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SPORT-RELATED EAR, NOSE AND THROAT DISEASES

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DOCTORAL DISSERTATION

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To my family

ABSTRACT

A large variety of sports carry many risks for ear, nose and throat diseases. These vary from swimmer's ear infections to surfer's ear canal exostoses, skier's running nose, nasal and facial fractures in multiple sports, olfaction loss in contact sports, audiovestibular symptoms after concussion, triathlete's dizziness, wrestler's ear deformity and endurance athlete's laryngeal obstruction in maximal effort exercise. They can affect sport performance and disturb training. These problems have been studied to various degrees, yet the effect, especially on sport performance and training, has seldom been clarified. This doctoral thesis includes four separate studies covering a large variety of different aspects of sport-related ear, nose, and throat diseases.

The first study was about cauliflower ear, its prevalence, symptoms and treatment and the athletes' attitude towards it. We distributed a paper questionnaire to elite wrestlers and judokas. In our study, the prevalence of cauliflower ear (73%, 46/63) was higher than in previous studies. Almost all athletes (96%, 44/46) had some symptoms of cauliflower ear but no one regretted it, and only two athletes (3%, 2/63) considered it an aesthetic disadvantage.

In the second study, we examined special features and the mechanism behind triathlete's dizziness by an electronic questionnaire and a cold-water swimming test. The majority (85%, 106/125) of the athletes answering the questionnaire had suffered dizziness in connection to the swimming leg. Dizziness was disturbing as it affected the sport performance for half of the athletes with dizziness. Our hypothesis was that caloric reaction explains the dizziness during swimming. Both the questionnaire answers and cold-water swimming test confirmed at least partially our suspicion. Dizziness caused by caloric reaction can be easily prevented by using earplugs during swimming leg.

In the third study, we found that chemical irritation in swimming or recurrent head trauma in boxing or soccer did not affect elite athletes' odour identification test scores. Floorball players constructed a control group. In addition to the olfaction test, we evaluated other factors influencing the olfaction by a questionnaire. We confirmed an earlier finding about the high prevalence of rhinitis symptoms among athletes and that swimmers have more diagnosed asthma than other athletes.

In the fourth study, in total 599 sport-related nasal fractures treated at Helsinki University Hospital (HUH) were found from the HUH database from 2013 to 2018. A large variety of different sports caused nasal fractures, and more than half (56%, 334/599) of them were caused by team sports. Contact with another person was the most common injury mechanism (52%, 314/599). Young males were most prone to getting sport-related nasal fractures. Our

findings about the risk sports and injury mechanisms could help to prevent nasal fractures in the future.

Studies in this thesis clarify several sport-related ear, nose and throat diseases and have found a possible treatment for triathlete's dizziness. Still, there are many aspects to study in this interesting and variable area of sport-related ear, nose, and throat diseases to help athletes to reach their top performance, optimize their treatment, and add knowledge about risks in different sports.

TIIVISTELMÄ

Useat eri urheilulajit altistavat korva-, nenä- ja kurkkutautien alaan kuuluville ongelmille. Näitä ongelmia ovat muun muassa uimareiden korvakäytävätulehdukset, surffaajien korvakäytävien eksostoosit, hiihtäjien vuotava nenä, urheilijoiden kasvomurtumat, kontaktilajien harrastajien hajuaistin alenema, aivotärähdyksen jälkeiset kuulo- ja tasapaino-oireet, triathlonistien huimaus sekä kestävyysurheilijoiden kurkunpään ahtautuminen maksimaalisessa rasituksessa. Ne voivat vaikuttaa urheilijan suorituskykyyn ja häiritä harjoittelua. Näistä ongelmista on vaihtelevasti tutkimustietoa ja erityisesti niiden vaikutuksia suorituskykyyn ja harjoitteluun on harvoin selvitetty. Tämä väitöskirja koostuu neljästä erillisestä osatyöstä, jotka käsittelevät monipuolisesti neljää erilaista urheilijoiden korva-, nenä- ja kurkkutautien alan ongelmaa.

Ensimmäinen osatyö käsitteli painijan korvan yleisyyttä, oireita ja hoitoa sekä urheilijoiden suhtautumista siihen. Jaoimme kansallisen ja kansainvälisen tason painijoille ja judokoille paperisen kyselyn aiheesta. Totesimme tässä populaatiossa painijan korvan yleisyyden olevan 73 % (46/63), mikä on aiempia tutkimuksia korkeampi. Lähes kaikilla urheilijoilla (96 %, 44/46) oli painijan korvasta oireita, mutta yksikään urheilija ei harmitellut muodostunutta painijan korvaansa ja vain kaksi urheilijaa (3 %, 2/63) piti painijan korvaa ulkonäköhaittana.

Toisessa osatyössä selvitimme sähköisen kyselyn sekä kylmävesiuintitestin avulla triathlonistien huimauksen erityispiirteitä ja huimauksen taustalla olevaa mekanismia. Suurin osa kyselyyn vastanneista (85 %, 106/125) oli kärsinyt uimiseen liittyvästä huimauksesta. Puolella huimaus oli niin häiritsevää, että se vaikutti suorituskykyyn. Hypoteesimme oli, että kalorinen reaktio selittää uintiin liittyvän huimauksen. Sekä kyselyvastaukset että kylmävesiuintitestin tulokset vahvistivat ainakin osittain oletustamme. Kalorisen reaktion aiheuttamaa huimausta voidaan ehkäistä käyttämällä korvatulppia uidessa.

Kolmannessa osatyössä totesimme, etteivät uimareiden uintivedestä saama kemiallinen ärsytys tai nyrkkeilijöiden ja jalkapalloilijoiden toistuvat päähän kohdistuvat iskut vaikuta hajuntunnistustestin pisteisiin. Tutkimuksessa kontrolliryhmänä olivat salibandyn pelaajat. Hajuntunnistustestin lisäksi selvitimme kyselyn avulla mahdollisia muita hajuaistiin vaikuttavia tekijöitä. Aiempaa tietoa vahvistaen totesimme tutkimillamme urheilijoilla riniitin oireiden olevan yleisiä ja uimareilla olevan enemmän astmaa kuin muilla urheilijoilla.

Neljännessä osatyössä kävimme läpi 599 urheilussa nenämurtuman saaneen potilaan sairauskertomusmerkinnät Helsingin yliopistollisen sairaalan tietokannasta vuosilta 2013–2018. Useat erilaiset lajit aiheuttivat nenämurtumia, ja murtumista yli puolet (56 %, 334/599) tapahtui

joukkuelajeissa. Yleisin vammamekanismi oli kontakti toisen urheilijan kanssa (52 %, 314/599). Urheiluun liittyvät nenämurtumat olivat yleisimpiä nuorilla miehillä. Tieto riskilajeista ja vammamekanismeista voi jatkossa auttaa urheiluun liittyvien nenämurtumien ehkäisyssä.

Tämän väitöskirjan osatyöt lisäävät tietoa neljästä erilaisesta urheiluun liittyvästä korva-, nenä, ja kurkkutautien alaan liittyvästä ongelmasta. Lisäksi löysimme mahdollisen hoidon triathlonistien uintiin liittyvään huimaukseen. Jatkoon jää paljon tutkimusaiheita tästä mielenkiintoisesta ja monipuolisesta kokonaisuudesta. Tavoitteena on tutkimusten avulla auttaa urheilijoita saavuttamaan maksimaalinen suorituskyky, optimoida heidän hoitoaan ja lisätä tietoa urheiluun liittyvistä riskeistä.

CONTENTS

LIST OF ORIGINAL PUBLICATIONS

This thesis is based on the following publications:

I. Manninen IK, Blomgren K, Elokiuru R, Lehto M, Mäkinen LK, Klockars T. Cauliflower ear among Finnish high-level male wrestlers and judokas is prevalent and symptomatic deformity. Scand J Med Sci Sports. 2019 Dec;29(12):1952-1956. doi: 10.1111/sms.13530. Epub 2019 Aug 16.

II. Manninen IK, Jutila T, Hirvonen T, Mäkinen LK, Blomgren K, Hyytiä T, Klockars T. Dizzy triathlete-evidence supporting vestibular etiology. Scand J Med Sci Sports. 2021 Dec;31(12):2267-2271. doi: 10.1111/sms.14041. Epub 2021 Sep 4.

III. Manninen IK, Mäkinen LK, Laukka P, Klockars T, Blomgren K. Effect of head impacts and chemical irritation on elite athletes' olfaction. Eur J Sport Sci. 2021 Dec 9:1-6. doi: 10.1080/17461391.2021.2008014. Epub ahead of print.

IV. Manninen IK, Klockars T, Mäkinen LK, Blomgren K. Epidemiology and aetiology of sport-related nasal fractures: Analysis of 599 Finnish patients. Clin Otolaryngol. 2023 Jan;48(1):70-74. doi: 10.1111/coa.13976. Epub 2022 Sep 9.

The publications are referred to in the text by their roman numerals.

ABBREVIATIONS

BPPV	Benign paroxysmal positional vertigo
CLE	Continuous laryngoscopy exercise
cVEMP	Cervical ocular vestibular-evoked myogenic potentials
CT	Computerized tomography
EILO	Exercise-induced laryngeal obstruction
EAE	External auditory canal exostosis
FIFA	International Federation of Association Football
HUH	Helsinki University Hospital
MRI	Magnetic resonance imaging
NBA	National Basketball Association
NRS	Numerical rating scale
OE	Otitis externa
OR	Odds ratio
oVEMP	Ocular vestibular-evoked myogenic potentials
p	p-value
RR	Risk ratio
TDI	Olfaction test that combines threshold, discrimination, and identification tests
vHIT	Video head impulse test
VOR	Vestibulo-ocular reflex
VO2max	Maximal oxygen uptake
WADA	World Antidoping Agency
ZMO	zygomatic-maxillary-orbital

1 INTRODUCTION

Knowledge about different sport-related ear, nose and throat diseases permits doctors from different specialities to treat athletes more effectively and help them reach their top performance. Understanding the risks in sports is important, while breaks in training are minimized and the efficiency of training maximized.

The definition of sports is not unambiguous. The *Cambridge Dictionary* contains two different definitions: 'a game, competition, or activity needing physical effort and skill that is played or done according to rules, for enjoyment and/or as a job' and 'all types of physical activity that people do to keep healthy or for enjoyment'(1). The latter is broad and comprises almost all physical activity. The Council of Europe agrees with this broad definition: '"Sport" means all forms of physical activity which, through casual or organised participation, aim at expressing or improving physical fitness and mental well-being, forming social relationships or obtaining results in competition at all levels'(2). The *Oxford Languages Dictionary*, however, agrees with the narrower definition: 'An activity involving physical exertion and skill in which an individual or team competes against another or others for entertainment'(3). We have used this definition of sports that combines physical effort, skill and competing.

Ear, nose and throat diseases involve diverse aspects of different matters, varying from traumas, infections, and breathing to the evaluation of four senses: olfaction, taste, hearing and balance. The combination of sports and ear, nose, and throat diseases has not been discussed comprehensively, but many different ear, nose, and throat diseases that are prevalent among athletes have been studied. There is a broad diversity of both sports with different risks, and ear, nose, and throat diseases, the intersection of which makes the area highly interesting and multidimensional.

In this doctoral thesis we evaluated specific sport-related traumas of ear and nose, as well as two specific sense-related problems among athletes, including olfaction and balance. These examples demonstrate well the diversity and complexity of sport-related otorhinolaryngological problems. The literature review attempts to introduce a broader spectrum of diseases. However, this barely scratches the surface of otolaryngological sports-related problems, and many remain to be studied.

2 REVIEW OF THE LITERATURE

2.1 OTOLOGICAL PROBLEMS IN SPORTS

The ear can be anatomically divided to external, middle, and internal ear (Figure 1). The external ear consists of the pinna and the external auditory canal. The tympanic membrane separates it from the middle ear. The auditory ossicles (malleus, incus, stapes) are located in the middle ear which is connected to the nasopharynx via the Eustachian tube. The inner ear consists of the auditory (cochlea) and vestibular systems. Due to the ear's anatomy and function, sport-related diseases of the ear range from simple trauma to complex neurophysiological cascades causing dizziness and/or hearing loss.

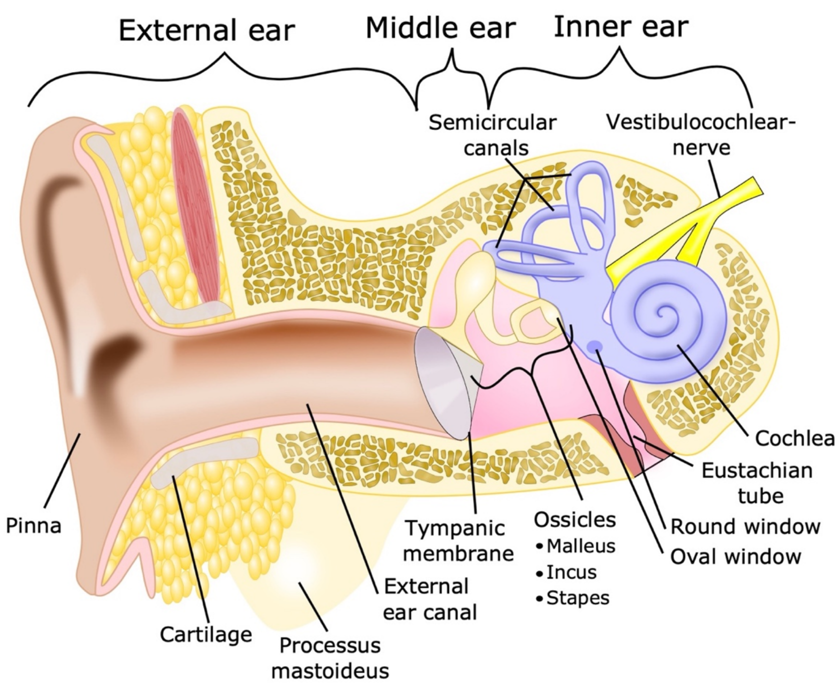


Figure 1 Anatomy of ear, right side. Figure: Iida-Kaisa Manninen.

2.1.1 EXTERNAL EAR

Auricular cartilage constructs the shape of the pinna and is covered by the perichondrium, thin subcutis and skin, all of which continue to the external auditory canal. The lateral one-third of the external auditory canal is cartilaginous, and the medial two-thirds are bony. Cartilage gets its blood supply from the perichondrium. Due to its prominence, the auricle is especially prone to trauma, whereas the inner parts of the external ear have more specific problems and diseases related to sport activities.

2.1.1.1 Cauliflower ear

Of the several names for cauliflower ear, many refer to sports: wrestler's ear, prizefighter's ear, pugilist's ear, and boxer's ear (4). It is an acquired deformity. Following a blunt trauma, a haematoma separates the perichondrium from the cartilage and later cause necrosis of the cartilage and the formation of fibroneocartilage. This causes deformity of the pinna and is known as a cauliflower ear (Figure 2).(5) Auricular haematoma is diagnosed clinically, as there is a blood-containing bulb in the auricle.

Figure 2 Example image of a former elite wrestler's cauliflower ear. Photo: Timo Nuutinen.

2.1.1.1.1 Risk sports and effect on life

Cauliflower ear is prevalent among martial art athletes (6–9). The prevalence has been reported to be 44% (181/411) among wrestlers in Teheran and 39% (209/537) among collegiate wrestlers in the United States (7,8). It has been considered mostly an aesthetic disadvantage (9). Wrestlers with cauliflower ear have reported more hearing loss (12%) than those without cauliflower ear (1.8%, $p < 0.05$) (7). Noormohammadpour et al. studied the hearing loss further and performed audiometric examinations for 201 wrestlers with cauliflower ear and 139 without. Wrestlers with cauliflower ear were found to have more hearing loss between 500 and 6000 Hz than those with non-cauliflower ears. The type of hearing loss (sensorineural or conductive) was not studied. Ear infections and cerumen accumulation were also more prevalent among those with cauliflower ears than non-cauliflower ears.(10)

Otherwise, the side effects and symptoms of cauliflower ear have not been studied.

2.1.1.1.2 Treatment and return to training

There are different options for cauliflower ear treatment. A Cochrane review did not find one that was better than another. Prompt treatment has been thought to give a better aesthetic result.(11) Possible modalities to remove haematoma are aspiration or incision (6,12,13). Dalal et al. didn't find any difference in haematoma recurrence rate between these two (6). Kordi et al. found that only 23% of the wrestlers with auricular haematomas have sought treatment (7).

After haematoma removal, some post-drainage care is suggested, such as pressure bandaging, tie-through compression with or without bandage, splints or steroid injection to prevent re-accumulation of the haematoma (6,11,13,14). The post-drainage care may prevent the return to contact sport training. The movement of the bandages may predispose one to the re-accumulation of the haematoma. Five days has been the average duration for bandaging (6). Tie-through sutures might permit an almost immediate return to training and competition (13,15). Still, there is no research about how early it is safe to return to training or which is the right duration for post-drainage intervention. The correction of already formed cauliflower ear is difficult and requires surgery (9).

2.1.1.1.3 Prevention

Protective headgear might prevent auricular haematoma (8). Headgear is mandatory in high school and university wrestling in the United States, but it is optional in international wrestling rules (16,17). Rugby players may use headgear to prevent auricular haematoma. The concern has been that protection influences the hearing level and therefore the performance, but Kieran et al. did not find hearing loss with ear protection (18).

2.1.1.2 Otitis externa

Otitis externa (OE), also called 'swimmer's ear', is a condition with inflammation or infection of the external auditory canal. It is normally caused by an impairment of the cerumen and skin protection in the external auditory canal. Warmth, humidity, and ear canal trauma predispose one to OE (19). Moisture alters normally acidic pH and permits the growth of pathogens (20). The most common pathogens are *Pseudomonas aeruginosa* (38%), *Staphylococcus epidermidis* (9.1%), *Staphylococcus aureus* (7.8%) and many other bacteria and fungi (1.7%) (21). OE causes different levels of the following symptoms: external auditory canal skin oedema, otalgia, otorrhea and a decreased level of hearing (19). Diagnostic methods include otoscopy and bacterial culture. Topical antibiotic drops and cleaning the ear are the cornerstones of treatment (20).

2.1.1.2.1 Risk sports, effect on training and prevention

Water sports athletes have recurrent water exposure, which predisposes them to OE. Swimmers and water polo players have more OE than football players, as do swimmers compared to non-swimming controls.(22,23) Avoidance of swimming is recommended for patients with OE for 7–10 days(24) which can be challenging for water sport athletes. There is no evidence or consensus on when it is safe to return to swimming. Returning to training or competition after 2–3 days without pain and with well-fitting earplugs has been proposed (24). Training other than swimming has not been discussed. Sweat may contribute moisture to the ear canal and disturb healing of the OE.

