 2, 3, and 4).

In table 3 all abbreviated statistical variables used in the present study are listed.

Associations between continuous variables were calculated using Spearman's rank correlation. For associations between continuous and categorial variables the Wilcoxon rank sum test or

Variable	Abbreviation
Radiographic OA grade of each segment C2-T1	none
Total radiographic OA score C2-C7	TS_{RX}
Total radiographic OA score C2-T1	TS_{RX+T1}
Cranial radiographic OA score	$TS_{RX,Cr}$
Caudal radiographic OA score (without C7-T1)	$TS_{RX,Cd}$
Caudal radiographic OA score with C7-T1	$TS_{RX,Cd+T1}$
Binary radiographic OA grade	none
Total left ultrasonographic OA score	none
Total right ultrasonographic OA score	none
Total bilateral ultrasonographic OA score	TS_{US}
Bilateral OA score C5-6, C6-7, and C7-T1	none
Binary ultrasonographic OA	none

Table 3: Variables and responding abbreviations used in the present study

Kruskal-Wallis test was used. Binomial regression models were used to test associations between binary dependent variables and potential predictors. A P-value < 0.05 was considered significant.
For the statistical analysis, R-Studio (Version 1.1.442) with the packages publish and DescTools was used.

5 Results

5.1 Animals, history and clinical examination

The sample group included 37 geldings (52.1%), 32 mares (45.1%) and 2 stallions (2.8%). Age ranged from 5 to 18 years (mean, 10.2 years; SD, 2.7 years). The horses were primarily used for show jumping (33.8%), dressage (29.6%), leisure (16.8%) and eventing (9.8%). The remaining horses (9.8%) were used for western style or endurance riding. Warmblood breeds accounted for the most common breed (74.6%). The mean withers height was 164 cm (SD, 7.5 cm; range, 139-181 cm) and the mean weight was 548.7 kg (SD, 61.3 kg; range 362-639 kg).

Forty-five horses (63.3%) were pastured daily, 19 (26.8%) horses 5 to 6 times a week. Three (4.2%) and two (2.8%) horses had access to the pasture 3 to 4 and 1 to 2 times per week, respectively. Two horses (2.8%) were not pastured at all. The average pasture time was 1 to 2 h for 6 horses (8.5%), 2 to 3 h for 22 horses (31.0%), 3 to 4 h for 9 horses (12.7%), 4 to 5 h for 9 horses (12.7%) and more than 5 h for 23 horses (32.4%), respectively.
Fifty-five (77.5%) horses were fed hay from the ground whereas elevated feeding was used in 12 (16.9%) horses.
The majority of the horses (39 horses, 54.9%) were exercised seven times a week. 17 horses (23.9%) were exercised six times, 13 (18.6%) five times, and 2 horses (2.8%) were exercised four times a week.
According to the riders, 9 (12.7%) horses showed a pronounced underneck or overdeveloped dorsal neck muscles and fat.

21 owners (29.6%) noted stiffness in their horses. Distribution of the rideability score based on several unspecific symptoms was as follows:

Rideability Score	0	1	2	3	4	5	6	7	8	9	10	11
Number of horses	20 (28.2%)	11 (15.5%)	10 (14.1%)	11 (15.5%)	7 (9.8%)	4 (5.6%)	2 (2.8%)	3 (4.2%)	0 (0%)	2 (2.8%)	0 (0%)	1 (1.4%)

Table 4: Distribution of the rideability score

During the clinical examination, a body posture in extension was noted in 23 (32.4%) horses, whereas a neutral body posture was seen in 40 (56.3%) horses. In 8 (11.3%) horses, the body posture could not be assessed.
The active lateral flexion was moderately or severely restricted in 10 (14.1%) horses. Asymmetric restriction (distributed evenly between left- and right-sided restriction) was found in 18 (25.7%) horses. Dorsoventral flexion at the withers was restricted in 16 (22.9%) horses. The brachiocephalic muscle was hypertrophied in 22 (31.0%) horses.