To prevent water sport-related OE, the cleaning of the swimming pool water is important. Swimming pool water can be contaminated by *Pseudomonas aeruginosa* and predispose athletes to OE.(25) Other preventive factors include drying ear canals with a hair dryer after swimming, avoiding ear canal manipulation, and preventing water from entering ear canals, for example, with a well-fitting swimming cap or earplugs (20,26). Acidifying and/or alcohol ear drops can also be used after swimming when contending with recurrent OE (20,26).

2.1.1.3 External auditory canal exostoses

External auditory canal exostoses (EAEs) are benign bony hyperplasia at the bony part of the external auditory canal (Figure 3). Exostoses have a broad base and dense lamellated bone. They are diagnosed by otoscopy and can be multiple and often bilateral (27).

The pathogenic mechanism behind exostoses is not known. Vasodilatation at the bony part of the external auditory canal caused by cold water has been considered to affect formation of exostoses.(28) Cold water causes more exostoses than warm (29,30), and the exposure time for the cold water and wind has been correlated with the exostoses and their higher grade (27,31–33). Severe exostoses are more prevalent among older people and males because of the longer exposure time to cold water (27,32).

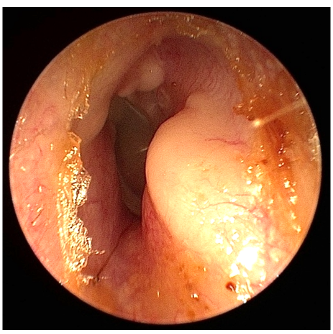


Figure 3 Multiple exostoses in the right ear of a previously active swimmer. Photo: Iida-Kaisa Manninen.

2.1.1.3.1 Risk sports and treatment

The prevalence of exostoses in the general population is 6/1000 (34). EAE is also called surfer's ear, diver's ear and swimmer's ear because its prevalence among water sport athletes like surfers (60%), wind- or kite surfers (75%) and kayakers (79%) is much higher (27,32,33), as a result of their exposure to cold water. Besides these sports, swimming has been associated with EAE (35). Some studies have found differences between water sports athletes' left and right ears in the prevalence and grade of exostoses. The exposure to colder environment because of wind or surfing position has been proposed as an explanation.(33,36)

External auditory canal obstruction by EAEs can cause symptoms like water trapping, conductive hearing loss, ear infections, cerumen accumulation, tinnitus, otalgia and itching (27,31,33). Surgical treatment is considered when non-surgical treatment like cleaning and acidifying and/or alcohol drops are not enough. Recurrence of the EAE is possible after the surgery especially if the cold water exposure continues.(37)

2.1.1.3.2 Effect on training and prevention

Ear canal exostoses predispose individuals to otitis externa, which is problematic for aquatic athletes because its treatment includes a pause in participation in water sports (24). As cold water exposure is the main factor in the formation of EAEs, they may be prevented by using earplugs, which prevent water entering the external auditory canal (37,38). The problem with earplugs is their effect on hearing level. Elastomeric plugs produced the smallest reduction in hearing level.(39) Sixty percent (55/92) of the surfers were aware of the preventability of exostoses (40).

2.1.2 MIDDLE EAR

The middle ear conducts sound waves from the tympanic membrane to the inner ear. Sport-related problems affecting solely the middle ear are rare, although diving causes pressure changes in the middle ear, and some traumas can affect the middle ear. The most prevalent trauma is tympanic membrane perforation. Cranial base fractures can extend to the middle ear and lead to dislocation or break of the ossicles and thus to conductive hearing loss. There are not many studies about sport-related temporal bone fractures, but only some case reports, including one about a mountain-bike accident where the incus was found in the external auditory canal (41).

2.1.2.1 Tympanic membrane perforation

Traumatic perforation of the tympanic membrane can be caused by a barotrauma, penetrating trauma, or blast injury. Sport-related traumatic tympanic membrane perforations constitute only 5.5% of all perforations and have not been studied widely.(42) Traumatic tympanic membrane perforation may cause pain, hearing loss, bloody otorrhea, and tinnitus. The vast majority (89–93%) of traumatic perforations heal spontaneously within 1–2 months.(42,43) If the perforation does not heal, it can be surgically repaired (44).

Traumatic tympanic membrane perforations are prevalent in surfing and water polo, where falling into water causes barotrauma perforation of the tympanic membrane (45,46). Water-related traumatic perforations may lead to middle ear infections (45), and protection from water is needed until the perforation has healed. This might disturb aquatic athletes' training in water; however, earplugs can be used for water protection and may prevent tympanic membrane perforations (46).

2.1.2.2 Middle ear barotrauma

Quick pressure changes, for example in diving, may lead to middle ear barotrauma. Normally, a diver equalizes the pressure between the nasopharynx and middle ear through the Eustachian tube by the Valsalva manoeuvre.(47) The majority (81%) of 1881 divers had suffered from middle ear barotrauma, and divers with poor subjective success in the Valsalva manoeuvre reported it more often. The most common symptoms of middle ear barotrauma were pain (80%), pressure (52%), hearing loss (6%), tinnitus (5%) and tympanic membrane perforation (3%). Symptoms lasted a maximum of 2 hours for 90% of those affected.(48) Severe barotrauma may lead to hemotympanum, transudation or tympanic membrane perforation causing conductive hearing loss (47).

2.1.3 INNER EAR

The inner ear is responsible for sound detection and, partially, balance. It is located within the temporal bone and consists of the cochlea and the vestibular organ. Sport activities can affect both of these.

2.1.3.1 Noise-induced hearing loss

Sound waves are converted to nerve impulses in the cochlea in the inner ear. Noise can predispose one to a decrease in hearing; noise-induced hearing loss can be temporary (temporary threshold shift) lasting 24 to 48 hours or permanent (49). Some sports can be quite loud. As examples, motor sports or shooting can create sounds loud enough to cause noise-induced hearing loss(50,51).

2.1.3.1.1 Risk sports

Many sports include some noise, such as motor sports, fitness classes with a loud instructor or music, windy weather, or air resistance (50,52,53). Noise exposure together with exercise has been considered to predispose one to hearing loss more than noise alone. Music and exercise together produce more temporary hearing threshold level shifts than music or exercise alone.(54)

Grand Prix motorcyclists have more noise-induced hearing loss than age- and sex-matched controls. Still, fewer than half (39%) used earplugs regularly as noise protection.(50) Otherwise, hearing levels of motor sports athletes have not been investigated.

Shooting holds great risk for hearing loss because of the nature of the sport. Sport shooters in Thailand have shown more hearing loss than a control group (51), and recreational shooters have more high-frequency hearing loss than controls (55). All tested target shooting guns used by youths exceeded the World Health Organization's recommended maximum limit of 120 dB for children (56). In a study of about 210 underage recreational shooters in the United States, 10% reported constant and 45% occasional tinnitus. Over half (56%) always used ear protectors during target shooting but 62% never used them during hunting.(57)

High sound levels have been measured in fitness and aerobics classes (52,58–60). Loud music is thought to be motivating in the classes, even though the instructors find it more motivating than the clients (52). Torre and Howell measured a significant decrease in 6 kHz otoacoustic emission after an aerobics class (60).

Seidman et al. measured wind noise during bicycling in an electronic wind tunnel and noted noise from 85 dB to 120 dB. Noise was louder in the downwind ear and at a higher speed. This was considered to be significant for healthy hearing on long rides.(53) Also, the level of noise of hitting golf balls with a titanium head golf driver has been measured at 119 dB, which was discussed as predisposing enthusiastic golfers to hearing loss (61).

2.1.3.1.2 Prevention

Knowledge about the harmful effects of noise needs to be shared with athletes, instructors, and coaches. Noise-caused hearing loss can be prevented by ear protectors, and in some situations the loudness of the noise can be reduced. Nowadays, novel technology permits self-detection of noise—for example, with iPhones (59).

Shooters can also use ear protectors, and one option is level-hearing protectors that allow speaking without taking off the protectors (62). Firearm suppressor significantly reduce noise exposure, even though they might need to be combined with ear protectors (63).

2.1.3.2 Balance

Balance is a combination of several senses: somatosensorial, visual, and vestibular inputs are combined in the central nervous system to maintain balance, provide general orientation, and stabilize gaze. Many other factors such as drugs, age and learning can also affect it.(64) That makes the evaluation of dizziness and imbalance complex. Patients with dizziness are examined not only by otorhinolaryngologists but also by general practitioners, neurologists and sport doctors.(65) Different sports include a variety of aspects that can improve balance, while others can cause dizziness.

In the inner ear three semicircular canals and otolith organs form the vestibular organ. Otolith organs detect linear accelerations while semicircular canals detect rotational movements in three different planes. The vestibulo-ocular reflex (VOR) detects rotational movement of the head and keeps one's gaze stabilized.(64) In dizziness caused by inner ear issues, the symptom is often vertigo, described as a spinning sensation.

2.1.3.2.1 Sports improving balance

Sport training can improve balance—for example, gymnastics training focuses a lot on balance. In one study the sensory organisation abilities of rhythmic gymnasts were superior to those of controls.(66) Children training in gymnastics had better reweighting processes during quiet standing than non-gymnastic children, and their values were comparable to adults. There were no differences between adults training in gymnastics and non-gymnastic adults.(67) Acrobats and dancers also had better equilibrium maintenance on a seesaw platform than did untrained controls (68). Kite surfers as well need good balance to keep themselves on the board amid waves, and their dynamic balance has been superior compared to controls (69). Archers need to keep a stable standing position to improve their shooting accuracy, and they had better postural stability during visual disturbance than ball game players or untrained individuals. They seemed to rely more on the proprioceptive sense.(70)

2.1.3.2.2 Dizziness in sports

I review only specific features of dizziness among athletes, focusing on vestibular symptoms, not all kinds of dizziness and their treatment. Dizziness is a prevalent symptom in the general population (71). In addition to balance improvement, some sports may help with dizziness—for example, t'ai chi (72). On the other hand, bradycardia and hypotension may produce more dizziness among athletes than in the normal population (73). Most studies considering sport-related dizziness are focused on dizziness as a symptom of concussion, which is discussed in the next chapter.

2.1.3.2.2.1 Risk sports

Vertigo has been more prevalent after training or competition among downhill mountain bikers than road cyclists, even though dizziness during daily living didn't differ between them or between cyclists and controls. Head trauma and vibration have been considered to explain vertigo among downhill bikers and exhaustion among road cyclists. Cervicogenic factors were also speculated about.(74) In addition, dizziness has been detected among throwers. In a small study, 11 discus throwers had significantly more dizziness during throwing than 11 hammer throwers do. Gaze fixation is easier to do in hammer throwing and was thought to be the difference between these two sports and explain the dizziness.(75)

Temporal bone fracture can cause dizziness and sensorineural hearing loss when it affects the inner ear. Still, there are not many studies about otology problems in sport-related temporal bone fractures. In a case report perilymphatic fistula was detected in two children with sport-related temporal bone fracture, one after a collision with another player in football and the other after falling off a bicycle (76).

2.1.3.2.2.2 Benign paroxysmal positional vertigo

Benign paroxysmal positional vertigo (BPPV) is the most common type of vertigo. It is caused when a calcified otoconia is displaced from the otolith organ. Then it spreads to the semicircular canal and produces short-lasting vertigo and nystagmus in connection to the change of head position.(77) The evaluation includes positional tests like the Dix-Hallpike test. The test provokes vertigo and nystagmus when it is positive. The otoconia can be moved back to the utricle by a repositioning manoeuvre such as the Epley manoeuvre.(78)

Trauma is one cause of BPPV (79), which is why it is common among athletes. American football players have more BPPV (25%, 16/63) than controls (0%, 0/49). The occurrence of BPPV was associated with longer football careers and training hours.(80) Mountain bikers also suffered from BPPV after an intensive ride without any head trauma. The vibration during the ride was considered to cause displacement of otoconia and thus lead to BPPV.(81) BPPV is crucial to notice as it is easily treatable, unlike many other causes of dizziness. An elite soccer player could return to playing symptom-free within 24 hours with proper BPPV treatment (82).

2.1.3.2.2.3 Triathlon-related dizziness

In many Internet forums, triathletes discuss dizziness during or after a swimming leg. This topic has not been studied previously. Twenty percent of the medical visits in a triathlon race comprise unspecific dizziness (83). Dizziness during swimming has been considered to be caused by cervicogenic causes, BPPV or a caloric reaction among patients with former mastoid surgery (84–87).

A caloric reaction is produced by asymmetrical warming or cooling of the external auditory canal, which causes stimulation or inhibition of the same-side vestibular organ. It causes vertigo and nystagmus if the athlete has a healthy vestibular organ on that side. The direction of nystagmus is defined by the fast phase; stimulation or inhibition of the vestibular organ affects the direction. Cold water irrigation to one ear causes nystagmus beating to the opposite ear.(88) In triathlon races freestyle swimming takes place in open water, which can be cold, and water can enter the ear canal, possibly causing caloric reaction and dizziness.

2.1.3.3 Audiovestibular symptoms of sport-related concussion

Sport-related concussions have been studied widely. Among high school and college athletes, high rates of sport-related concussions have been noted in football, ice hockey, wrestling, soccer, field hockey, softball and lacrosse with a total rate of 3.9–4.5/10,000 for either practice or competition (89,90). Concussion, which is also called mild brain injury, is defined as acute brain injury with one or more of the following signs: confusion, loss of consciousness less than 30 minutes, post-traumatic amnesia less than 24 hours, and/or transient neurological abnormalities (91). Audiovestibular symptoms are prevalent with sport-related concussion, as in one study with 1647 athletes with sport-related concussion: 68% had dizziness, 36% imbalance, 31% disorientation, 30% noise sensitivity, and 9% tinnitus (92).

2.1.3.3.1 Vestibular symptoms

After headache (92–95%), dizziness (69–75%) is the second most common symptom of concussion (89,90). In comprehensive clinical examinations, 90% of children with dizziness or imbalance after sport-related concussion have at least one abnormal clinical status finding (93).

The mechanism of dizziness after concussion is not clear. Both central and peripherical causes have been suggested (93,94). Peripherical would refer to the inner ear. A video head impulse test (vHIT) measures the function of the VOR activated by head rotation and semicircular canals (64). The semicircular canals have not been considered to have a role in dizziness from sport-related concussion because vHIT has been normal and similar to the controls, even though the rotation has resulted in symptoms like headache, dizziness and nausea (95–97). Otolith organ testing of ocular vestibular-evoked myogenic potentials (oVEMP) has been absent or asymmetrical more often among athletes with concussion than among the controls, but no difference in cervical vestibular-evoked myogenic potentials (cVEMP) was found. These findings in oVEMP tests might refer to the peripherical cause of dizziness in the otolith organ or a problem in another part of the reflex arc.(97)

As described earlier, post-traumatic BPPV can cause dizziness in athletes, who can have both BPPV and concussion simultaneously. Almost one-third of children or young adults with concussion had BPPV.(98) This is important to notice as BPPV is easily treatable with repositioning manoeuvres (98).

2.1.3.3.2 Audiological symptoms

Audiological symptoms are not as common as vestibular symptoms with sport-related concussion. Still, in one study as many as 92% (45/52) of patients with concussion had some auditory symptoms, which is more than controls reported (31%, 17/55) (99). Hyperacusis (30–67%) is the most common auditory symptom (89,92,99). Although hearing level with concussion did not decrease, athletes with concussion and sound sensitivity had lower loudness discomfort levels than athletes with concussion but without sound sensitivity (100).

2.1.3.3.3 Healing, treatment and effect on training and performance

In more than half of the athletes with concussion, symptoms resolve within a week (60%), but for 6% it takes over 4 weeks (101). Both auditory and vestibular symptoms have been suggested to predict prolonged symptoms and a later return to competition (92,102). Previous concussion predisposes one to orthopaedic traumas. One explanation may be the dizziness caused by concussion and its effect on balance, but the cause for the traumas is not clear.(103)

Athletes with concussion should not return to play on the day of the concussion. Both physical and cognitive rest is recommended for 24–48 hours after concussion. After that, return to play and competitions should be resumed step by step, and if symptoms worsen, the exercise is eased again. That takes at minimum 7 days. If the vestibular symptoms persist over 10–14 days for adults or over 4 weeks in children, vestibular physical therapy might help.(104)

2.1.3.4 Inner-ear barotrauma and decompression sickness

Diving causes changes in ambient pressure, and with a forceful Valsalva manoeuvre, pressure between the middle and inner ear can change quickly. This may lead to inner ear barotrauma or rupture of the oval or round window. The symptoms can be sensorineural hearing loss, tinnitus and/or vertigo. Inner ear decompression sickness can cause the same symptoms, but the aetiology and treatment are different. In decompression sickness, bubbles form in the inner ear during the diving. Hyperbaric oxygen is used as an acute treatment in inner ear decompression sickness and bed rest in inner ear barotrauma.(105) With similar symptoms, these two can be hard to distinguish from each other, but there are some typical features (106).

2.2 NASAL PROBLEMS IN SPORTS

The nose gets its shape from both bony and cartilaginous parts. The nasal bones are located in the upper part of the nose. Skin covers the outer surface of the nose and mucosa the nasal cavities. The nasal cavities contain superior, middle, and inferior turbinates, and the nasal septum separates the two nasal cavities (Figure 4). The cartilage part of the septum gets its blood supply from the perichondrium.

The nose takes part in the respiratory function and olfaction. The nasal cavities warm, humidify, and clear the inspired air and cool and dry the expired air. Clearance may include allergens, pathogens, and irritants. Nasal mucosa has a notable part in the primary defence system against microorganisms.(107)

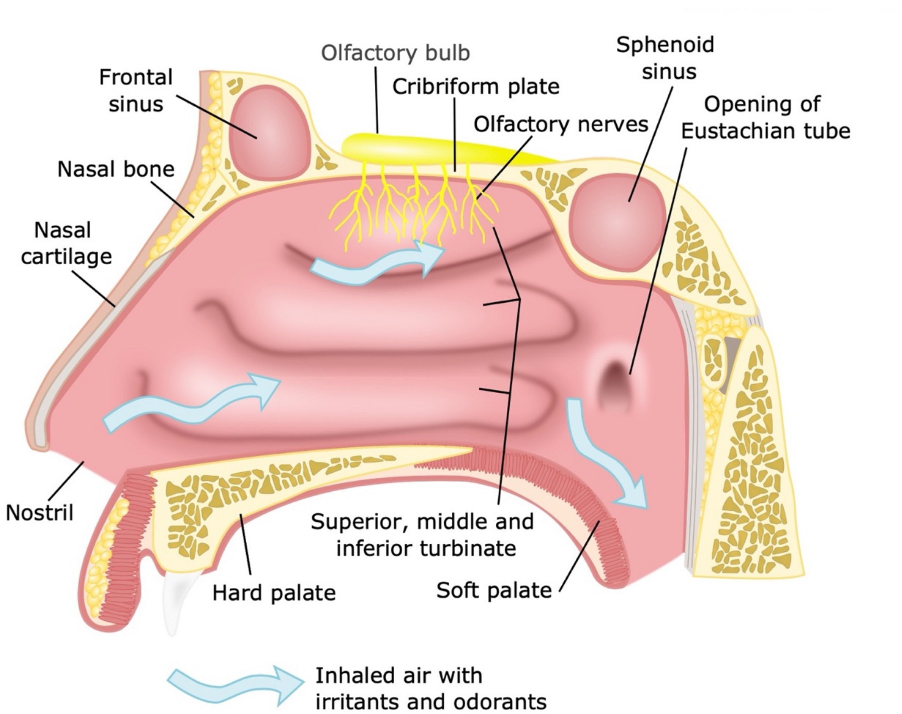


Figure 4 Anatomy of nasal cavity. Figure: Iida-Kaisa Manninen.