Sixty-nine horses were assessed visually for lameness on the treadmill (table 5). 51 horses showed a frontlimb and/or hindlimb lameness. Two horses had to be excluded due to uncooperativeness on the treadmill. The following results were obtained:

	Grade 0	Grade 1	Grade 1.5	Grade 2	Grade 2.5	Grade 3
FL lameness Number of horses	16 (22.5%)	24 (33.3%)	0 (0%)	27 (38.0%)	1 (1.4%)	1 (1.4%)
HL lameness Number of horses	13 (18.3%)	20 (28.2%)	1 (1.4%)	32 (44.1%)	0 (0%)	3 (4.2%)

Table 5: Distribution of frontlimb (FL) and hindlimb (HL) lameness grades

5.2 Diagnostic Imaging

5.2.1 Radiographs

The radiographs of 71 horses were evaluated. In 18 cases the most caudal APJ (C7-T1) could not be evaluated due to underexposure.

The total radiographic OA score C2-C7 (TS_{RX}) ranged from 0 to 12 (mean, 2.6; median, 2.0; SD, 2.5). The total radiographic OA score C2-T1 (TS_{RX+T1}) ranged from 0 to 12 (mean 3.0; median, 2.0; SD 2.8) (table 6).

Score	0	1	2	3	4	5	6	7	8	9	10	11	12
TS_{RX} number of horses	15 (21.1%)	9 (12.7%)	18 (25.4%)	13 (18.3%)	4 (5.6%)	3 (4.2%)	2 (4.2%)	1 (1.4%)	0 (0%)	4 (5.6%)	1 (1.4%)	0 (0%)	1 (1.4%)
TS_{RX+T1} number of horses	10 (18.9%)	6 (11.3%)	14 (26.4%)	8 (15.1%)	3 (5.7%)	4 (7.5%)	2 (3.8%)	0 (0%)	0 (0%)	3 (5.7%)	2 (3.8%)	0 (0%)	1 (1.9%)

Table 6: Distribution of the total radiographic osteoarthritis (OA) scores C2-C7 (TS_{RX}) in 71 horses and the total radiographic OA score C2-T1 (TS_{RX+T1}) in 53 horses.

The cranial radiographic OA score ($TS_{RX,Cr}$) ranged from 0 to 3 (mean, 0.5; median, 0; SD, 0.8).
The caudal radiographic OA score without C7-T1($TS_{RX,Cd}$) ranged from 0 to 11 (mean, 1.7; median, 2, SD, 1.6). The caudal radiographic OA score including C7-T1 ($TS_{RX,Cd+T1}$) ranged from 0 to 6 (mean, 2.0; median, 2.0; SD, 1.7).

Both, median caudal radiographic OA score with ($TS_{RX,Cd+T1}$) and without C7-T1 ($TS_{RX,Cd}$) were significantly higher ($p < 0.001$) than median cranial radiographic OA score ($TS_{RX,Cr}$). The most severe grades were diagnosed in the APJs of C6-7 (table 7).

	C2-3	C3-4	C4-5	C5-6	C6-7	C7-T1
Grade 0 Number of horses	67 (94.4%)	58 (81.7%)	61 (85.9%)	55 (77.5%)	21 (29.6%)	43/53 (81.1%)
Grade 1 Number of horses	3 (4.2%)	11 (15.5)	8 (11.3%)	6 (8.5%)	16 (22.5%)	9/53 (17.0%)
Grade 2 Number of horses	1 (1.4%)	2 (2.8%)	2 (2.8%)	10 (14.1%)	22 (31.0%)	1/53 (1.9%)
Grade 3 Number of horses	0 (0%)	0 (0%)	0 (0%)	0 (0%)	11 (15.5%)	0/53 (0%)
Grade 4 Number of horses	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (1.4%)	0/53 (0%)

Table 7: Distribution of the radiographic osteoarthritis (OA) grades in each segment of the neck

5.2.2 Ultrasonography

Ultrasonographic examination was performed in 71 horses, 63 of those generated images suitable for grading.

Total bilateral ultrasonographic OA score (TS_{US}) ranged from 0 to 10 (mean, 2.5; median, 2.0; SD, 2.2) (table 8). The most severe grades were diagnosed at the level of C6-7 in both the left and right APJs (table 9 and 10).

	0	1	2	3	4	5	6	7	8	9	10
TS_{US} number of horses	11 (17.5%)	13 (20.6%)	11 (17.5%)	13 (20.6%)	6 (9.5%)	2 (3.2%)	4 (6.3%)	0 (0%)	1 (1.6%)	1 (1.6%)	1 (1.6%)

Table 8: Distribution of the total bilateral ultrasonographic osteoarthritis (OA) scores (TS_{US})

	0	1	2	3	4
C5-6: L / R number of horses	49 / 48 (69.0% / 67.6%)	14 / 16 (19.7% / 22.5%)	1 / 0 (1.4% / 0%)	0 / 0 (0% / 0%)	0 / 0 (0% / 0%)
C6-7: L / R number of horses	31 / 38 (43.7% /53.5%)	23 / 17 (33.4% / 23.9)	10 / 8 (14.1% / 11.3%)	0 / 1 (0% / 1.4%)	0 / 0 (0% / 0%)
C7-T1: L / R number of horses	46 / 39 (64.8% / 54.9%)	12 / 20 (16.9% / 28.1%)	5 / 5 (7.0% / 7.0%)	0 / 0 (0% / 0%)	0 / 0 (0% / 0%)

Table 9: Distribution of the ultrasonographic osteoarthritis (OA) grades for each left (L) and right (R) APJ of each segment

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	0	1	2	3	4	5
C5-6	39 (54.9%)	18 (25.4%)	7 (9.9%)	0 (0%)	0 (0%)	0 (0%)
C6-7	23 (32.4%)	18 (25.4%)	14 (19.7%)	4 (5.6%)	4 (5.6%)	1 (1.4%)
C7-T1	30 (42.3%)	20 (28.2%)	9 (12.7%)	2 (2.8%)	2 (2.8%)	0 (0%)

Table 10: Distribution of bilateral osteoarthritis (OA) grades for each segment

5.2.3 Correlation of radiographic and ultrasonographic findings

There was a significant positive correlation of the total bilateral ultrasonographic OA score TS_{US} with both caudal radiographic OA scores ($TS_{RX,Cd+T1}$ and $TS_{RX,Cd}$) ($P < 0.001$, rho = 0.47 and 0.43, respectively).

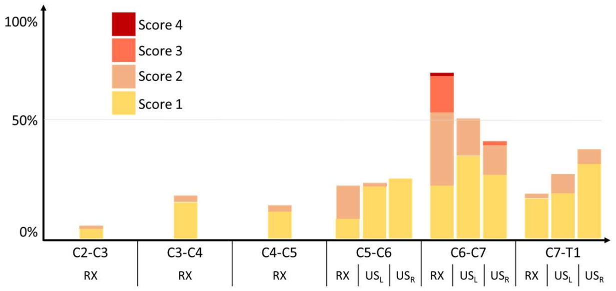

Figure 13: Graphic representation of the distribution of radiographic (total radiographic OA score, RX) and ultrasonographic (total left and right ultrasonographic OA score, US_L and US_R) in the different segments

5.3 Association of imaging findings with epidemiologic factors

There were trends for a positive correlation between age and TS_{RX} (p = 0.05, rho = 0.23) and $TS_{RX,Cd}$ (p = 0.09, rho = 0.20). However, there was no significant correlation of age with $TS_{Rx,Cr}$ (p = 0.23), the ultrasonographic score TS_{US} (p= 0.91) or with the radiographic scores including the C7-T1 junction TS_{Rx+T1} (p = 0.22) and $TS_{RX,Cd+T1}$ (p = 0.29).
Warmbloods had significantly (p < 0.001) higher TS_{US} than the other breeds in this study. There was a trend for higher $TS_{RX,Cd+T1}$ (p = 0.058, rho = 0.27) in warmbloods. No significant differences between breeds were found for TS_{RX+T1} (p = 0.22), TS_{RX} (p = 0.88), $TS_{RX,Cd}$ (p = 0.58) and $TS_{RX,Cr}$ (p = 0.71).
A significant positive correlation was found for the withers height and TS_{US} (p = 0.01), and a trend towards a positive correlation between the withers height and the $TS_{RX,Cd+T1}$ (p = 0.05) was found. However, there were no significant correlations between withers height and TS_{RX} (p = 0.88), TS_{RX+T1} (p = 0.17), $TS_{RX,Cd}$ (p = 0.40) or $TS_{RX,Cr}$ (p = 0.82).
There were no significant associations between all radiographic/ultrasonographic variables and sex, body weight or use of the horse (show jumping, dressage, leisure and eventing). However there was a trend for a positive correlation between $TS_{Rx,Cr}$ and body weight (p = 0.09).