Normally, people breathe through the nose when they are resting. Sympathetic activation causes arterial vasoconstriction in nasal mucosa, which leads to nasal decongestion, increased nasal cavity size and airflow (108). Exercise increases sympathetic activation and causes higher peak nasal inspiratory flow (109). During exercise, the increased ventilation switches breathing through the nose to a combination of oral and nasal breathing at submaximal exercise levels (110). The favourable effect of the nose on warming, humidifying, and clearing the air is bypassed during oral breathing.

Increased airflow during exercise predisposes mucosa to several irritants and pathogens. In addition, due to the central location of the nose, it is prone to being injured during sport activities. The most prevalent nasal problems among athletes are rhinitis, nasal obstruction, nasal traumas, and olfaction loss. Nasal obstruction can be caused by structural changes or mucosal changes, for example, in rhinitis.(111)

2.2.1 STRUCTURAL NASAL CONCERNS

2.2.1.1 Nasal trauma

The nose with its thin bone and prominent shape in the middle of the face is prone to traumas and fractures (Figure 5). According to a systematic review, 15% of nasal fractures in adults and 59% in children are sports-related (112). In addition to bony fractures, the septal cartilage also may fracture. Septal fractures may lead to haematoma formation under the perichondrium, which can further lead to cartilage necrosis and nasal deformation. Nasal fractures are diagnosed through inspection and palpation of the nose and anterior rhinoscopy to rule out septal fracture or haematoma. Imaging studies are usually not required.

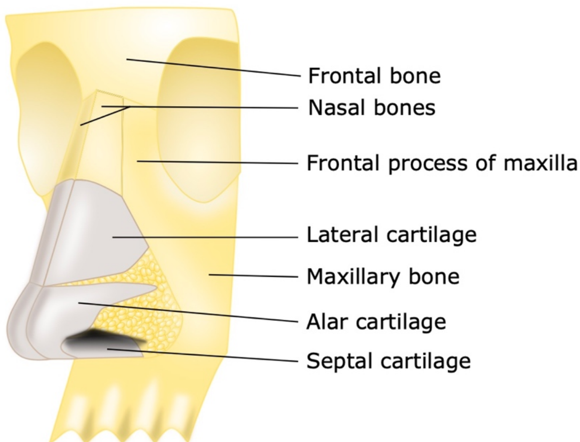


Figure 5 External nasal anatomy. Figure: Iida-Kaisa Manninen.

2.2.1.1.1 Treatment

If correction to the position of the nasal bones is needed, the reduction is best performed within 10–14 days after the injury (113,114). It can be done under local or general anaesthesia. Reductions for sport-related fractures are more common than for other aetiologies (115). To save the cartilage from necrosis and infection, septal haematoma needs to be evacuated promptly (116).

Nasal fracture and its treatment cause pain and decrease quality of life (117). Despite treatment, about 10% of patients with nasal fractures have permanent aesthetic disadvantage, 10% have remaining nasal obstruction, and 10% septum deviation. Olfaction loss has also been reported.(118) Later repairs of aesthetically unpleasant or functionally problematic nasal fractures require a septoplasty, rhinoplasty, or septorhinoplasty. In an Indian clinic, previous sport-related nasal fractures were the indication in 7.5% of rhinoplasties (119).

2.2.1.1.2 Risk sports

Nasal fractures are the most prevalent facial fractures in combat sports, soccer, basketball, bicycling, rugby, and baseball (120–126). Various team sports, especially ball-related ones like basketball, baseball, football, soccer, Gaelic football, rugby and softball, also often cause nasal fractures and traumas (112,113,127). Risk sports and injury mechanisms for facial and nasal bone fractures are presented in Table 1. Cannon et al. studied solely sport-related nasal traumas with 91 patients, of whom 65% had nasal fractures. Basketball with 26%, baseball 22%, and football 13% were the top 3 sports in their study. Of the patients, 92% could return to their sport after nasal fracture, and 44% of the injuries happened during a game.(127) In other studies, sport-related nasal fractures are presented together with other facial fractures (Table 1).

2.2.1.1.3 Effect on training and performance

After treatment, the nose needs to be protected from additional impact for 6–8 weeks, which at minimum interrupts contact sport training (116,127). Still, the proper length of time to pause contact sport training has not been studied. Scott et al. recommended nasal fracture treatment for athletes immediately after the injury to permit as rapid a return to play as possible (128).

The pause has been avoided by using protective face masks after nasal fracture among elite athletes (128). There are both generic and custom-made facial masks. Of these, the latter are considered more comfortable and offer better visibility.(129) Athletes have returned to playing with the mask 7–10 days after the injury (130,131). Elite professional basketball players in the NBA like Kobe Bryant have even continued playing immediately after the injury with a face mask (129).

In addition to the pause in training and competitions, as many as 30% (26/87) of the athletes with treated nasal fractures have some concerns regarding sports. The fear of reinjury (14%) was the most common, followed by functional problems (8%), thinking about quitting the contact sport (5%) and self-reported decrease in performance (3%).(113) If an athlete has major nasal deformity after a nasal fracture and its treatment, the definitive bigger operations like rhinoplasties are usually recommended only after the active sport career (128).

2.2.1.2 Structural nasal obstruction

Nasal obstructions are often divided into structural or mucosal. Structural obstruction can be further divided into static (permanent) and dynamic (intermittent) obstructions, both of which can be sports-related. Static obstructions stay similar despite the airflow. Causes for static obstruction are anatomical, like septal deviation or enlargement of turbinates. Dynamic obstructions are altered by changes in airflow.(132) The narrowest part of the nasal airway is called the nasal valve. High airflow may cause this valve to collapse and thus create dynamic nasal obstruction (108,132). The causes of nasal obstruction can be evaluated by inspection, anterior rhinoscopy, endoscopy, acoustic rhinomanometry, rhinomanometry and computerized tomography (CT) (132).

2.2.1.2.1 Treatment

Septal deviations and/or large turbinates can be treated operatively. However, the benefits of septoplasty have been questioned (133,134). Septoplasty is a prevalent surgery with variable rates in different countries. A systematic review concluded that outcomes had improved both subjectively and objectively after septoplasty. Still, the objective and subjective values were not congruent. The benefit of additional turbinate operations was not evident.(133)

Splints and dilatators have been tried to reduce nasal obstruction due to the nasal valve and to improve athletic performance. Dilatators can be internal or external.(109,135,136) They may delay the switch from nasal breathing to oronasal breathing later during the exercise (109,136). The benefits of nasal dilatators on sport performance, heart rate, oxygen saturation, VO2max (maximal oxygen uptake) or nasal parameters is not scientifically proven (109,135,137,138). Dinardi et al. reported VO2max improvement among adolescent athletes with nasal dilatators. The VO2max was not measured directly but was an estimate from the speed or race time (139,140).

One of the problems with studies on nasal dilatators is that many of them are done on athletes with healthy noses and no reported problems in nasal breathing. Thus, it is not known if some subgroup would benefit significantly from nasal dilatators.

2.2.1.2.2 Risk sports and effect on performance

Many different sports predispose athletes to nasal trauma and structural obstruction. As example, boxers, possibly due to previous nasal trauma, have significantly higher nasal airway resistance and extended mucociliary transport time compared to normal values (141). However, septal deviation prevalence was comparable in female boxers in Italy (43%) and in the general population (142).

Nasal obstruction can affect sleep and quality of life, which may have a further effect on the athletes' performance (143). However, the direct effect on performance remains unclear. Meir et al. found no objective effect of a nasal clip preventing nasal breathing to the performance, heart rate or lactate levels in high-intensity training, because oral breathing compensates for nasal breathing during exercise (144).

2.2.2 RHINITIS IN SPORT

Rhinitis is a mucosal inflammation with symptoms like rhinorrhea, nasal obstruction, sneezing and itching. It can be allergic, infectious, non-allergic, or exercise-induced (111). Allergic rhinitis especially, but also non-allergic, can predict asthma, which is more prevalent among athletes than among the general population (145,146). Athletes suffer from many rhinitis symptoms (147). Still, the reported prevalence has a wide range (21–74%), and the type of rhinitis is often unspecified (148).

2.2.2.1 Irritant-induced rhinitis

The role of the nose in the clearance of the inspired air exposes it to many different irritants, such as allergens, pollutants, pathogens, cold air, and chlorinated water. During exercise, breathing volume and the volume going through the nose increase (132). Thus, athletes' noses are exposed to a large number of irritants.

According to a systematic review, rhinitis is more common among swimmers (40–74%) and cross-country skiers (46%) than in the general population or land-based athletes (21–49%). The effect of irritants in their training environment was considered to explain this.(148)

Swimmers are the most studied athletic group in connection with rhinitis. The chlorinated water is thought to affect respiratory mucosa (149). Swimmers have more bronchial asthma and non-allergic rhinitis than other athletes (143,150). In addition, nasal symptoms and olfaction loss are more prevalent in swimmers than in athletes practicing other sports or in non-athletes (149,151). Prolonged mucociliary transport time among swimmers may indicate mucosal damage (141,149). Thus it is not surprising that rhinitis-related quality of life is reduced among elite swimmers (143,152). There is a significant reduction in rhinitis symptoms after 2 weeks' break in swimming training (152). Not all nasal problems among swimmers need to be related to rhinitis or mucosal irritation: there is a case report about a swimmer with a one-sided nosebleed and obstruction caused by a live leech in the middle meatus (153).

Almost every (96%) skier has experienced cold-induced rhinorrhea and half of the skiers (50%) have some degree of nasal obstruction (154). An objective increase in the amount of rhinorrhea has been noticed in cold weather and even more during exercise in the cold. Nasal air flow is higher during exercise in cold air than at rest in a cold or warm environment.(155) At rest the nasal resistance for skiers is higher than normal values, and nasal decongestion tests have normalised the resistance. This refers to the mucosal problem causing the skier's nasal obstruction during the rest.(141)

Mucociliary clearance and the possible effect of street pollutants have been studied in runners. Runners in street environments have prolonged mucociliary clearance time when compared to those running away from traffic (158). However, this was not confirmed by another study (159).

2.2.2.2 Allergic rhinitis

Allergic rhinitis is a common complaint which has also been studied in athletes. Athletes with allergies report more nasal symptoms during and just after exercise than athletes without allergies (156). More than one-third (37%) of 977 Australian Olympic athletes has allergic rhino-conjunctivitis and more than half (56%) at least one positive skin-prick test. This is comparable to the Australian population in general.(150) Allergic rhinitis has been more prevalent among swimmers and endurance athletes than among other sport groups (150,157).

2.2.2.3 Infectious rhinitis

Infectious rhinitis (the common cold) is a highly prevalent illness worldwide. It is caused by various viruses. For an athlete, even a common cold can be problematic—it causes a pause in training and a decrease in performance. At the FIFA (the International Federation of Association Football) Confederations Cup, ear, nose and throat was the most common (37%) area of illness, and it caused on average 0.46 days lost from sports (158). It is also a common reason to consult healthcare professionals, for example, during the Olympic games (159).

Recreational training decreases the probability for upper respiratory tract infection compared to elite athletes and inactive controls (160). The phenomenon is known as a J-curve, which represents the relationship between the amount of training and upper respiratory infection incidence. The incidence is at the lowest with moderate training. Large amounts of high-intensity training may lead to increased incidence of upper respiratory tract infections.(161) Intensive exercise decreases the effectiveness of the immune system within 24 hours. Not allowing sufficient recovery time could be the explanation for the finding.(162) Compared to physically inactive individuals, active ones had lower risk for COVID-19 infection, severe disease, and death. High levels of physical activity did not decrease the risk for COVID-19 infection, severe disease, and death as much as moderate activity.(163)

2.2.2.4 Exercise-induced rhinitis

Exercise itself may induce rhinitis symptoms. Sympathetic activation during exercise decreases nasal resistance and increases nasal air flow. After the exercise the nasal volume reverts to rest values in approximately 20 minutes.(164) There are not many studies about exercise-induced rhinitis. Almost two-thirds (61%) of athletes with and without allergy report nasal symptoms (rhinorrhea and/or nasal congestion) with indoor exercise in a study from United States (156).

Spence et al. found the pathogen in only 30% of the upper respiratory tract infections among elite athletes (160). It has been considered that there might also be a non-infectious component behind the acute rhinitis symptoms among athletes (111).

2.2.2.5 Treatment

The treatment of rhinitis among competitive athletes differs from treatment of the general population because some of the drugs used for rhinitis are considered to be doping, ie, performance-enhancing substances (111). For example, many oral decongestants are not allowed because of their stimulant effects (147). When treating athletes, physicians must confirm the current recommendations from the World Anti-Doping Agency (WADA) documents. They publish a list of the prohibited substances and methods.(165)

Possible treatment methods are listed below. They can be used separately or as a combination:

- **Allergens and other irritants** that worsen the symptoms of the athletes' rhinitis need to be noticed and athletes advised to avoid them (111). Sometimes this is impossible for athletes. A skier cannot avoid cold air or a swimmer chlorine.
- **Intranasal corticosteroid** is the first-line treatment for chronic rhinitis, backed by much evidence about its effectiveness and safety (166). It is superior to antihistamines in treatment of allergic rhinitis (167). Oral, intravenous, intramuscular and rectal glucocorticoids are prohibited, but intranasal use is allowed (165). With intranasal budesonide treatment symptoms, sport performance and quality of life increased significantly as perceived by Olympic athletes with seasonal allergic rhino-conjunctivitis (168).
- **Oral or topical antihistamines** can be used in addition to nasal corticosteroids to treat allergic rhinitis (167). Topical options include eye drops and nasal sprays.
- **Immunotherapy** is an option for athletes with IgE-mediated allergies and will cause a long-term benefit. It can be done by the sublingual or subcutaneous route.(169) The knowledge about allergen immunotherapy among athletes could be at a better level as only 22% of athletes with allergic rhinitis knew about an option of non-invasive immunotherapy (170).
- **Decongestants** can be used orally or topically, but many of these are prohibited by WADA (165,171). Some are allowed (for example, xylometazoline) and the others are allowed at certain levels (165). Short use during acute obstruction might

be beneficial, but long-lasting use of decongestants may cause rhinitis medicamentosa (111,171).

- **Saline irrigation** is also recommended for rhinitis (166). It can be combined with other treatments. Among athletes, saline irrigation has been considered to clean the mucosa after exposure to irritants, but there is no evidence to support this assumption (111).
- **Atropine sulphate and ipratropium bromide** nasal sprays help symptoms of cold-induced rhinorrhea among skiers with mild side effects (154,172).
- **Surgery** may be considered if an athlete has disturbing paranasal sinus and nasal symptoms for at least 8 weeks with adequate medical therapy. The aim with surgery is to create better conditions for local treatment (166).

People with rhinitis have elevated risk for asthma (146). Hence, athletes with rhinitis are recommended to be evaluated for asthma and treated if necessary (147). Treatment of rhinitis has a favourable effect on asthma (166).

Athletes seem to use less medication for their rhinitis symptoms than the general population (143,150), although this is not confirmed by all studies (157). As example, 12% of athletes in a budesonide study declined to participate in the study because they did not want to use regular medication (168). Only 24% of allergic Italian Olympic athletes had received any medical treatment for their allergy or asthma (173). In a Finnish study 50% of athletes with allergic rhinitis used medication to control their symptoms (157). Knowledge about possible medications and their side effects needs to spread among athletes (111).

2.2.2.6 Effect on performance

There are not many studies about rhinitis and its effect on sport performance. Allergic athletes had lower quality-of-life ratings than their non-allergic counterparts (174). In a questionnaire, 40% of physically active individuals reported that nasal symptoms affected their performance negatively. This was more prevalent among allergic individuals than non-allergic (53% vs. 28%).(156) Olympic athletes with allergic rhinitis reported better sport performance with medication than without (168).

There are no objective studies about the effect of rhinitis on sport performance. The effect of rhinitis on performance is unlikely to be massive, as fully one-fourth (26%) of the 23 Italian Olympic medals were won by allergic/asthmatic athletes in three Olympics (173). However, even though there might not be a direct connection between rhinitis and sport performance, all the frustrating symptoms that affect quality of life may have an effect on elite athletes' top performance and focus.

2.2.3 OLFACTION LOSS

The olfactory epithelium is located at the top of the nasal cavity (Figure 4). For the odour sensation, the odorant needs to reach the epithelium and bind to a receptor. The activation of the nerve cell goes along the axon through the bony cribriform plate to the olfactory bulb located at the base of the brain.(175)

Upper respiratory tract infections (26%), head trauma (18%), and sinonasal diseases (15%) are the most common causes for olfaction impairment; 22% are idiopathic (176). These causes are prevalent among athletes. However, sports-related olfaction impairment has not been widely studied. People do not always notice their olfaction loss, and subjective and objective findings do not always correlate (177,178).

2.2.3.1 Evaluation of olfaction

Olfaction can be evaluated with different tests: odour threshold, discrimination and identification, or the combination of these (TDI) (179). TDI is more sensitive to detecting olfaction impairment than the subtests alone (180). Whitcroft et al. evaluated the TDI subtest scores among different olfaction impairment aetiologies. Post-traumatic and postinfectious olfaction impairments scored lowest in the odour identification test, sinonasal diseases in the threshold test, and Parkinson's disease in the discrimination test.(181)

2.2.3.2 Risk sports and effect on performance

Subjective olfaction loss is more prevalent among competitive swimmers than in the control population (143). Ottaviano et al. reported higher odour threshold but no difference in odour identification when comparing elite swimmers to other athletes (149). In addition, boxers and American football players have been reported to have olfaction impairment (182,183). Vent et al. examined 50 amateur boxers and found a clear decrease in the Sniffin' Sticks odour threshold test compared to controls, significant but less decrease in the odour identification test, and no difference in odour discrimination. The cushioning of training gloves and head protection in fights might have a protective effect on olfaction.(183) Former football players with self-reported cognitive, behavioural, and mood symptoms had lower scores in the smell identification test than age-matched controls. Also, a low score in the olfaction test was correlated with worse neurophysiologic and neuropsychiatric functions. The association of olfaction and chronic traumatic encephalopathy was speculated on.(182)

There are no studies about the effect of olfaction on athletes' performance. The perception of taste is noticeably affected by olfaction, and the impairment of olfaction may lead to decreased quality of life and changed diet (184,185). Olfaction loss may also increase the risk for hazardous events like missing a fire or eating spoiled food, but patients with olfaction loss do not consider it to affect sport and exercise (185,186). Olfaction impairment has been suggested to increase salt usage and body mass index (184,187), but this is not confirmed by all studies (188). These kinds of changes might affect athletes' lifestyle and disturb their preparation for top performance at a competition.