5.4 Association of imaging findings with clinical factors

There was no significant association between restricted active lateral flexion and any imaging variable. However, there was a significant positive association of asymmetrically restricted active lateral flexion and total left and total right ultrasonographic OA scores (p = 0.03, rho = 0.27), meaning that a higher score on one side correlated with a decreased active lateral flexion on the same side. No significant association was found between any imaging variable and restricted dorsoventral flexion at the withers. There was a trend (p = 0.054) indicating that a hypertrophied brachiocephalic muscle was associated with the presence of at least one moderately or severely affected APJ (≥ grade 2) in the ultrasonographic examination (binary ultrasonographic OA). However, no significant associations were found between brachiocephalic muscle hypertrophy and total radiographic or ultrasonographic OA scores.
No association was found between neck conformation or body posture and total radiographic or ultrasonographic OA scores. However, horses with a body posture in extension showed a trend (p = 0.08) for at least one moderately or severely affected APJ (≥ grade 2) in the ultrasonographic examination (binary ultrasonographic OA).

No significant association was found between lameness grade and imaging variables.

Frequency and duration of turn out and frequency of training did not show a significant influence on imaging variables, although there was a trend for an association between frequency of training and the prevalence for at least one moderate to severe finding (≥ grade 2) in the ultrasonographic examination (binary ultrasonographic OA). Horses which received their roughage from elevated feeders (compared to being fed on ground level) had lower $TS_{RX,Cd+T1}$ (p = 0.04) and a tendency for lower $TS_{RX,Cd}$ (p = 0.05), TS_{RX+T1} (p = 0.06) and TS_{RX} (p = 0.07). No significant association was found between elevated feeding and total bilateral ultrasonographic OA scores (TS_{US}, p = 0.46).

There was a trend for horses with stiffness to have at least one moderate to severe (≥ grade 2) finding in the ultrasonographic examination (binary ultrasonographic OA) (p = 0.083).

A strong trend towards a positive correlation ($p = 0.054$, $rho = 0.24$) was found between the rideability score and total bilateral ultrasonographic OA score (TS_{US}) and a significant ($p = 0.01$) positive association was found between the ridability score and the binary ultrasonographic OA. However, there was no correlation between the ridability score and all radiographic variables.

6 Discussion

Animals, epidemiology and history

The general aim of the present study was to determine the status of the neck health of horses used for riding in Switzerland. All horses were defined as riding sound by the riders themselves. The majority represented middle-aged warmblood mares and geldings used for show jumping or dressage. This represents the Swiss population of horses fairly well, although warmbloods are overrepresented in this study compared to 40% in the overall Swiss population. More than half of the horses were pastured and exercised 5 to 7 days per week. Most horses were fed from ground level. Stiffness of their horses during riding was reported by almost a third of all riders. In the clinical examination most horses showed a neutral body posture and no restriction in lateral and dorsoventral flexion.

Clinical examination

Of the 71 riding sound horses, more than two thirds were diagnosed with a front and/or hind limb lameness. Similar results were obtained by other studies looking at the lameness scores of riding sound horses [069, 070]. Although horses were only included if a lameness grade ≤ 2 was diagnosed at the initial lameness examination on hard ground, some horses were scored grade 2.5 or 3 on the treadmill. It is well known from equine clinicians experienced in assessing horses overground and on the treadmill, that lameness is more easily detected on the treadmill and therefore often graded higher in comparison to the overground evaluation. Several reasons for the unnoticed lameness by the rider may be hypothesized. Riders are often not experienced in lameness evaluation and do not usually have someone to trot up the horse in a straight line. Additionally, mild lameness may be misinterpreted as tact irregularities or may be compensated by good riders' skills [071].
Body posture and mobility of the neck and at the withers was altered in a part of the horses.

Imaging findings

In the majority of APJs, no or only mild OA was diagnosed radiographically or ultrasonographically, and the overall proportion of marked or severe OA was very low. Nevertheless, as reported previously [030, 031], the radiographic OA scores were significantly higher in the caudal neck and the most severe grades were diagnosed in the APJs of C6-7. Similarly, the most severe ultrasonographic OA scores were found in the APJs of C6-7.
Interestingly, horses which were fed from an elevated level showed significantly lower caudal radiographic OA scores and a trend towards lower overall radiographic OA scores. However, ultrasonographic scores did not differ between the groups. It is possible that the prolonged flexion of the APJs due to feeding roughage from ground level may increase the load on these joints, which modern sport horses may not tolerate as well as original horses that evolved to be grazing animals. The finding may also be explained by owners raising the feed in response to noticing signs of stiffness in their horses. In this study, the sample size of horses with elevated feeding was low; therefore, further studies are needed to validate these results and investigate their cause.

Taller horses and warmbloods showed significantly higher ultrasonographic OA scores and a trend towards a higher radiographic OA score. This may again be explained with the higher load on the APJs associated with a heavier head and longer neck [001]. It is also possible that warmbloods are ridden with the neck in a more flexed position than other breeds.

In this study the radiographic OA scores of the caudal cervical vertebrae were significantly higher than in the cranial cervical vertebrae and the most severe grades were given for the region of C6-7. This is in agreement with other studies, that have found pathologies of the APJs to be most common in the caudal neck (C5-C7) [030, 031].

Similar to previous studies, a trend for a positive correlation between age and some radiographic and ultrasonographic variables was observed, which supports the results of most studies [001, 026]. However, contrary to some studies claiming that male horses had significantly more radiographic changes [045], this study found no association between gender and radiographic and ultrasonographic variables.

Overall, ultrasonographic variables have been found to correlate well with findings on radiographic variables.

A restricted lateral flexion to one side was associated with a significantly higher total US score on the same side. In horses with hypertrophied brachiocephalic muscles or with a body posture in extension there was a trend towards a higher prevalence of at least one moderate or severe grade on ultrasonographic evaluation. Also, there was a strong trend towards a positive correlation between the ridability score and the total bilateral US OA score, and a significant positive association between the ridability score and the binary ultrasonographic OA score. There was also a trend that horses with reported stiffness had a higher binary ultrasonographic OA score. On the other hand, radiographic variables were neither significantly associated with stiffness, restricted active lateral flexion, hypertrophied brachiocephalic muscles nor ridability. Since US depicts more active signs of OA than radiography, US appears more sensitive for the detection of clinically relevant OA of the APJs in the neck.

Lameness was not associated with cervical OA in the present study, and therefore, it may be likely due to other musculoskeletal diseases.

In conclusion, results of the present study support the hypothesis that OA changes of the cervical equine APJs are present to a certain degree in the average riding horse population in Switzerland. Some associates were found between the imaging findings and epidemiological factors, however there is only a limited association between clinical and imaging findings when it comes to osteoarthritis of the equine cervical spine. This implies that radiographically and ultrasonographically visible changes do not always lead to clinical signs. US appears more sensitive for the detection of clinically relevant OA of the APJs in the neck.

Limitations

A few drawbacks of the present study have to be discussed. All horses were defined as riding sound by the riders themselves and were only excluded from the study if a lameness grade > 2 was diagnosed at the initial lameness examination. However, the authors of the present study cannot exclude that some riders participated in particular because they suspected a back problem in their horse in connection with a rideability problem.

Due to a mean time-interval of 130 days between the examination in the field (including the clinical examination) and the diagnostic imaging work-up at the university, findings at the chiropractic examination, second lameness examination, radiography, ultrasonography and gait analysis on the treadmill may have only developed or worsened during this time. This could explain the lack of correlation.