2.2.4 SINUS BAROTRAUMA

Diving with ambient pressure changes can affect paranasal sinuses with inadequate ventilation and cause pain or a pressure sensation at the frontal or maxillary sinus region or epistaxis. As many as 49% of 1881 divers answering a questionnaire reported these symptoms. The symptoms usually lasted a short time, that is < 2 minutes for 56% of those with symptoms. Pollen allergies, smoking and a high number of upper respiratory tract infections were associated with sinus barotraumas.(189)

2.3 LARYNGEAL PROBLEMS IN SPORTS

The pharynx and larynx have functions in breathing, swallowing and phonation. The skeleton of the larynx consists of the hyoid bone, thyroid cartilage, arytenoid cartilages, and cricoid cartilage. Thyroid cartilage is the largest cartilage in the larynx, and it protects the vocal cords, which are attached to its anterior inner surface (Figure 6). Posteriorly, vocal cords attach to mobile arytenoid cartilages. There are several muscles moving them. Epiglottic cartilage is located on the anterior interior surface of the thyroid cartilage. The mucosae continuing from the epiglottis to the arytenoids are called aryepiglottic folds.(190)

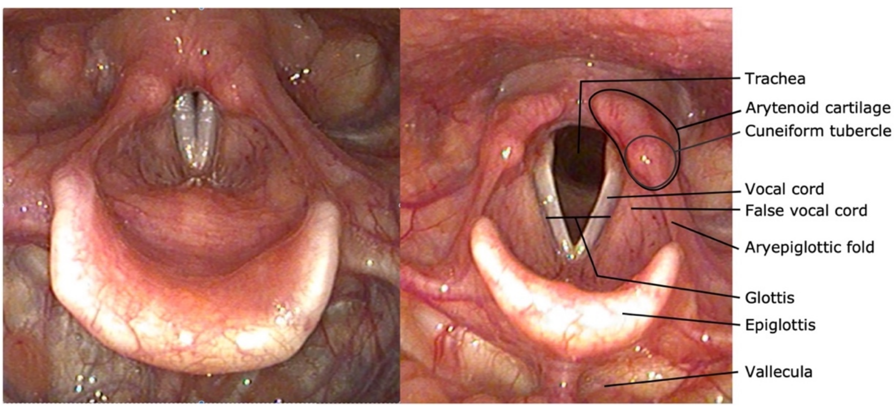


Figure 6 Endoscopic view of the larynx. On the left side vocal cords are adducted during phonation and on the right side they are abducted. Photo: Iida-Kaisa Manninen.

Internal laryngeal muscles control the position of vocal cords and the amount of air going through them. During exercise, vocal cords are abducted to let the maximal amount of air go through (Figure 6). Vocal cords close the larynx during weight bearing to let the thorax be a stable fulcrum for arms and shoulder muscles, while the air does not escape, and chest walls collapse. The larynx also closes during swallowing to protect the lower airways from digested material. During phonation, vocal cords are adducted close to each other (Figure 6), and they start to vibrate while exhaled air goes through them and creates the voice.(191)

Almost all physical activity increases the need for oxygen and thus the airflow through the larynx. Thus, normal laryngeal function is critical for athletes. In addition, especially in team sports, oral communication with teammates is important, and voice problems may disrupt it.

2.3.1 EXERCISE-INDUCED LARYNGEAL OBSTRUCTION

During exercise, vocal cords and arytenoid cartilages are maximally abducted and the laryngeal airway is open. Obstruction at this level during exercise has many names: exercise-induced laryngeal obstruction (EILO), exercise-induced vocal cord dysfunction, exercise-induced laryngomalacia, and exercise-induced paradoxical vocal fold motion (192). The obstruction can be caused at the glottic (vocal cords) or supraglottic (aryepiglottic folds, arytenoid cartilages) level (193).

EILO is a subgroup of different laryngeal obstruction situations (inducible laryngeal obstruction) where obstruction is created only during maximal exercise. EILO is not a dangerous situation, but symptoms may be frustrating and scary and affect sports performance. The laryngeal structures get back to normal quickly after stopping the exercise.

The most prevalent symptoms of EILO are exercise-induced inspiratory stridor, dyspnoea, cough, throat tightness, and hoarse voice (192,194,195). The symptoms resemble asthma symptoms, and EILO is often misdiagnosed as asthma, or athletes may have both asthma and EILO (195,196). In some studies EILO patients have had more stridor and throat tightness compared to other causes of exercise-induced dyspnoea (194), but not all researchers have found these differences (195). About three-fourths of the patients with EILO are females, and the median age at the time of diagnosis is normally under 20 (from 15 to 27) (194,196–199).

2.3.1.1 Diagnosis and treatment

The gold standard for diagnosing EILO is continuous laryngoscopy during exercise (CLE) (193,200). It can be performed on a treadmill or bicycle and combined with cardiopulmonary ergo-spirometry (199,200). The test attempts to provoke the symptoms, and the patient runs or cycles until dyspnoea or exhaustion. More symptoms and clinical findings are found in maximal effort exercise.(193) CLE is the diagnostic method of choice for supraglottic, glottic, or combined obstruction. There is a standardized scoring system where glottic and supraglottic obstruction is scored from 0–3 in both moderate and maximal effort exercise.(193) Supraglottic obstruction is more common (70–100%) during the exercise than glottic (0–10%) or combined (0–19%) (195–197).

Treatment of EILO is not unambiguous. Most patients get relief from laryngeal control therapy (69%)(201) and inspiratory muscle training (79%) (202). Laryngeal control therapy includes education, relaxation, and respiratory retraining with a target to get maximal vocal cord or supraglottic abduction during the exercise (203). Therapeutic laryngoscopy during exercise has been used in combination with laryngeal control therapy to get real-time biofeedback for athletes. In one study, 75% of the patients got benefits from therapeutic laryngoscopy.(204) According to a case report, botulin toxin has helped symptoms with glottic EILO, but it carries a risk of dysphonia (205).

Supraglottoplasty surgery is suggested to yield better outcomes compared to non-surgical treatment (197). In supraglottoplasty, mucosa around the top of cuneiform cartilages is removed, and releasing incisions are made to aryepiglottic folds (206). Surgery can be considered only in the cases where the obstruction is mainly at the supraglottic level and only in severe cases that do not respond to non-surgical treatment because it is always an irreversible procedure.

2.3.1.2 Risk sports and effect on performance

Among 294 paediatric patients with exercise-induced dyspnoea, several sports were seen behind the symptoms: for example, soccer, running, basketball, hockey, and swimming. Among these, 29% had EILO and others had, for example, physiologic dyspnea or exercise-induced asthma.(194) A high prevalence of EILO (27%) had also been diagnosed among elite cross-country skiers; 11% of the skiers had both asthma and EILO. However, 17% of the skiers who had an EILO diagnosis in CLE did not have symptoms of EILO.(196)

There were no studies about the effect of EILO on competitive athletes' competition or training performances and how non-surgical or surgical treatment would affect the performance. Nevertheless, the dyspnoea symptoms appear at maximal effort exercise and are likely to disturb the performance.

2.3.2 DYSPHONIA

Voice alterations are prevalent among children on school basketball teams. Alterations are found in half of them: 47% have a slightly hoarse voice and 53% slight or moderate roughness in their voice. They might be prone to scream to communicate in sport events.(207) Primov-Fever et al. presented that high physical activity affects the voice and may lead to voice disorders. They recommended not to use the voice during high-intensity training.(208) That may be one aspect that predisposes athletes to voice disorders, but there is not much research about this.

2.4 FACIAL AND NECK TRAUMAS IN SPORTS

Almost all sports carry a risk for injuries. The face is a main target for impact in some combat sports, like boxing. In other sports—for example, ball-related team sports—the face and neck can be damaged accidentally, as can other parts of the body. Facial traumas include lacerations, contusions, and fractures (209). Besides these, vascular, tracheal, oesophagus or thyroid gland injuries are possible in neck traumas.

2.4.1 FACIAL TRAUMAS

The proportion of sport-related traumas among all facial traumas differs from 15% to 55% depending on the population and classification system (210–213). Older people and small children (0–6 years old) have fewer sport-related facial fractures than adults or older children (214,215).

Lacerations and contusions are more common and need less hospitalization than fractures (122,216). The studies about sport-related facial fractures and traumas are summarised in Table 1. Facial fractures are most prevalent among young males, and sport distribution represents the country where the study was performed. Both recreational and professional sport activity can cause sport-related facial traumas (217,218). Classification of facial fractures (for example, maxillary fractures) varied among studies.

Table 1. *Studies about sport-related facial traumas.*

Author, year, and title	Country	N	Mean age (years)	Males (%)	Top 5 sports	Top 5 fractures (or traumas)	Top 3 injury mechanisms
Puolakkainen et al. 2021 (219) Sports-based distribution of facial fractures - findings	Finland	213	28	78	Ice hockey 26% Soccer 21% Equine sport 16%	Unilateral ZMO 40% Mandible 34% Combined mid facial 11%	Impact against player 44% Impact against equipment 30%

from a four-season country.					Martial arts 10% Baseball 6%	Nasal 8% Combination of facial thirds 4%	High-energy impact against environment 14%
Murphy et al. 2015 (220) Sports-Related Maxillofacial Injuries.	Ireland	162	27	91	Gaelic football 35% Soccer 22% Rugby 12% Equine sport 12% Biking 4%	Zygomatic complex 36% Mandible 33% Orbit 14% Nasal 12% Soft tissue injury 9%	Impact against player 75% Equine injury 12% Impact against equipment 7%
Hwang et al. 2009 (221) Outcome analysis of sports-related multiple facial fractures.	South Korea	236	24	93	Soccer 38% Baseball 16% Basketball 13% Martial arts 6% Skiing or snowboarding 5%	Nasal 54% Mandible 16% ZMO 11% Orbit 9% Zygoma 7%	Impact against player 51% Impact against equipment 26% Self-inflicted causes (i.e. fall) 23%
Exadaktylos et al. 2004 (222) Sports related maxillofacial injuries: the first maxillofacial trauma database in Switzerland	Switzerl and	90	34	87	Skiing and snowboarding 30% Cycling 21% Soccer 13% Ice hockey 9% Mountain climbing 7%	Mandible 26% Zygoma 21% Orbit 19% Nasal 8% Maxillary sinus 8%	Impact against person 41% Other without contact with another person
Maladière et al. 2001 (223) Aetiology and incidence of facial fractures sustained during sports: a prospective study of 140 patients.	France	140	29	88	Soccer 25% Rugby 15% Mountain biking 10% In-line skating 9% Horse riding 8%	Mandible 34% Zygoma 23% Nasal 16% Arch of zygoma 7% Le Fort 5%	Impact against player 51% Impact against ground 35% Impact against equipment 10%
Carroll et al. 1995 (224) One hundred and ten sports related facial fractures.	Ireland	110	70% under 30	95	Gaelic football 26% Soccer 24% Hurling 21% Rugby 13%	Nasal 56% Zygomatic 23% Mandibular 13% Orbit 4% Multiple 4%	Not reported
Plawecki et al. 2017 (218) Recreational Activity and Facial Trauma Among Older Adults.*	United States	205 19	67	61	Bicycling 27% Team sports 15% Outdoor activities 10% Gardening 10% Dog walking <10%	Nasal 65% Orbit 14% Multiple fracture <10% Mandible <10% Maxilla or Zygoma <10%	Not reported
MacIsaac et al. 2013 17/03/2023 12:42:00(225) Nonfatal sport-related craniofacial fractures: characteristics, mechanisms, and demographic data in the pediatric population.**	United States	167	13	81	Baseball/softball 44% Skateboarding 8% Soccer 8% Basketball 7% Skiing/snowboarding 5%	Nasal 36% Orbit 34% Skull 31% Maxilla 13% Mandible 7%	Impact against equipment 47% Impact against player 25% Fall 19%

ZMO= zygomatic-maxillary-orbital. *About older adults over 55 years old. **About paediatric facial and cranial fractures.

2.4.1.1 Treatment and effect on training and performance

When treating athletes with facial fractures, the possible concomitant injuries like neck injuries or brain injuries need to be kept in mind. Of soccer players studied, 42% (55/135) had neurological symptoms with facial fracture, representing a possible sign of minor brain injury (226).

Sport-related facial traumas are treated like other facial traumas with different aetiologies. The main difference is that many elite and professional athletes are often keen to return early to their sport activity and competitions after their injury. The type of injury, sport and its risks for contact, possible use of facial protection, role of the athlete on the team, and phase of training and competition season must be considered individually by the athlete and the team medic when the treatment and return to sports activity are decided (128,227). There are no evidence-based guidelines about when it is safe to return to competing, but Scott et al. have made a consensus statement and Ansari et al. a systematic review about return-to-play times. There is large variation in the recommended pause before the return to competing.(128,227)

Return to competition will take longer in sports in which the face is the target for contact, like boxing, than, for example, in ball sports or sports with no contact between athletes (128,227). According to the consensus statement, return after zygomatic fracture varies from 3 to 6 weeks depending on the type of fracture and surgery. Surgery using miniplates is more stable than elevation alone. The use of face masks can advance the return. After a simple isolated mandibular fracture and its open reduction and internal fixation, the return to soccer and rugby can be considered even 1–2 weeks after injury. With orbital fractures, normally 3 weeks after the operation is enough to return to ball sports if there is no diplopia or any problems in visual fields. Lacerations can normally be cleaned and treated primarily on-site to permit immediate continuation of play. Definitive treatment can be done afterwards.(128)

In football, a protective facial mask shortens return-to-play time by 10 days from the average time of 34 days after a mid-facial fracture (226). For professional NBA players, the return-to-play time after a facial fracture was on average shorter (18 days) than among football players, but for athletes with surgically treated fractures, return time was much longer (51 days) than among non-surgically treated (6 days) (228). Among NBA players, no effect on performance was detected after facial fracture and its treatment (228).

2.4.1.2 Prevention

Rule changes and facial protection can reduce facial traumas. In ice hockey, facial protection has been efficient in preventing facial injuries. In a systematic review, the authors concluded that full-face protection provides better protection than half-face against facial injuries. Facial protection did not affect the risk of concussion in ice hockey, but players with facial protection and concussion returned to training or games on average 1.7 sessions earlier than athletes without facial protection and with concussion (229). In girls' lacrosse the mandatory use of headgear reduced risk for facial lacerations (risk ratio (RR) = 0.08 vs 0.01) and abrasions (RR = 0.28 vs 0.12) but did not affect haemorrhage or fractures (230). Bicycle helmets have reduced facial fractures (odds ratio (OR) 0.67) and to a lesser extent facial soft tissue injuries (OR 0.77) in addition to skull fractures (OR 0.48). The reduction is bigger in the upper face than in the middle face and lowest in the lower face.(231)

2.4.2 NECK TRAUMA

Sport-related neck traumas are rare. Most of them are blunt traumas. Blunt neck trauma can lead to laryngeal cartilage fracture (thyroid or cricoid cartilage), fracture of the hyoid bone, and/or vascular, tracheal or oesophageal injury. It should be noted that 10% of laryngeal injuries have concomitant cervical spine injuries (232). As the larynx has a major role in breathing and the airway, trauma there can become life-threatening in minutes if oedemas or haematomas obstruct the airway (233,234). On the other hand, some traumas are mild, and athletes do not always meet with the doctor, or they come to healthcare after a delay (235). Symptoms of laryngeal trauma include changes in voice, breathing problems, dysphagia, globus sensation, and pain (234,235). Possible clinical findings include subcutaneous emphysema, oedema or haematoma in neck, pneumomediastinum, and in fiberoscopic examination, oedema in larynx, mucosal injury, and haematoma (234,236).

Laryngeal fractures are diagnosed by CT. Vascular injuries such as carotid artery dissection must be assessed (237). Dislocated fractures are recommended to be operated on to restore normal airway and voice (234). However, about 40% of the laryngeal fractures can be treated non-surgically with adequate 24- to 48-hour follow-up at the hospital. Antibiotics, proton-pump inhibitors and corticosteroids can be considered in cases with mucosal damage.(232,234)

2.4.2.1 Risk sports, effect on training

The scientific literature on sport-induced laryngeal trauma consists mainly of case reports. Reports cover a spectrum of sports including ice hockey, judo, rugby, mountain biking, lacrosse, and basketball. The injury mechanisms vary, ranging from hits by a puck, ball or stick to contact with other athletes and the helmet clasp cracking the larynx.(233,235,236,238–240)

Delaney et al. examined neck traumas at emergency rooms among ice hockey, soccer, and American football players from 1990 to 1999 in the United States. Of these, American football carried the greatest risk for neck trauma. Luckily, over 90% of all traumas are mild, including sprains, contusions, and strains. Most of the fractures and lacerations were among football players.

Soccer had the second highest number of fractures and ice hockey of lacerations.(241)

The time to return to sport after neck trauma varied from 2 weeks to several months, depending on the severity of the injuries and the need for surgery (233,242,243). As neck traumas can be life-threating, preventing them needs to be considered in different sports (233,238).

3 AIMS

The aim of this study was to add information about athletes' less-studied ear, nose, and throat problems, including cauliflower ear, triathlete's dizziness, olfaction of the athletes, and sport-related nasal fractures. Increased knowledge may improve the treatment, understanding and prevention of these problems.

The specific aims for sub-studies were the following:

1. To evaluate prevalence of cauliflower ear among elite wrestlers and judokas, the symptoms that they might have, previous treatment and effect of the treatment. (Study I)

2. To investigate caloric reaction as a possible explanation for the dizziness among triathletes and special features in connection with the dizziness. (Study II)

3. To find out whether head impacts in boxing and soccer or chemical irritation in swimming has an effect on the subjective or objective sense of smell among the elite athletes compared to floorball players. (Study III)

4. To investigate the occurrence, characteristics, related sport activities, injury mechanism, and treatment of sport-related nasal fractures. (Study IV)

4 MATERIALS & METHODS

4.1 PARTICIPATING ATHLETES (I, II, III)

All participating athletes were adults. They were recruited through sport clubs for studies II and III and through national teams for study I (judo, wrestling) and study III (boxing). Both sexes were included in studies I and II. In study III only males were included because of the confounding effect of menstrual cycle on olfaction among females (244). Studies I and III examined elite athletes with active competitive careers or athletes who had ended their careers earlier (study I) or within 5 years (study III). In studies I and II there was no upper age limit, but in study III only adult athletes under 40 years old were included as age decreases performance in olfaction tests (179).