It is also plausible that the clinical and radiographic/ultrasonographic findings may correlate better in horses with more severe findings on diagnostic imaging. Such horses were probably excluded from this study, as the requirement was for the horses to be riding sound.

There was no even distribution of breed and gender of the horses (a majority were warmbloods and mares or geldings), so the influence of those factors could not be safely assessed.

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8 Annex

8.1 Overview of the Statistical Tests

Test oder Modell	P	Rho	AIC	W	Chisq
Spearman's rank correlation	0.000	0.43			
Spearman's rank correlation	0.001	0.47			
Binomial regression	0.014		56.429		
Binomial regression	0.007		70.798		
Wilcoxon rank sum test	0.000			2982	
Wilcoxon rank sum test	0.000			3803	
Spearman's rank correlation	0.905	0.02			
Spearman's rank correlation	0.050	0.23			
Spearman's rank correlation	0.225	0.17			
Spearman's rank correlation	0.290	0.15			
Spearman's rank correlation	0.094	0.20			
Spearman's rank correlation	0.229	0.14			
Binomial regression	0.230		77.937		
Binomial regression	0.503		76.843		
Binomial regression	0.218		100.72		
Binomial regression	0.503		76.843		
Binomial regression	0.158		100.31		
Binomial regression	0.636		39.935		
Spearman's rank correlation	0.613	0.06			
Spearman's rank correlation	0.488	-0.08			
Spearman's rank correlation	0.839	-0.03			
Spearman's rank correlation	0.612	0.07			
Spearman's rank correlation	0.718	0.04			
Spearman's rank correlation	0.091	-0.20			
Binomial regression	0.153		77.247		
Binomial regression	0.314		76.255		
Binomial regression	0.578		101.99		
Binomial regression	0.314		76.255		
Binomial regression	0.403		101.7		
Binomial regression	0.886		40.151		
Spearman's rank correlation	0.022	0.29			
Spearman's rank correlation	0.884	0.02			
Spearman's rank correlation	0.169	0.19			
Spearman's rank correlation	0.053	0.27			
Spearman's rank correlation	0.404	0.10			
Spearman's rank correlation	0.816	-0.03			
Binomial regression	0.548		79.014		
Binomial regression	0.072		73.51		
Binomial regression	0.519		101.88		
Binomial regression	0.072		73.51		

Binomial regression	0.439		101.8		
Binomial regression	0.647		39.949		
Kruskal-Wallis rank sum test	0.755				1.1901
Kruskal-Wallis rank sum test	0.762				1.1624
Kruskal-Wallis rank sum test	0.902				0.57414
Kruskal-Wallis rank sum test	0.421				2.8177
Kruskal-Wallis rank sum test	0.549				2.1149
Kruskal-Wallis rank sum test	0.884				0.65427
Binomial regression	Individuelle P value für jede Disziplin, nirgends signifikant				
Binomial regression	Individuelle P value für jede Disziplin, nirgends signifikant				
Binomial regression	Individuelle P value für jede Disziplin, nirgends signifikant				
Binomial regression	Individuelle P value für jede Disziplin, nirgends signifikant				
Binomial regression	Individuelle P value für jede Disziplin, nirgends signifikant				
Binomial regression	Individuelle P value für jede Disziplin, nirgends signifikant				
Wilcoxon rank sum test	0.001			148	
Wilcoxon rank sum test	0.861			490.5	
Wilcoxon rank sum test	0.217			161	
Wilcoxon rank sum test	0.058			133	
Wilcoxon rank sum test	0.569			434.5	
Wilcoxon rank sum test	0.681			502.5	
Binomial regression	0.150		76.886		
Binomial regression	0.120		74.683		
Binomial regression	0.836		102.26		
Binomial regression	0.120		74.683		
Binomial regression	0.539		102.03		
Binomial regression	0.776		40.086		
Wilcoxon rank sum test	0.490			540	
Wilcoxon rank sum test	0.851			607.5	
Wilcoxon rank sum test	0.877			339	
Wilcoxon rank sum test	0.634			321	
Wilcoxon rank sum test	0.785			600.5	
Wilcoxon rank sum test	0.948			619	
Binomial regression	0.575		79.068		
Binomial regression	0.707		77.163		
Binomial regression	0.747		102.2		
Binomial regression	0.707		77.163		
Binomial regression	0.914		102.4		
Binomial regression	0.813		40.115		
Binomial regression	0.137		52.757		
Binomial regression	0.260		60.11		
Binomial regression	0.240		47.138		
Binomial regression	0.243		47.418		
Binomial regression	0.464		61.153		
Binomial regression	0.296		60.257		
Binomial regression	0.650		55.458		

Binomial regression	0.353		48.088		
Binomial regression	0.885		61.701		
Binomial regression	0.353		48.088		
Binomial regression	0.962		61.72		
Binomial regression	0.993		60.143		
Spearman's rank correlation	0.485	-0.09			
Spearman's rank correlation	0.512	-0.08			
Spearman's rank correlation	0.845	-0.03			
Spearman's rank correlation	0.784	0.04			
Spearman's rank correlation	0.844	-0.02			
Spearman's rank correlation	0.942	-0.01			
Wilcoxon rank sum test	0.713			383	
Wilcoxon rank sum test	0.552			320	
Wilcoxon rank sum test	0.902			619	
Wilcoxon rank sum test	0.552			320.5	
Wilcoxon rank sum test	0.755			605.5	
Wilcoxon rank sum test	0.820			174.5	
Spearman's rank correlation	0.027	0.27			
Binomial regression	0.608		69.978		
Binomial regression	0.821		57.613		
Binomial regression	0.392		78.548		
Binomial regression	0.940		57.657		
Binomial regression	0.207		77.67		
Binomial regression	0.804		79.196		
Binomial regression	0.201		68.639		
Binomial regression	0.466		57.118		
Binomial regression	0.382		78.474		
Binomial regression	0.466		57.118		
Binomial regression	0.316		78.229		
Binomial regression	0.875		79.231		
Binomial regression	0.506		78.945		
Binomial regression	0.735		70.395		
Binomial regression	0.755		90.132		
Binomial regression	0.514		70.084		
Binomial regression	0.658		90.034		
Binomial regression	0.859		90.197		
Binomial regression	0.083		76.404		
Binomial regression	0.991		70.508		
Binomial regression	0.624		89.987		
Binomial regression	0.991		70.508		
Binomial regression	0.736		90.115		
Binomial regression	0.630		89.974		
Spearman's rank correlation	0.054	0.24			
Spearman's rank correlation	0.331	0.14			
Spearman's rank correlation	0.161	0.17			

Spearman's rank correlation	0.687	0.06			
Spearman's rank correlation	0.417	0.10			
Spearman's rank correlation	0.672	0.05			
Wilcoxon rank sum test	0.013			243.5	
Wilcoxon rank sum test	0.927			344.5	
Wilcoxon rank sum test	0.824			609.5	
Wilcoxon rank sum test	0.927			344.5	
Wilcoxon rank sum test	0.925			621.5	
Wilcoxon rank sum test	0.298			119	
Spearman's rank correlation	0.294	0.14			
Spearman's rank correlation	0.792	0.04			
Spearman's rank correlation	0.650	0.06			
Spearman's rank correlation	0.948	-0.01			
Spearman's rank correlation	0.456	0.09			
Spearman's rank correlation	0.585	-0.07			
Wilcoxon rank sum test	0.310			326	
Wilcoxon rank sum test	0.745			340.5	
Wilcoxon rank sum test	0.779			571.5	
Wilcoxon rank sum test	0.745			340.5	
Wilcoxon rank sum test	0.536			546	
Wilcoxon rank sum test	0.931			156	
Spearman's rank correlation	0.942	-0.01			
Spearman's rank correlation	0.276	-0.16			
Spearman's rank correlation	0.140	-0.18			
Spearman's rank correlation	0.434	-0.11			
Spearman's rank correlation	0.188	-0.16			
Spearman's rank correlation	0.910	-0.01			
Wilcoxon rank sum test	0.368			440.5	
Wilcoxon rank sum test	0.269			379	
Wilcoxon rank sum test	0.318			672	
Wilcoxon rank sum test	0.269			379	
Wilcoxon rank sum test	0.231			688	
Wilcoxon rank sum test	0.823			169.5	
Spearman's rank correlation	0.927	0.01			
Spearman's rank correlation	0.763	0.04			
Wilcoxon rank sum test	0.230			349	
Wilcoxon rank sum test	0.745			313	
Wilcoxon rank sum test	0.471			596	
Wilcoxon rank sum test	0.766			311.5	
Wilcoxon rank sum test	0.499			592.5	
Wilcoxon rank sum test	0.889			529.5	
Binomial regression	0.054		75.646		
Binomial regression	0.386		76.545		
Binomial regression	0.208		100.69		
Binomial regression	0.386		76.545		