4.2 QUESTIONNAIRES (I, II, III)

Questionnaires were used in three studies (I, II, III). We designed the questionnaires and they have not been used previously. In addition to questionnaires, study methods included ear photographs (study I), a cold-water swimming test (study II), and both an olfaction test and anterior rhinosckopy (study III). Questionnaires were in Finnish. In the olfaction study (III), if the athletes were English-speaking, the researcher (I-KM) filled out the questionnaire by interviewing them. All the athletes were asked about age, training history and more specific questions concerning the studied topic.

4.2.1 PAPER QUESTIONNAIRES (I, III)

Paper questionnaires were handed to athletes before or after a training session or training camp by the researchers (I-KM, ML).

The “Cauliflower ear questionnaire” (study I) enquired about possible auricular haematoma, cauliflower ear, use of headgear, treatments for auricular haematoma, symptoms of cauliflower ear, and the athlete’s attitude towards it. Some questions were open-ended and some closed. Respondents were asked to grade symptoms by Likert scale from 1 to 5 (1= no symptoms, 5= a lot of harm).

In the “Olfaction study” (study III) athletes were asked about smoking status, nasal and respiratory diseases, nasal fractures, and self-estimation about their sense of smell and taste. Most of the questions were closed-ended. Self-estimation was assessed on a numerical rating scale from 0 to 10 (0= total lack of sense of smell or taste, 10= totally normal sense) and on a dichotomous scale.

4.2.2 ELECTRONIC QUESTIONNAIRE (II)

In the “Triathlete’s dizziness” study an electronic questionnaire (Helsinki University E-lomake) was delivered to athletes by triathlon clubs. The athletes were asked about possible dizziness during the triathlon training or competition, the timing of the symptoms, swimming technique, and possible ear and other diseases. If athlete had suffered from dizziness, questions were asked about the type of dizziness, effect on performance, and factors alleviating or exacerbating dizziness.

4.3 EAR PHOTOGRAPHS (I)

Lateral ear photographs were taken from athlete volunteers with or without cauliflower ear after they had returned the questionnaire. Photos were analysed later by a senior author (TK) without information about the athlete other than the photograph. The possible cauliflower ear was identified, and it was graded from 0 to 5 (0 = no cauliflower ear and 5 = massive cauliflower ear). The association between the grade and different symptoms was calculated.

4.4 COLD-WATER SWIMMING TEST (II)

Triathletes who reported often having dizziness in connection to swimming and lived near Helsinki were recruited to the cold-water swimming test. It was executed in connection with their regular swimming training.

The test was performed in small lakes for 11 athletes, in a seawater pool for 3, and in the Baltic Sea for 1 athlete. In all these environments water was cold (maximum 20 °C). During the first swimming leg, the triathletes swam without earplugs or swimming cap covering their ears, allowing water freely to enter the ear canals. Wetsuits and all the other equipment that athletes normally used were allowed. Immediately after the swimming leg, the eye movements were recorded with specific goggles designed for nystagmus recording. The athletes were also asked about possible dizziness. If athletes had dizziness or nystagmus, they swam a second leg with earplugs with similar video recording and questions about dizziness. All athletes used a freestyle swimming technique, and there were no big waves in any of the test situations. Each swimming leg lasted at least 5 minutes.

4.5 VIDEO ANALYSES (II)

The video recordings were analysed twice in random order by two experienced neurotologists. They were blinded to their own previous and each other’s evaluations, reporting of sensation of dizziness, and use of earplugs. They classified each video according to the possible nystagmus: ‘yes’, ‘maybe’ and 'no' and the direction of the nystagmus: 'right' and 'left'. A minimum of five beats was needed for the diagnosis of nystagmus. So, every video was analysed four times. Nystagmus was confirmed if all four analyses were 'yes' or three times 'yes' and one 'maybe'.

4.6 OLFACTION TEST (III)

Olfaction of the athletes was examined with Sniffin´ Sticks smell identification test including 12 different odorants (orange, leather, cinnamon, peppermint, banana, lemon, liquorice, coffee, clove, pineapple, rose and fish)(179). All odorants looked identical. Athletes first smelled the odorant. Then four options were given to them verbally, and they decided the right one. One point was given for the right answer and no minus point for a wrong one. The points were counted (0–12), and a higher score reflected better olfaction function. There were no time limits for the answer, and athletes had a chance to smell the odorant long enough. Either Finnish or English was used for the test, depending on the athlete's language.

4.7 ANTERIOR RHINOSCOPY, LUND-KENNEDY SCORE (III)

Anterior rhinoscopy was performed for all athletes in study III, and the finding was graded according to modified Lund-Kennedy score to evaluate possible findings of rhinitis (245,246). Both nostrils were graded together for polyps (0 = no polyps, 1 = polyps on middle meatus, 2 = polyps beyond meddle meatus), mucosal oedema (0 = no oedema, 1 = mild oedema, 2 = severe oedema) and discharge (0 = no discharge, 1 = clear, thin discharge, 2 = thick, purulent discharge). The sum of these (0–6) was obtained. Higher values reflected more findings of rhinitis. The appearance and possible external deformity of the nose was detected and graded from 0 to 2 (0 = no deformity, 1 = mild deformity, 2 = severe deformity).

4.8 DATABASE RESEARCH (IV)

The data about sport-related nasal fractures were collected from Helsinki University Hospital (HUH) electronic database according to ICD-10 codes (S02.0, S02.1, S02.2, S02.3, S02.4, S02.5, S02.6, S02.7, S02.8, and S02.9) for the years 2013–2018. The aetiology (sport-related, accident, assault, suicide attempt, traffic accident, not known, or other) and possible inclusion of the nasal fracture were recorded from all acute traumas (Figure 7).

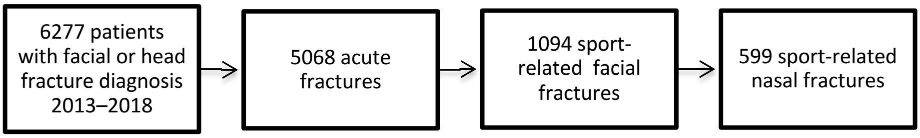


Figure 7 Selection process for sport-related nasal fractures.

Sport-related nasal fractures were explored more specifically, including data on patient characteristics, the sport involved, injury mechanism, possible concomitant injuries, treatment, and the season (Dec–Feb, Mar–May, Jun–Aug, Sep–Nov) of the injury.

4.9 ETHICS OF THE STUDY (I-IV)

The Ethics Committee of Helsinki University Hospital approved the study protocols for studies I (HUS/2441/2017) and II (HUS/3494/2018). Study III is not a medical research and study IV is based on database data, and the Ethics Committee evaluation were not needed for these. A research permit was obtained from the Department of Otorhinolaryngology – Head and Neck Surgery at the Helsinki University Hospital for every study.

All participants were adult volunteers who gave their written informed consent before taking part in studies I, III and the cold-water swimming test in study II. Written information was given for every participant (study I, III and the cold-water swimming test in study II). The information and consent were electronic at the beginning of the electronic questionnaire about triathlete's dizziness in study II.

An ethical problem might have presented in athlete recruitment. The appointments for examination in studies I and III were most often arranged with team coaches. Some athletes could have experienced pressure to take part in the study. In every study there were athletes who declined to participate. The voluntary nature of participation was disclosed to every athlete verbally in addition to providing written information.

Another ethical concern was how to evaluate sufficient language skills for participants in studies I and III. There are many athletes, especially among combat sports athletes and soccer players, for whom Finnish is not their native language. Paper questionnaires were handed to many athletes at the same time in study I. Those who could not fill them out did not take the questionnaire or did not return it. Someone might have asked a friend the meaning of a question. In study III all athletes were examined individually. For non-Finnish-speaking athletes the questionnaire was filled out in the investigator's interview, and if an athlete's English language skills were considered insufficient, the olfaction test was not performed. Also, the odour of fish was unpleasant for many athletes but the time to smell it was short.

In study II triathletes needed to swim in cold water. They were all asked to participate individually, and the appointment was tried to arrange in conjunction with their normal training. The 5 minutes' swimming might have been unpleasant for some athletes in cold water or with troublesome dizziness. Still, many triathletes swam more than the required 5 minutes and continued training after the swimming test.

Overall, our studies did not carry any risk for impairment of the physical or psychological well-being of the participants. In addition, adult participants should understand the voluntary nature of the studies as it had been explained to them. The possible discomfort caused by the studies did not last long. In study II participants would have swum in cold water even without the study as it was part of their triathlon training.

4.10 STATISTICAL METHODS (I-IV)

Statistical analyses were done solely by an independent professional statistician in studies I, II and III and together with him in study IV. The professional statistician used NCSS 12 Statistical Software, and we used IBM SPSS version 26 and 27.

To compare means for normally distributed continuous variables, the t-test was used and for continuous variables which were not normally distributed, the non-parametric Mann-Whitney U test or Kruskal-Wallis one-way ANOVA. Spearman rank correlation was used to analyse correlation between continuous variables.

Categorical variables were compared with cross-tabulation and chi-squared or Fisher's exact tests, depending on the number of findings. A stepwise multiple regression model was used in study III to evaluate the effect of independent variables on the olfaction test score. In study IV crosstabs with pairwise z-test and Bonferroni correction were used to analyse categorical variables between many different sport groups.

5 RESULTS

5.1 PARTICIPANTS

In total 313 athletes were recruited to studies I-III. In study IV 599 sport-related nasal fractures were evaluated. Participants' age, sex distribution and training history are represented in Table 2. There are more training years among competitive elite athletes in studies I and III than among athletes in study II ($p < 0.0001$) where all adult triathletes were allowed to answer the electronic questionnaire. Also, weekly training hours were longer among elite athletes in study III than in study II ($p < 0.0001$) with a broader spectrum of triathletes.

Table 2. *Demographics of the participants.*

Study	I	II	III	IV
	Cauliflower ear	**Triathlete's dizziness**	**Athlete's olfaction**	**Sport-related nasal fractures**
N	63	125	125	599
Mean age (SD)	22.2 (± 4.7)	43.3 (± 9.9)	23.8 (± 5.2)	26.3 (± 14.2)
Males (%)	87	48	100	71
Training years (SD)	14.6 (± 3.8)	5.3 (± 5.2)	13.0 (± 6.2)	Not known
Weekly training hours (SD)	Not asked	8.1 (± 2.9)	14.2 (± 6.2)	Not known
Sport (number of athletes)	Wrestling (32) Judo (31)	Triathlon (125)	Boxing (35) Swimming (30) Soccer (30) Floorball (30)	47 different sports (599)

5.2 CAULIFLOWER EAR

Sixty-three athletes completed the paper questionnaire about cauliflower ear. They included 32 wrestlers and 31 judokas. Basic demographics are presented in Table 2. A total of 73% (46/63) reported having a cauliflower ear, and 61% of these were bilateral (28/46). Cauliflower ear was more common among males (84%, 46/55) than females (0%, 0/8, $p < 0.001$). The prevalence of cauliflower ear did not differ among male judokas (75%, 18/24) and male wrestlers (90%, 28/31, $p = 0.16$). One-fourth (25%, 14/57) of the athletes used headgear occasionally, but no one used them regularly. Three (21%, 3/14) athletes said in an open question that they use them after auricular haematoma or its treatment and 3 (21%, 3/14) when they had pain in the ear.

5.2.1 TREATMENT

Almost everyone with cauliflower ear had received treatment for their auricular haematoma (96%, 45/47). Only one athlete (2%, 1/45) reported treatment for haematoma but had no formation of cauliflower ear. Still, the majority (88%, 38/43) of athletes with cauliflower ear considered the haematoma evacuation helpful.

Needle aspiration was the most prevalent treatment (96%, 43/45), and 88% (38/43) wore a pressure dressing after the aspiration. Over half (55%, 21/38) wore pressure dressing a maximum 24 hours and 42% (16/38) longer (range from 1 day to 1–2 months). Cold treatment (36%, 16/45) and surgery (7%, 3/45) were other treatment modalities used. Athletes got treatment on average 8 times (range from 0 to 20). A medical doctor most often (58%, 26/45) gave the treatment; other options were a friend (42%, 19/45), self-treatment (33%, 15/45), a relative (13%, 6/45), a nurse (11%, 5/45), and a coach (11%, 5/45). Altogether 76% (34/45) got treatment from a non-healthcare professional. No complications from the treatment were reported.

5.2.2 SYMPTOMS

Cauliflower ear is often symptomatic, as nearly all athletes (96%, 44/46) had at least some symptom. Pain was the most common symptom as 76% (35/46) reported at least mild pain. Other reported symptoms were warmth, dysesthesia, ulcers, cold sensitiveness, earwax problems, hearing loss, and infections. They are presented in Table 3. The majority (96%, 44/46) did not have problems with sunburn. Fifty-four percent (25/46) of athletes with cauliflower ear mentioned in an open question that cauliflower ear causes harm while using earphones.

Table 3. *Symptoms related to cauliflower ear among 46 wrestlers and judokas with cauliflower ear.*

Symptoms	Average of grades	No symptom (%)	Mild symptoms (%)	Troublesome symptoms (%)
Pain	2.74	24	50	26
Warmth	2.02	43	41	15
Dysesthesia	1.63	63	33	4
Ulcers	1.59	59	37	4
Cold sensitiveness	1.57	72	24	4
Earwax problems	1.50	70	24	7
Hearing loss	1.39	70	28	2
Infections	1.26	83	15	2
Sunburn	1.07	96	4	0

Symptoms were graded from 1 to 5 (1 = no harm, 5 = a lot of harm). 1 was considered no harm, 2 and 3 mild symptoms and 4 and 5 troublesome symptoms.

5.2.3 PHOTOGRAPHS

Lateral photographs were taken of 87 (69%, 87/126) ears of 46 athletes (73%, 46/63). Of the participants, 63% (41/63) had both ears photographed and 11% (5/63) only one ear. Senior author and athlete agreed on the diagnosis of cauliflower ear in 92% (80/87) of the ears. The mean cauliflower ear grade was 2.0 from all photographs (n = 87) and 3.0 from worse or only cauliflower ear (n = 40). Ear grade did not differ among wrestlers and judokas, headgear users and non-users, or among those who considered cauliflower ear an aesthetic disadvantage or not. Higher worse ear grade was correlated with ulcers ($r = 0.48$, $p = 0.002$) but not with other symptoms.

5.2.4 ATTITUDE TOWARDS CAULIFLOWER EAR

The attitudes towards cauliflower ear among males and females are presented in Table 4. No athlete regretted their cauliflower ear, and it was even a desired deformity for 41% (19/46) of the athletes with cauliflower ear. Almost all the athletes with cauliflower ear had heard some comments about their ears (93%, 43/46) but no one felt this disturbing. In an open question, individual athletes reported benefits from it such as: 'Everyone respects you in Ostrobothnia when you have a cauliflower ear' or 'Women like when you have cauliflower ear'.

Table 4. *Differences between male and female judokas and wrestlers and their attitude and behaviour concerning cauliflower ear.*

	All (n = 63)		Males (n = 55)		Females (n = 8)		Difference
	n	%	n	%	n	%	p
Cauliflower ear	46/63	73	46/55	84	0/8	0	< 0.001
Wrestlers	32/63	51	31/55	56	1/8	13	0.026
Occasional use of headgear	14/57	25	13/52	25	1/5	20	1.0
Would recommend headgear	23/59	39	16/51	31	7/8	88	0.0042
Would recommend treatment	31/59	53	25/51	49	6/8	75	0.26
Views cauliflower ear as a desirable deformity	20/59	34	20/51	39	0/8	0	0.042
Aesthetic disadvantage	2/59	3	1/51	2	1/8	13	0.25

Not all athletes answered every question. Percentages are from those who answered the question.

5.3 TRIATHLETE'S DIZZINESS

5.3.1 QUESTIONNAIRE

Altogether 23 triathlon clubs were contacted, and two-thirds (65%, 15/23) of them distributed the electronic questionnaire to their members. We got 125 answers, but we do not know the participation rate as we cannot tell how many athletes received the questionnaire. The basic demographics of the athletes are presented in Table 2. Not all triathletes answered every question.

The majority (87%, 109/125) of the triathletes who completed the questionnaire had experienced dizziness at least once during a triathlon race or training. The background data about triathletes with and without dizziness are presented in Table 5. No significant differences between triathletes with and without dizziness were found regarding factors affecting dizziness.

The most common occasion for dizziness was during or after swimming (97%, 106/109). Only 7% (8/109) experienced it while cycling and 6% (6/109) with running. Overall 76% (80/105) of the triathletes with dizziness experienced it solely during open-water swimming, 1% (1/105) during indoor swimming and 23% (24/105) in both indoor and open-water swimming. Almost all athletes (97%, 121/125) trained in both milieus.