Binomial regression	0.271		101.18		
Binomial regression	0.587		39.844		
Kruskal-Wallis rank sum test	0.854				0.31536
Kruskal-Wallis rank sum test	0.451				1.5935
Kruskal-Wallis rank sum test	0.456				1.571
Kruskal-Wallis rank sum test	0.701				0.70923
Kruskal-Wallis rank sum test	0.986				0.028592
Kruskal-Wallis rank sum test	0.252				2.7581
Binomial regression	Individuelle P value für jede Disziplin, nirgends signifikant				
Binomial regression	Individuelle P value für jede Disziplin, nirgends signifikant				
Binomial regression	Individuelle P value für jede Disziplin, nirgends signifikant				
Binomial regression	Individuelle P value für jede Disziplin, nirgends signifikant				
Binomial regression	Individuelle P value für jede Disziplin, nirgends signifikant				
Binomial regression	Individuelle P value für jede Disziplin, nirgends signifikant				
Wilcoxon rank sum test	0.313			419	
Wilcoxon rank sum test	0.517			300	
Wilcoxon rank sum test	0.499			507	
Wilcoxon rank sum test	0.905			264	
Wilcoxon rank sum test	0.688			432	
Wilcoxon rank sum test	0.250			524.5	
Binomial regression	0.081		69.664		
Binomial regression	0.654		70.007		
Binomial regression	0.285		90.041		
Binomial regression	0.654		70.007		
Binomial regression	0.285		90.041		
Binomial regression	0.625		33.538		
Wilcoxon rank sum test	0.463			260	
Wilcoxon rank sum test	0.056			265.5	
Wilcoxon rank sum test	0.075			437.5	
Wilcoxon rank sum test	0.040			270.5	
Wilcoxon rank sum test	0.047			449	
Wilcoxon rank sum test	0.353			375.5	
Binomial regression	0.230		72.966		
Binomial regression	0.057		70.226		
Binomial regression	0.060		92.849		
Binomial regression	0.057		70.226		
Binomial regression	0.060		92.849		
Binomial regression	0.996		27.286		
Spearman's rank correlation	0.361	-0.12			
Spearman's rank correlation	0.716	-0.04			
Spearman's rank correlation	0.500	-0.09			
Spearman's rank correlation	0.730	0.05			
Spearman's rank correlation	0.547	0.07			
Spearman's rank correlation	0.454	-0.09			
Binomial regression	0.384		78.619		

Binomial regression	0.246		75.925		
Binomial regression	0.294		101.18		
Binomial regression	0.246		75.925		
Binomial regression	0.295		101.3		
Binomial regression	0.844		40.133		
Spearman's rank correlation	0.196	0.17			
Spearman's rank correlation	0.667	0.05			
Spearman's rank correlation	0.781	0.04			
Spearman's rank correlation	0.619	0.07			
Spearman's rank correlation	0.924	0.01			
Spearman's rank correlation	0.887	0.02			
Binomial regression	0.083		75.814		
Binomial regression	0.793		77.235		
Binomial regression	0.688		102.14		
Binomial regression	0.793		77.235		
Binomial regression	0.555		102.06		
Binomial regression	0.414		39.534		