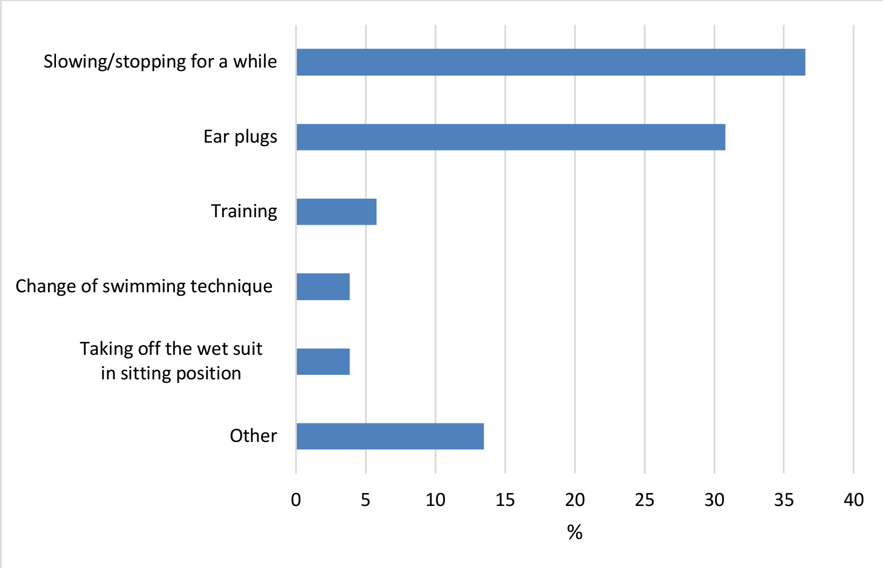
Table 5. *Background data of 125 triathletes.*

	All n=125		History of dizziness during triathlon races or training n=109		No history of dizziness n=16	
	n	%	n	%	n	%
Frequent symptoms of orthostatic hypotension	39/123	32	37/107	35	2/16	13
Easily get motion sickness	41/125	33	37/109	34	4/16	25
Dizziness at an amusement park or on a boat	54/125	43	49/109	45	5/16	31
Hobby that trains balance	61/125	49	53/109	49	8/16	50
Impaired balance during alcohol use	8/119	7	8/103	8	0/16	0
Previous ear diseases *	18/120	15	18/107	17	0/13	0
Previous ear operations **	11/120	9	11/107	10	0/13	0
Earplugs while swimming	24/125	19	23/109	21	1/16	6
Freestyle swimming technique	124/124	100	108/108	100	16/16	100
Bilateral breathing in freestyle swimming	62/124	50	52/109	48	10/15	67
Has visited doctor because of any dizziness	11/125	9	9/109	8	2/16	13

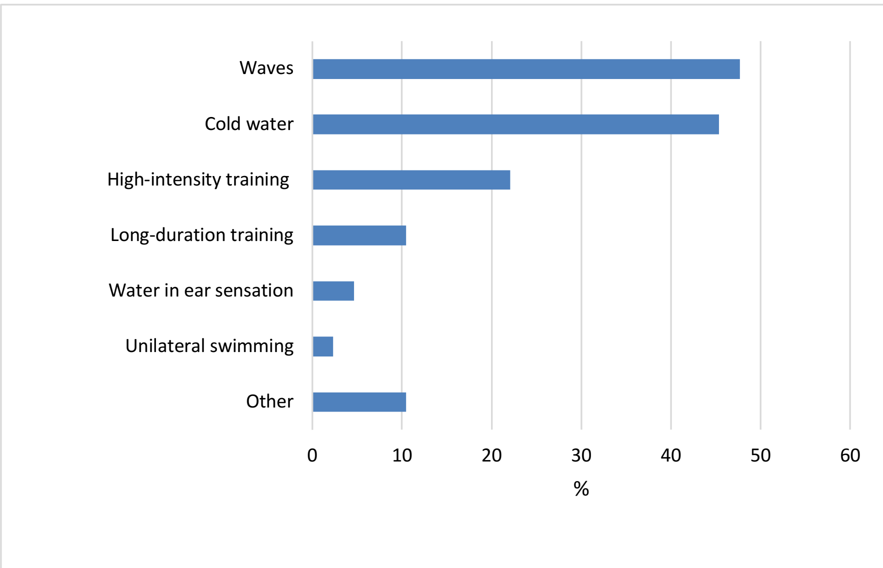
Not all athletes answered every question. There were no significant differences between these two groups regarding factors mentioned in the table. In addition, they did not differ regarding age, sex distribution or training history. *Majority (72%, 13/18) infectious diseases and 11% (2/18) hearing loss, 5% (1/18) exostoses and 11% (2/18) not defined. **Majority (73%, 8/11) myringotomy or tympanostomy tubes, 1% (1/11) adenoidectomy, 1% (1/11) polyp removal and 1% (1/11) not defined. No mastoidectomies.

About half (53%, 58/109) of the athletes reported that the dizziness was rotatory, and 39% (42/109) felt a sensation of falling. For the majority (84%, 86/102) the dizziness lasted a maximum of 5 minutes (range from a few seconds to 30 minutes). Many athletes reported alleviating and exacerbating factors, and they are presented in Graphic 1 and 3. Dizziness influenced sport performance in half (50%, 51/102) of the athletes with dizziness. The effects are presented in Graphic 3.

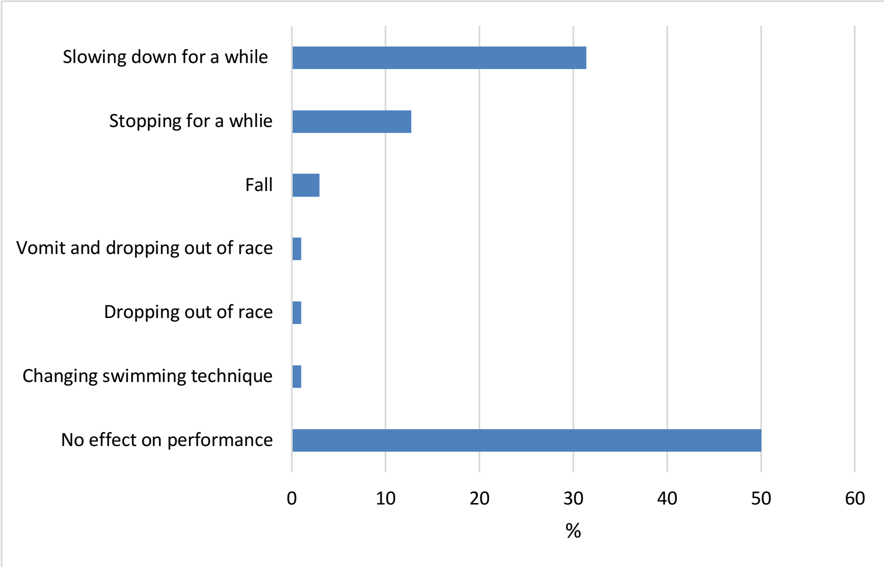
Two-thirds of triathletes (68%, 85/125) had some hypotheses about the origin of dizziness, and some participants had more than one hypothesis. The considered causes were: water in the ear (31%, 26/85), orthostatic hypotension (27%, 23/85), motion sickness (19%, 16/85), head movement (11%, 9/85), cold water (11%, 9/85), disorder of the vestibular system (8%, 7/85), tension neck, (7%, 6/85) and oxygen deprivation (7%, 6/83).



Graphic 1 Alleviating factors for dizziness reported by 48% (52/109) of triathletes.



Graphic 2 Exacerbating factors for dizziness reported by 79% (86/109) of triathletes.

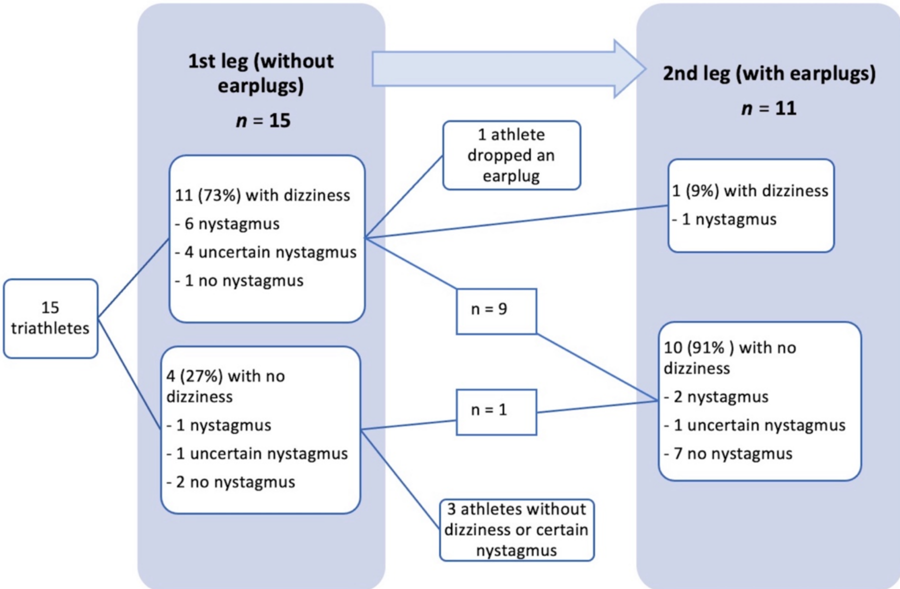


Graphic 3 Effect of the dizziness on triathlon performance among 102 triathletes.

5.3.2 COLD-WATER SWIMMING TEST

Fifteen athletes who frequently suffered dizziness during or after a swimming leg took part in the cold-water swimming test. The average temperature of the water was 17.4 °C (SD ± 2.6 °C) and average swimming time was 9.2 min (SD ± 4.3 min) for the first leg and 7.5 min (SD ± 1.8 min) for the second. During the first leg, without earplugs 73% (11/15) of the athletes had dizziness. Half (55%, 6/11) of those with dizziness also had nystagmus, 36% (4/11) had uncertain nystagmus and 9% (1/11) did not have nystagmus. Dizziness was less common (9%, 1/11) during the second swimming leg with earplugs ($p = 0.0039$). No significant differences were found in the amount of nystagmus between swimming legs with and without earplugs. The findings from the cold-water swimming test are presented in Graphic 4.

There were in total 27 eye movement recordings to analyse. Each was evaluated twice by two neurotologists, which means four evaluations for each recording. All four evaluations (nystagmus, maybe nystagmus and no nystagmus) coincided in 67% (18/27) of them. All (10/10) of the evaluations agreed on the direction of nystagmus. Five of the six athletes with nystagmus and dizziness after the first swimming leg used unilateral breathing. They all had the direction of nystagmus opposite from the breathing side. One athlete used bilateral breath and had nystagmus rightward.



Graphic 4 Cold-water swimming test. During the first swimming leg, the triathletes swam without earplugs or swimming cap covering their ears, allowing water freely to enter the ear canals. Immediately after the swimming leg, the eye movements were recorded and the athletes were also asked about possible dizziness. If athletes had dizziness or nystagmus, they swam a second leg with earplugs with similar video recording and questions about dizziness. Dizziness was less common during the 2nd leg, p = 0.0039.

5.4 ELITE ATHLETES' OLFACTION

Altogether 125 athletes were examined, and they all filled in the questionnaire. One athlete did not notice the second page and answered only part of the questions. The study groups consisted of 35 boxers (12 professional and 23 amateur), 30 swimmers and 30 soccer players, and the control group consisted of 30 floorball players. Two athletes had limited language skills and they were excluded. Basic demographics of all athletes are presented in Table 2.

5.4.1 ODOUR IDENTIFICATION TEST AND SELF-EVALUATION OF THE OLFACTION

The athlete groups did not differ regarding mean score on the olfaction identification test (Table 6). Boxers reported subjectively more often decreased sense of smell (24%, 8/34, $p < 0.002$) and taste (12%, 4/34, $p < 0.005$) than other athletes (smell 3%, 3/90, taste 0%, 0/90) on a dichotomous scale. Still there was no difference in self-evaluation on a numerical rating scale (NRS) from 1 to 10 or an objective odour identification test (Table 6). According to a stepwise multiple regression model, only nasal obstruction during the test was associated to the lower odour identification test score. Athletes with obstruction during the test had a lower score in the odour identification test (mean score 10.0, median 10) than the athletes without obstruction (mean 10.6, median 11, p = 0.01). Their subjective evaluation about the olfaction did not differ from the others (8.7 vs. 8.8, p = 0.7).

The mean score of the smell identification test for all athletes was 10.4, which reflects normal olfaction. The range was from 7 to 12. No athlete had a score that would suggest anosmia. Nine (7%, 9/125) athletes had scores of 7 or 8, which reflects evident hyposmia. They also scored their subjective olfaction lower on NRS than the others (7.8, vs. 8.8, medians 7 vs. 9, p < 0.014) but did not differ otherwise from athletes with better olfaction test results.

The majority of the athletes were non-smokers (91%, 112/123) and none smoked regularly. Occasional and ex-smokers self-evaluated their olfaction lower than non-smokers on a dichotomous scale (36%, 4/11 vs. 6%, 7/112, p = 0.009) and NRS (mean 7.9 vs. mean 8.8, p = 0.046). The odour identification test scores did not differ (mean score 9.9 vs. 10.4, p = 0.3).

Table 6. *Subjective and objective olfaction of 125 elite athletes*

	Boxers n=35		Swimmers n=30		Soccer players n=30		Floorball players n=30		All n=125	
Mean olfaction test score on scale 1 to 12 (SD)	10.29 (± 1.3)		10.27 (± 1.1)		10.23 (± 1.1)		10.73 (± 0.9)		10.38 (± 1.1)	
Range of scores (minimum - maximum)	7 - 12		8 - 12		8 - 12		9 - 12		7 - 12	
Mean self-evaluated sense of smell on scale 1 to 10 (SD)	8.5 (± 1.8)		8.8 (± 1.1)		8.8 (± 1.2)		8.9 (± 1.2)		8.7 (± 1.4)	
Mean self-evaluated sense of taste on scale 1 to 10 (SD)	8.9 (± 1.4)		9.3 (± 0.9)		8.9 (± 1.2)		9.2 (± 1.0)		9.1 (± 1.1)	
Self-evaluated decreased sense of smell, yes/no *	8/34	24%	1/30	3%	0/30	0%	2/30	7%	11/124	9%
Self-evaluated decreased sense of taste, yes/no *	4/34	12%	0/30	0%	0/30	0%	0/30	0%	4/124	3%

*Boxers reported a more decreased sense of smell and taste on a dichotomous scale than other athletes (p < 0.005), but otherwise the sport groups did not differ significantly considering the olfaction.

5.4.2 NASAL AND RESPIRATORY DISEASES

Many athletes self-reported nasal symptoms in the paper questionnaire: 41% (50/122) reported often having nasal congestion, 43% (53/123) allergic rhinitis and 31% (39/124) other long-term nasal discharge. These are summarised in Table 7. Symptoms of chronic rhinitis were prevalent. Allergic rhinitis was more prevalent among swimmers (57%, 17/30) and floorball players (59%, 17/29) than among others (soccer players (27%, 8/30) and boxers (32%, 11/34, p < 0.2)). Swimmers reported asthma (30%, 9/30) more often than other athletes (7.6%, 7/92, p < 0.002). They also reported more history of sinus problems, as they had had more often 2 or more sinusitis episodes (70%, 21/30 vs. 20% 18/92, p < 0.0001), sinus operations (10%, 3/30 vs. 0%, 0/92, p = 0.013) or previous antral irrigation (17%, 5/30 vs 2% 2/92, p < 0.01) than others.

The mean modified Lund-Kennedy score was 0.65 for all athletes. None had polyps. Most points came from thin discharge (53%, 43/81). Floorball players had more often modified Lund-Kennedy score 1 or more than others (87%, 26/30 vs 34%, 35/95, p < 0.0001). They also had more common colds during the test (30%, 9/39) than the other athletes (9%, 8/ 94, p < 0.005). Athletes with a modified Lund-Kennedy score at least 1 reported more allergic rhinitis (56%, 33/59) than other athletes (31%, 20/64, p < 0.006), but other differences were not found.

Table 7. *Reported sinonasal and respiratory diseases, nasal traumas and smoking status of 125 elite athletes.*

	Boxers n=35		Swimmers n=30		Soccer players n=30		Floorball players n=30		All n=125	
	n	%	n	%	n	%	n	%	n	%
Allergic rhinitis symptoms	11/34	32	17/30	57	8/30	27	17/29	59	53/123	43
Chronic rhinitis symptoms	11/34	32	8/30	27	10/30	33	10/30	33	39/124	31
Use of any medication for respiratory diseases	7/34	21	20/30	67	6/30	20	16/30	53	49/124	40
Two or more sinusitis episodes	8/34	24	21/30	70	3/30	10	7/28	25	39/122	32
Self-reported nasal congestion during the test	18/34	53	19/30	63	16/30	53	22/30	73	75/124	60
Common cold symptoms during the test	3/34	9	4/30	13	2/30	7	9/30	30	18/124	15
Asthma	2/32	6	9/30	30	1/30	3	4/30	13	16/122	13
Diagnosed nasal fracture	6/35	17	0/29	0	3/30	10	2/30	7	11/124	9
Suspected nasal fracture	14/34	41	1/30	3	2/29	7	1/30	3	18/123	15
Non-smoker	23/33	70	29/30	97	30/30	100	30/30	100	112/123	91
Occasional or ex-smoker	10/33	30	1/30	3	0/30	0	0/30	0	3/123	2

Not all athletes answered every question.

5.4.3 NASAL TRAUMA

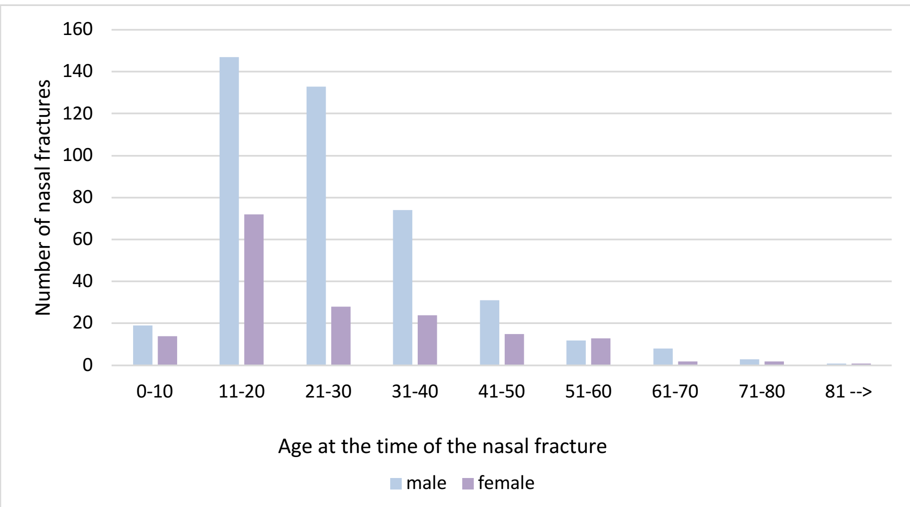
Boxers reported more self-suspected nasal fractures (41%, 14/34) and diagnosed nasal fractures (17%, 6/35) than other athletes (4%, 4/89 and 6%, 5/89, p < 0.001 and p = 0.07) but the difference was not significant considering diagnosed fractures. The number of nasal fractures is presented in Table 7. The researcher diagnosed more nasal deformities among athletes with a history of suspected (64%, 7/11, $p < 0.002$) or diagnosed nasal fractures (55%, 10/18, $p < 0.001$) than among others 16%, 18/ 113 and 13%, 14/105). As a result, boxers also had more diagnosed nasal deformities (46%, 16/35) than other athletes (10%, 9/90, $p < 0.001$). Athletes with a history of nasal fractures did not report more unilateral nasal obstruction and olfaction scores did not differ from the others.

5.5 SPORT-RELATED NASAL FRACTURES

Altogether 599 patients with sport-related acute nasal fractures were found in the HUH database from 2013 to 2018. The selection process is presented earlier in Figure 7. There were 2465 nasal fractures, of which 24% were caused by sports.

5.5.1 SPORT, AGE, AND SEX DISTRIBUTION

The majority of the patients with sport-related nasal fractures were male (71%, 428/599). The average age for all was 26.3 years (SD ± 14.2 y, median 23 y) with no difference between sexes. Underage patients comprised 36% (213/599), and male dominance was not as evident among them (62%, 133/213) as among adults (76%, 295/386; $p < 0.001$). Gender and age distribution is presented in Graphic 5.



Graphic 5 Gender and age distribution among 599 sport-related nasal fracture patients

Nasal fractures were prevalent in several different sports as a total of 47 different sport activities were involved. Over half (56%, 334/599) had happened in team sports followed by individual sports (25%, 148/599) and combat sports (11%, 68/599). Different sports are presented in Table 8. The sport distribution was slightly different among underage patients and adults. Among underage patients nasal fractures were caused more often by team sports together (62%, 133/213 vs. 52%, 201/386), cheerleading (8% vs. 0.8%), Finnish baseball (6% vs. 3%), skateboarding (4% vs. 0.5%) and gymnastics (4% vs. 0.5%) ($p < 0.05$) and among adults by cycling (20% vs. 7%), combat sports together (15% vs. 5%), wrestling (3% vs. 0%), and boxing (5% vs. 0.9%, $p < 0.05$).

Table 8. *Distribution of 599 nasal fractures between sports, proportion of males, and number of concomitant injuries.*

Sport	Frequency	Male proportion	Concomitant injuries
	n (% of all cases)	n (% of males)	n (% of the fractures within the sport)
Team sports	334 (55.8)	257 (77)	20 (6)
Soccer	122 (20.4)	102 (84)	6 (5)
Basketball	62 (10.4)	42 (68)	0 (0)
Ice hockey	44 (7.3)	43 (98)	7 (16)
Floorball	29 (4.8)	27 (93)	1 (3)
Finnish baseball	23 (3.8)	15 (65)	4 (17)
Cheerleading	19 (3.2)	0 (0)	0 (0)
Handball	12 (2.0)	5 (42)	0 (0)
Rugby	7 (1.2)	7 (100)	1 (14)
Bandy	4 (0.7)	4 (100)	0 (0)
Cricket	3 (0.5)	3 (100)	0 (0)
American football	2 (0.3)	2 (100)	0 (0)
Rink bandy	2 (0.3)	2 (100)	0 (0)
Not defined ball-related sport	5 (0.8)	5 (100)	1 (20)
Individual sports	148 (24.7)	83 (56)	55 (37)
Cycling	92 (15.4)	58 (63)	42 (46)
Equine sports	17 (2.8)	1 (6)	8 (47)
Skateboarding	11 (1.8)	8 (73)	2 (18)
Swimming	8 (1.3)	3 (38)	0 (0)
Kick scooting	7 (1.2)	6 (86)	2 (29)
Downhill skiing	6 (1.0)	3 (50)	1 (17)
Surfing	3 (0.5)	2 (67)	0 (0)
Jogging	2 (0.3)	0 (0)	0 (0)
Snowboarding	2 (0.3)	2 (100)	0 (0)
Combat sports	68 (11.4)	58 (85)	5 (7)
Boxing	23 (3.8)	22 (96)	1 (4)
Wrestling	11 (1.8)	10 (91)	1 (9)
Thai boxing	8 (1.3)	7 (88)	1 (13)
Judo	7 (1.2)	6 (86)	0 (0)
Mixed martial arts	4 (0.7)	4 (100)	0 (0)
Jujitsu	3 (0.5)	2 (67)	0 (0)
Savate	2 (0.3)	2 (100)	0 (0)
Taekwondo	2 (0.3)	1 (50)	0 (0)
Karate	2 (0.3)	1 (50)	0 (0)

Taido	2 (0.3)	0 (0)	1 (50)
Not defined combat sport	4 (0.7)	3 (75)	1 (25)
Others	30 (5.0)	16 (53)	1 (3)
Gymnastics	10 (1.7)	3 (30)	0 (0)
Physical exercise class	9 (1.5)	7 (78)	0 (0)
Gym	5 (0.8)	3 (60)	1 (20)
Skating	3 (0.5)	2 (67)	0 (0)
Dance	3 (0.5)	1 (33)	0 (0)
Not defined	7 (1.2)	7 (100)	0 (0)
Miscellaneous*	12 (2.0)	7 (58)	3 (25)
Total	599 (100.0)	428 (71)	84 (14)

*Only one case per sport.

The ratio of nasal fractures during the 6-year time period in different team and combat sports to the number of athletes training in the sport is presented in Table 9.

Table 9. *The ratio of nasal fractures in a six-year time period at HUH district to the number of athletes training per sport in the district.**

Sport	Ratio to athletes
Rugby	1:33
Finnish baseball	1:68
Cheerleading	1:152
Wrestling	1:159**
Basketball	1:163
Boxing	1:164**
Handball	1:342
Ice hockey	1:368
Soccer	1:417
Floorball	1:736
Equine sport	1:899

* Team and combat sports with 5 or more nasal fractures are included. ** Sport federations did not know the number of athletes at HUH district. So, ratio is to athletes in Finland (population 5.5 million people) with 3.4 times bigger population.

5.5.2 INJURY MECHANISMS

Half (52%, 314/599) of the sport-related nasal fractures were caused by contact with another person. Within these, impacts of elbow to the nose covered over one-third (36%, 112/314). Sixteen percent (96/599) of the fractures were caused by contact with equipment, 11% (70/599) fall from a bike, 6% (37/599) collision, 6% (34/599) falling, 3% (16/599) equine injury, 2% (10/599) own knee hitting the nose and 4% (22/599) unspecified. Mechanisms in different sports are presented in more detail in Table 10.

Table 10. *Nasal-fracture injury mechanisms in sports with more than 20 nasal fractures in our study and in team, individual, and combat sports together.*

Sport (n)	Contact with another person					Contact with equipment				Fall	Colli-sion	Other *
	Upper limb	Lower limb	Head	Other *	Total	Ball or puck	Stick	Other *	Total			
	n %	n %	n %	n %	n %	n %	n %	n %	n %	n %	n %	n %
Soccer (122)	35 29	26 21	25 20	8 7	94 77	14 12			14 12	2 2	2 2	10 8
Cycling (92)										70 76	22 24	
Basketball (62)	48 77	1 2	8 13	1 2	58 94	1 2			1 2	2 3	1 2	
Ice hockey (44)	6 14		1 2	5 11	12 27	17 39	11 25		28 64	1 2	2 5	1 2
Floorball (29)	16 55		3 10		19 66		8 28		8 28			2 7
Finnish baseball (23)						22 96	1 4		23 100			
All team sports (334)	126 38	32 10	47 14	22 7	227 68	57 17	20 6	1 0.3	78 23	6 2	5 2	18 5
All individual sports (148)		3 2			3 2			6 4	6 4	94 64	29 20	16 11
All combat sports (68)	22 32	25 38	2 3	18 26	65 96			1 2	1 2			2 3

*Other or unspecified injury mechanisms.

5.5.3 CONCOMITANT INJURIES AND SEASONAL DISTRIBUTION

A total of 14% of the patients had concomitant injuries. Their prevalence was higher in all individual sports together (37%, 55/148), in cycling (46%, 42/92), and in equine sports (47%, 8/17) than in other sports ($p < 0.05$). On the other hand, fewer concomitant injuries were recorded in all team sports together (6%, 20/334), soccer (5%, 6/122) and basketball (0%, 0/62) than in other sports ($p < 0.05$). Also, adults (17%, 64/386) had more of them than underage patients (8%, 17/213) ($p = 0.003$). The types of concomitant injuries are presented in Table 11.

Table 11. *Diagnosis of concomitant injuries among 599 patients with sport-related nasal fracture.*

Type of injury	n	%
Other facial fracture	53	8.8
Orbital fracture	31	5.2
Le Fort fracture	12	2.0
Naso-orbito-ethmoidal fracture	5	0.8
Frontal sinus fracture	4	0.7
Zygomatic fracture	3	0.5
Mandibular fracture	1	0.2
Other*	11	1.8
Skull or skull-base fracture	2	0.3
Neck fracture	6	1.0
Other fracture	6	1.0
Wound or superficial injury	17	2.8
Eye injury	6	1.0
Tooth injury	14	2.3
Intracranial injury	10	1.7
No concomitant injury	515	86.0

6% (36/599) of patients had more than one concomitant injury. *Nonspecified fractures of maxilla

Sport-related nasal fractures were prevalent throughout the year; 30% (179/599) of injuries happened in spring, 25% (151/599) in summer, 28% (169/599) in fall and a bit less 17% (100/599) in winter. Between summer and winter, there were differences within isolated sports. Among ice hockey, basketball, and floorball players, there were more nasal fractures during winter than summer (50% vs. 9%; 24% vs. 8% and 38% vs. 10%, $p < 0.05$), and among cyclists and soccer players more nasal fractures during summer than winter (46% vs. 5% and 34% vs. 6%, $p < 0.05$).

5.5.4 DIAGNOSTICS

The majority (93%, 555/599) of the sport-related nasal fractures at HUH were treated at the department of otorhinolaryngology and head and neck surgery and the rest (7%, 44/599) at the department of oral and maxillofacial diseases. Those who were treated at the department of oral and maxillofacial diseases more often had concomitant injuries (86%, 38/44) compared to patients treated at the department of otorhinolaryngology and head and neck surgery (8%, 43/555, $p<0.001$).

The time from injury to the first university hospital appointment varied from the same day to 248 days, and the mean was 5.4 days (SD ± 11.1 days, median 5). The mean period to the first appointment was shorter at the department of oral and maxillofacial diseases (0.6 days) than at the department of otorhinolaryngology and head and neck surgery (5.8 days, $p = 0.003$). The nasal fracture was diagnosed most often clinically (77%, 458/599), one-fifth (19%, 115/599) with CT and seldom with native X-ray (4%, 26/599). Most of the fractures were closed (95%, 570/599), 16 (3%) were open fractures and 13 (2%) remained suspicious.

5.5.5 TREATMENT

The assessment of the need for surgical treatment was performed mainly clinically (81%, 485/599) and at the department of otorhinolaryngology and head and neck surgery sometimes according to admission (12%, 73/599) or on the telephone (7%, 41/599). One-third (31%, 184/599) of the fractures did not need surgical correction. The mean duration from the injury to the primary surgical treatment was 11.0 days (SD ± 35.5 days, median 8). The most often used primary surgical treatment modality was closed reduction (65%, 388/599), of which 79% (306/388) were performed under local anaesthesia and 21% (82/388) under general anaesthesia. Open reduction was performed for 14 (2.3%) patients, septoplasty for 4 (0.6%) and the treatment of septal hematoma or bleeding for 4 patients (0.6%). In 2 (0.3%) cases treatment modality wasn’t recorded (for example, treatment abroad). Secondary treatment was needed in 5% (30/599) of the nasal fractures. They included 15 (50%, 15/30) closed reductions under local anaesthesia, 8 (23%) closed reductions under general anaesthesia, 3 (10%) septoplasties, 3 (10%) rhinoplasties, 1 (3%) bleeding treated at operating room and 1 (1%) open reduction.

The mean number of doctor contacts was 2.2 (SD ± 1.5) at the department of otorhinolaryngology and head and neck surgery for one sport-related nasal fracture patient. Ten percent (53/555) of the patients recontacted after the treatment or appointment.

6 DISCUSSION

6.1 CAULIFLOWER EAR

6.1.1 PREVALENCE OF CAULIFLOWER EAR

In our study the prevalence of cauliflower ear (73%) was considerably higher than previously reported 39–44% (7,8). The difference may be explained by the fact that wrestlers and judokas in our study were competing on at least a national level and had a long history of training years in their sport. In our study the average number of training years was 14.6 (SD ± 3.8), which is over three times more than in the study of wrestlers in Teheran (4.0 years, SD ± 3.4), which included wrestlers with at least one year of training history and membership in a wrestling club (7).

6.1.2 CAULIFLOWER EAR TREATMENT AND ATTITUDE TOWARDS IT

In our study almost all athletes had had some treatment for their cauliflower ear. A remarkable proportion of athletes with cauliflower ear considered it a desired deformity (41%), but they had still sought treatment. Kordi et al. reported that only 23% of wrestlers had sought treatment for their cauliflower ear, a much smaller percentage than in our study. They discussed that it might be because cauliflower ear has been considered a 'badge of courage' in Iran, but this assumption is not confirmed by our results.(7) The vast majority (88%) reported help from the haematoma evacuation in our study. So, the attitudes towards cauliflower ear did not appear to affect athletes' willingness to seek treatment of auricular haematoma.

Treatment results were not excellent as all but one athlete had cauliflower ear after treatment of auricular haematoma. One possible reason for that might be too short a use of pressure dressing as 55% used it a maximum of 24 hours. Dalal et al. reported bandaging usage on average 5 days (6). The possibility for tie-through sutures to let athletes return to training and competing earlier should be kept in mind while treating athletes' auricular haematomas (13,15). The usage of tie-through sutures was not asked about in our study. Increase in the use of tie-through sutures might improve the treatment results.

There are no previous studies about the occurrence of haematoma evacuation by non-healthcare professionals. In our study three-quarters (76%) of athletes with auricular haematoma treatment had received the treatment from non-healthcare professionals. Luckily, none of the athletes reported complications such as infections from the treatment. Many athletes got treatment from several people, and over half (58%) were also treated by a medical doctor.

Sharing information about the ideal treatment for auricular haematoma with the combat sports clubs and athletes could be a useful way to improve auricular haematoma treatment. A tough question is if non-healthcare professionals should be encouraged to perform haematoma evacuations. There might be problems in the hygiene, but good instructions could decrease the risk for infection. Besides, in our study none reported complications, even though they were treated on average 8 times, of which a major part was done by non-healthcare professionals. Unfortunately, according to our study we cannot say if this treatment by non-healthcare professionals was helpful or not. The risk of infection is bigger in tie-through sutures, so I do not encourage non-healthcare professionals to perform them.

6.1.3 SYMPTOMS AND PREVENTION

Only 2 athletes (4% 2/46) did not report symptoms from their cauliflower ear. Pain was the most common symptom. Three athletes reported headgear usage when the ear is painful. Symptoms have not been sorted out this extensively in earlier studies. Thirty percent of athletes with cauliflower ear had some degree of earwax problems. This fits well to Noormohammadpour et al's study that found large earwax deposits more often in cauliflower ear than in ears without cauliflower deformity (10).

At least some mild hearing loss was reported by 30% of the athletes in our study; 24% reported the lowest symptom score on the Likert scale. Hearing loss has been reported previously in connection to cauliflower ear (7,10). The mechanism of hearing loss is not clear. Noormohammadpour et al. speculated on the role of trauma in the middle or internal ear, changed resonance frequencies or ear infections behind the hearing loss. There were more ear infections among athletes with cauliflower ear, but external and middle ear infection rates were not reported separately.(10) Anatomically, external ear infection should not affect long-term hearing. There were no differences in tympanic membranes or impedance audiometry between cauliflower and non-cauliflower ears which implies a healthy middle ear (10). So the resonances may have changed because of the new shape of the pinna.

Knowledge about the symptoms of cauliflower ear needs to be shared with athletes and their coaches along with the information about ideal treatment. This might influence the treatment modalities and possibly the usage of ear protectors. The number of symptoms and possible hearing loss have to be considered when rules regarding ear protection are made in combat sports. The high symptom proportion of the deformity could justify obligatory headgear usage at least among underage combat sports athletes. Athletes themselves do not consider cauliflower ear a problem as none of them regretted it and only 2 (3%) athletes found it as an aesthetic disadvantage.

Thus, use of headgear in combat sports cannot be justified for cosmetic reasons.

6.1.4 EFFECT ON SPORTS

Unfortunately, we did not ask about the effect of cauliflower ear on sport performance. Some athletes reported the use of headgear after haematoma and its treatment. None disclosed in the open questions how long a pause in training they had had after the treatment. That would be an interesting aspect to study later.

6.2 TRIATHLETE'S DIZZINESS

The dizziness among open-water or even cold-water swimmers has not been studied before. Our study reveals that dizziness is a common problem among triathletes as 87% (109/125) of the triathletes who answered the questionnaire reported dizziness during triathlon trainings or races. Still, we cannot report the exact prevalence of dizziness as selection bias is likely when triathletes with dizziness might have been more prone to answer the questionnaire. Besides that, we do not know how many athletes got the questionnaire and what the participation rate was.

6.2.1 CAUSE OF THE DIZZINESS

Athletes themselves had many suggestions about the aetiology of the dizziness. As dizziness is often a multifactorial problem with several organs involved, it might be that all the dizziness among triathletes is not identical. Our aim was to study caloric reaction as a cause of the dizziness. Both the questionnaire answers and the cold-water swimming test confirmed our suspicion at least partially.

Over half (53%) reported dizziness to be rotatory, which can refer to vertigo caused by a vestibular organ. Slowing or stopping for a while was the most often reported (37%, 19/52) alleviating factor, and earplugs (31%, 16/52) were the second. About the exacerbating factors, waves (48%, 41/86) were reported most often followed by cold water (45%, 39/86) and high-intensity training (22%, 19/86). Earplugs as alleviating factor and cold water as exacerbating factor might indicate the caloric reaction behind dizziness. There is no other cause of dizziness that earplugs should help, and cold water makes caloric response stronger. Another explanation for the dizziness caused by cold water can be some cardiovascular change; high-intensity training might make it stronger. Waves may cause dizziness by a visual-vestibular mismatch as the horizon or coastline cannot be seen easily during freestyle swimming. Slowing or stopping may alleviate several causes of the dizziness, such as dizziness caused by high-intensity training with possible hypo- or hyperventilation.

One explanation for dizziness just after the swimming leg might be the orthostatic hypotension when athletes rise from a horizontal position to an upright position. There was no difference in symptoms of orthostatic hypotension among athletes with and without dizziness (Table 5), which does not confirm the hypothesis of orthostatism causing the dizziness. Otherwise, triathletes with and without dizziness during the triathlon did not differ regarding dizziness caused in other situations like motion sickness, dizziness in amusement parks, or impaired balance during the use of alcohol. And there was no difference in hobbies that improve balance (Table 5). This does not refer to worse balance or bigger overall sensitivity to dizziness among triathletes with dizziness during training.

In the cold-water swimming test, dizziness was more prevalent without earplugs than with them ($p = 0.0039$). Also, nystagmus was more common without earplugs (47%, 7/15 certain nystagmus and 33%, 5/15 uncertain nystagmus) than with them (27%, 3/11 certain nystagmus and 9%, 1/11 uncertain nystagmus), but the difference was not statistically significant. These findings strongly support our hypothesis about caloric reaction. Nystagmus and the help of earplugs are quite specific for caloric reaction.

The direction of nystagmus (defined by the fast phase) is connected with the stimulation or inhibition of the vestibular system: cold water irrigation to one ear causes nystagmus beating to the opposite ear (247). In our study, nystagmus was most often seen to beat to the opposite direction from the breathing side. Thus, it seems that the vestibular organ on the breathing side gets more cold-water exposure than the non-breathing side. This is logical, considering that during the breathing phase, the breathing side ear canal is higher than the non-breathing ear canal, resulting in an asymmetric water entrance to the ear canal and a caloric response.

6.2.2 EFFECT ON PERFORMANCE AND PREVENTION OF DIZZINESS

Dizziness is a real concern for triathletes as half of the triathletes with dizziness reported that it affected their sport performance (Graphic 3). Slowing and stopping for a while were the most common effects, and 2% (2/102) had even needed to drop out of a race because of the dizziness. As it affects the sport performance, it would also disturb training. Severe dizziness can even be a safety risk when it appears during swimming. Earplugs are an inexpensive and easy way to prevent dizziness during the swimming leg. They can also prevent the formation of exostoses (38). Earplug usage will make swimming safer and more comfortable for triathletes who suffer from dizziness in the swimming portion. Earplugs may also have some undesirable effects from decreasing the wearer's hearing level. A swimmer with earplugs might not hear a warning as easily as without them, which can cause a safety risk. Some athletes might find earplugs uncomfortable. Knowledge about dizziness and its prevention needs to be shared with competing and recreational triathletes, for example, through triathlon clubs or triathlon magazines.

6.3 ELITE ATHLETES' OLFACTION

6.3.1 OLFACTION TEST SCORES

Olfaction test scores did not differ between the athlete groups in our study even though they had a long history of chemical irritation (swimmers) or recurrent head trauma (boxers and soccer players) (Table 2 and 6). This is encouraging news for athletes, as olfaction loss decreases the quality of life, predisposes one to hazardous events like missing a fire or eating spoiled food, can change diet and has even been connected to traumatic brain injury and chronic traumatic encephalopathy (182,184–186,248). The vast majority in our study had normal olfaction function as only 7% (9/125) had scores of 7 or 8, reflecting evident hyposmia. None had anosmia. According to our study, olfaction loss during an active sport career is not a reason for athletes to avoid head trauma or chemical irritation. These exposures may, however, cause other problems.

In previous studies patients with a decreased sense of smell had not noticed it easily (177,178,249). Older age and low cognitive function have been associated with impairment to detecting olfaction loss (177,249). In our study athletes with hyposmia (with scores of 7 of 8) self-evaluated their olfaction lower than the others. They were young and presumably had normal cognitive functions, which may explain this. Still, in our study there was not an absolute correlation between self-evaluation of the olfaction and olfaction test score. Boxers and occasional smokers and ex-smokers self-evaluated their olfaction lower than others, but olfaction test scores did not differ between these groups. On the other hand, athletes with nasal obstruction during the test had lower scores in the odour identification test than others, but the self-evaluation did not differ from the others.

6.3.2 SINONASAL AND RESPIRATORY DISEASES

Many athletes in our study reported symptoms of chronic rhinitis such as long-term nasal discharge (31%, 39/124). This is quite comparable to the highest reported symptom-based prevalence in the general population (28%) and well comparable to the previously reported prevalence among athletes (21–74%) (148,166).

Our study supports the previous finding that swimmers are more prone to asthma than other athletes (150,151). Interestingly, floorball players in addition to swimmers had more allergic rhinitis than soccer players or boxers. Swimmers have been presented to have more allergies than other athletes (150), which can explain the prevalence of allergic rhinitis among them. But there is no evident reason for high prevalence among floorball players. In many ways their training is comparable to the soccer players' training. One difference is that soccer players train outside a lot and in cold sport halls while floorball players train in indoor sports halls. Hence one possible explanation might be the indoor air of sports halls, but this assumption will need more research.

Floorball players had the highest Lund-Kennedy score that evaluated nasal findings for rhinitis. This might be explained by their reporting more common cold symptoms during the test than the others. Unlike soccer players, they had the competition season going on when they were examined, and they might not have been as prone to skip trainings during the competition season because of a common cold. The study was done before the COVID-19 pandemic. Many floorball players were also examined in the middle of their training, which can cause findings of exercise-induced rhinitis. Other athletes were mostly examined before or after their training sessions. Almost all (96%, 120/125) athletes and all floorball players (100%, 30/30) were examined between October and March when there is not much pollen in Finland, so that does not explain the high Lund-Kennedy score among floorball players.

The high prevalence of rhinitis symptoms among athletes needs to be noticed by healthcare professionals, and they should also proactively ask about the symptoms. Rhinitis can decrease quality of life (152) and in that way affect the athletes' performance and training. There are supporting findings about intranasal corticosteroid treatment among athletes with allergic rhinitis. Olympic athletes not only report alleviation of symptoms after using intranasal budesonide but also increased quality of life and sport performance (168). In our study 40% of all athletes and 62% (49/79) of athletes with asthma, chronic rhinitis symptoms, and/or allergic rhinitis used some medication for respiratory and nasal diseases. So our study does not confirm the finding of low use of medication among athletes with rhinitis (143,150). In another Finnish study athletes also used medication for their allergic rhinitis quite compliantly (157). This is encouraging information about the treatment of allergic diseases among athletes in Finland.

6.3.3 NASAL TRAUMA

The nature of boxing as a sport clearly explains the high prevalence of diagnosed and self-suspected nasal fractures in study III. The face is a target for impacts. Also, soccer and floorball players had some nasal fractures (Table 7). Diagnosed or self-suspected nasal fractures did not correlate to the nasal obstruction, which would have been logical. The sample size is quite small in our study with only 24 (20%, 24/123) diagnosed or suspected nasal fractures. The small number of fractures might be a reason why we did not find any effect of nasal fractures on the subjective nasal congestion.

6.4 SPORT-RELATED NASAL FRACTURES

We found in total 599 sport-related nasal fractures treated at the HUH within the six-year time period. They comprise 24% of all nasal fractures. It is more than Hwang et al. reported in their systematic review, where 15% of nasal fractures were caused by sports globally, 19% in Europe and 56% among children (112). In our study, children were included, which can partially explain the difference. Other possible explanations may be the definition of sport and low traffic accident rates in Finland (250). Many studies about facial fractures count cycling with traffic accidents but we included it in sport injuries (210,251).

6.4.1 SPORTS INVOLVED

There was a huge variety (47 in total) of different summer, winter, indoor and outdoor sports involved. Team sports and especially ball-related team sports caused most of the nasal fractures just as in the earlier studies about sport-related nasal injuries (112,127) and facial fractures, as seen in Table 1. Popular Finnish sports floorball and Finnish baseball were specialities in our studies as were Gaelic football in Ireland and skiing and snowboarding in Switzerland (220,222). Otherwise, the sport distribution recalls previous studies (112,127,210,220,222–224). Statistics Finland reports the most popular sports in the Helsinki region, and of these only cycling and soccer stand out regarding nasal fractures in our study (Table 8) (252).

Table 9 presents the ratio of nasal fractures treated at HUH to the number of athletes training in the sport at the HUH district. Athletes training in team and combat sports have more licenses than athletes in individual sports. So, only team and combat sports were included in Table 9. Basketball carried the highest risk for nasal fractures among popular team sports in the HUH district with over 10,000 training athletes (soccer, floorball, ice hockey, and basketball). The nature of the sport explains that, as players often have upward-extended arms and there are a lot of jumps and speed. Overall, 77% (48/62) of basketball-related nasal fractures were caused by another player's upper limb and 68% (42/62) by another player's elbow (Table 10). Unfortunately, boxing and wrestling federations did not know the number of athletes in the HUH district, so nasal fractures were compared to the number of athletes in Finland with a 3.4 times bigger population. Still, nasal fractures seemed highly prevalent in these two combat sports as well as in contact sport rugby (Table 9). The same was seen in study III when a major part of the boxers had history of nasal fractures (Table 7). Better protection for the nose should be considered in these sports with high rates of nasal fractures.

6.4.2 GENDER AND AGE DISTRIBUTION

Young males had the most sport-related nasal fractures, which confirms earlier findings about sport-related nasal injuries (127) and facial fractures as seen in Table 1. The mean age in our study was 26, and 71% were males. The mean age was well comparable to the studies presented in Table 1, but the proportion of males was slightly lower than in other studies (78–95%) while the study about facial fractures among older adults was excluded. The lower percentage of males may be caused by gender equality in Finland, which encourages athletes to take part in different sports regardless of gender. Puolakkainen et al. studied facial fractures in the department of oral and maxillofacial diseases in HUH, and they had the closest proportion of males (78%) compared to ours, which confirms this assumption.

Male dominance was less evident among underage patients with nasal fractures (Graphic 5). This may be explained by the fact that before adolescence, both sexes train quite similarly in the different sports. The difference in the sports distribution between sexes comes clearer during the teenage years. At the same time, the strength of males increases more than that of females, which causes higher injury energy and more fractures among males undergoing similar training.

6.4.3 CONCOMITANT INJURIES, DIAGNOSTICS AND TREATMENT

Concomitant injuries were more prevalent in individual sports like cycling (46%) and equine sports (47%) than in team sports with lower injury energy. For example, basketball carries a remarkable risk for nasal fractures, as described previously, but none of the players (0%, 0/62) had concomitant injuries. Our finding that 9% (53/599, Table 11) of all sport-related nasal fracture patients also had other simultaneous facial fractures is comparable to previous reporting (8%, 11/139) (221). Concomitant injuries (Table 11) often need more treatment—for example, a surgery under general anaesthesia. They are important to consider when the prevention of nasal fractures is considered.

At HUH isolated nasal fractures and some facial fractures are treated at the department of otorhinolaryngology and head and neck surgery, and more complex traumas with possible orthopaedic concomitant injuries and mandibular fractures are treated at the department of oral and maxillofacial diseases. As a result of this, more sport-related nasal fracture patients treated at the department of oral and maxillofacial diseases had concomitant injuries (86%, 38/44) than those treated at the department of otorhinolaryngology and head and neck surgery (8%, 43/555). This also explains that the first appointment was clearly earlier at the department of oral and maxillofacial diseases (0.6 days vs. 5.8 days). The treatment of nasal fracture is not that acute. It takes time for the patient to get the admission to the university hospital and for the admission to be handled. The concomitant injury need often quicker evaluation.

In our study the timing for the first treatment was adequate, as the median was 8 days and the mean 11 days after the injury (113,114). The problem in earlier treatment is that the nose is often swollen after the trauma, and the position of the nasal bones is hard to evaluate before the swelling decreases. Scott et al. recommended treatment on the injury day for athletes with nasal fracture (128). Then the swelling might not be that bad and athletes are allowed to return their training earlier. This practice should be considered among sport team doctors and at the department of otorhinolaryngology and head and neck surgery. Then athletes need an emergency admission to the university hospital and to be treated at the emergency room.

6.4.4 INJURY MECHANISMS AND NASAL FRACTURE PREVENTION IN SPORTS

The prevention of nasal fractures is important, as they can cause long-term functional and aesthetic problems despite treatment and may disturb sports performance (113,118). One-fourth of the cosmetic rhinoplasties are done because of the previous nasal fracture (253).

Injury mechanisms were comparable to previously reported mechanisms of facial fractures, as is seen in Tables 1 and 10. The most common mechanism was contact with another athlete (52%). To decrease the number of sport-relates nasal fractures, an important way is to reduce physical contact between players, for example, by rule changes that discourage contact between athletes. More specific injury mechanisms in different sports reveal the situations where nasal fractures are common, and these can be influenced more specifically. Another option to reduce the number of sport-related nasal fractures is better facial protection, which has already clearly decreased facial injuries in ice hockey (229).

Also, the incidence of concomitant injuries needs to be considered. The prevention of multiple facial traumas is even more important than the prevention of isolated nasal fractures. Multiple facial fractures can cause more aesthetic and functional disadvantage than isolated nasal fractures. Their treatment often causes a longer pause to sport training. Concomitant injuries were prevalent in cycling, equine sports, and kick scooting (Table 8) with high injury energy. In these individual sports, injury mechanisms differ from those in team sports (Table 10), so the prevention is also different. In mountain biking and competitive alpine skiing, facial protection is already commonly used. Already, conventional bicycle helmets decrease the risk for facial fracture (231). Thus, the modification of existing helmets, for example, in cycling, equine sports, boxing or Finnish baseball could offer better protection for the face. The use of novel technology like airbags would be an interesting way to protect the upper and middle face. In equine sports, half of the nasal fractures occurred unmounted, so facial protection only during riding would be insufficient. Protection needs to be available also when riders are unmounted, or facial safety needs to be improved another way with strong and responsive animals.

6.5 PARTICIPANTS (I-III)

The strength of our studies is that all the data were collected individually to answer each research question, and participants were recruited to each study separately. Elite athletes were targets in studies I and III, and we succeeded well as they all had a long history of training in their sports (Table 2).

In study I, the size of the study population was sufficient for our aims. Still, there were only 8 (13%, 8/63) females and none of them had cauliflower ear. With a larger study population and more females, we would have been better able to compare treatment strategies, symptoms and attitudes towards cauliflower between genders.

In study II only 15 participants took part in the cold-water swimming test. We had evaluated this previously and considered it an adequate study size. It was a pilot study with the aim to evaluate our hypothesis about the aetiology of dizziness. Altogether 125 triathletes completed the electronic questionnaire. The questionnaire reached the target population well, but the information on participation rate would have been useful.

The number of actively competitive male boxers and swimmers was the limiting factor for the size of athlete groups in study III. Ideally, there would have been at least 50 athletes from each sport group for detecting smaller differences in the olfaction scores. Power calculation could have been done in advance.

6.6 METHODOLOGICAL CONSIDERATION (II AND III)

One problem in study II was that the earplugs which we used in the cold-water swimming test were not fully water resistant (254). Still, we believe that they decreased considerably the amount of water entering the medial parts of the external ear canal. The small amount of water that can possibly enter the ear canal warms to the body temperature quickly and does not cause caloric reaction. That is why totally waterproof earplugs might not be essential for preventing the dizziness caused by caloric reaction. The same idea can be utilized for preventing the formation of exostoses. But for preventing otitis externa, the water resistance of earplugs is more important as bacteria and moisture can enter the ear canal in a small amount of water. The water temperature is not so relevant in the progress of otitis externa as it is in caloric reaction or formation of exostoses.

In study II, we could have recorded the eye movements both before and after the swimming because nystagmus can also be seen in the general population (255). Some quantitative measurement, like slow-phase velocity, for the nystagmus could have been useful in defining it.

In study III, the odour identification test alone does not detect small impairments in olfaction as easily as the combined TDI score, which would have been more accurate in our study (180). The TDI test would have been too long-lasting for our purposes, with volunteer athletes who were examined in connection to their regular trainings or training camps. In addition, the odour identification test notices all major drops in olfaction and was sufficient for our study aims. Odour identification tests have been more sensitive for olfaction loss caused by trauma, infection or central causes than sinonasal diseases (181). This means that the test probably has better detected olfaction loss among soccer players and boxers than among swimmers in our study. One possible method could have been to use magnetic resonance imaging (MRI) to detect the olfactory bulb volume among athletes (256). This would have been much more laborious for athletes, and their recruitment might have been harder. Also, MRI is expensive, and for that we would have needed bigger funding.

6.7 FUTURE DIRECTIONS

6.7.1 ACCORDING TO OUR STUDIES

There are several interesting research questions for the future in the area of sport-related ear, nose and throat diseases. Although our studies answered some former questions, they also created new ones.

Unfortunately, we did not ask athletes whether cauliflower ear or auricular haematoma affected their sport training or performance in study I. It would have been interesting to ask how long a pause they had before they returned to training or competitions after auricular haematoma and its evacuation and whether the haematoma reaccumulated during trainings or competitions. The new information on cauliflower ear treatment by non-healthcare professionals raised a question about whether good instruction for the sport teams would help in treating auricular haematomas properly and whether the number of formed cauliflower ears would decrease.

Our study II about triathlete's dizziness was a pilot study with a relatively small study population especially in the cold-water swimming test (15 athletes). It brought out the probable mechanism and treatment for the dizziness. Still larger studies will be needed to confirm caloric reaction to be behind the dizziness. It would be interesting to evaluate other possible causes for the dizziness at the same time—for example, the role of orthostatism or the effect of waves. Also, other sport groups swim in open and cold water, and it would be useful to investigate whether they suffer from the same problem. The information about preventing dizziness with earplugs can be shared with them.

In study III, olfaction of boxers, soccer players, and swimmers did not differ from floorball players at the stage where they were in their active competition career or had just stopped it. It would be interesting to know if the situation stays similar after 10 or 20 years as olfaction loss is more prevalent among older people (249,257), and possible differences can come clearer later. More olfaction loss has been detected among former football players (40–69 years old) compared to age-matched controls (182). In another study, athletes with longer time delay following concussion had lower scores in olfaction identification tests than athletes with a shorter delay following concussion (258). One possibility would be to perform the whole TDI olfaction test, which is more sensitive to small changes in olfaction (180).

In the HUH database the recommended training pause after nasal fracture was poorly recorded, which is why we did not report anything about it. It would be useful for athletes and people working with them to know how long a pause to training is needed after nasal fracture. A long pause (6–8 weeks) has been recommended (116,127) but there is no evidence as to how long would be enough. How often is there a need for re-reposition because of new sport trauma or can facial protection prevent that? It is not an easy subject to study. It might be done prospectively where patients with sport-related nasal fractures are recruited to the study and followed. They could also be interviewed later about the effect of nasal fracture on their sport performance and training.

6.7.2 OTHER TOPICS

There are also many other interesting research topics in this field. Knowledge about the effect of sport-related ear, nose, and throat diseases on athletes' training and performance is often missing. Information is needed, for example, about rhinitis, exercise-induced laryngeal obstruction, otitis externa, and nasal obstruction. Both subjective and objective information would be useful while treating athletes.

Hearing loss has not been studied widely among sport-shooters or motorsports athletes. For example, audiometry for the shooting national team would be informative. It would be important to know if the available hearing protection is already on a sufficient level or if it needs to be improved. Also, referees are exposed to a large amount of noise while they whistle many times during one single game, and their hearing would be a fascinating topic to study.

Voice problems have been reported among sport instructors and coaches but only a little among athletes (207). Team sport players need to communicate more during sport activities compared to individual athletes. That may cause more voice problems for them, but this has not been evaluated.

7 CONCLUSIONS

- Cauliflower ear is a prevalent and almost always symptomatic deformity among elite wrestlers and judokas.

- Wrestlers and judokas do not regret their cauliflower ears, and athletes with cauliflower ear do not consider them as aesthetic disadvantages.

- Non-healthcare professionals often evacuate athletes' auricular haematomas with no reported complications.

- Dizziness in connection to open-water swimming in triathlons is a real concern as it affects the sport performance of half of triathletes.

- Caloric reaction explains at least a part of the triathlete's dizziness and can be prevented by earplug usage during the swimming leg.

- Recurrent head impacts in boxing or soccer or chemical irritation in swimming does not affect the odour identification among elite athletes during or just after their active sports career.

- Nasal symptoms are prevalent in athletes as are both sinusitis and asthma among swimmers.

- Nasal fractures are prevalent in many different sports, and most of them are caused by team sports. The most prevalent injury mechanism is contact with another player.

- Concomitant injuries of sport-related nasal fractures are most prevalent in individual sports with high injury energy such as in cycling or equine sports.

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