
Brain damage in boxers and soccer players

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To the State Secretary of Health, Welfare and Sport
Parnassusplein 5
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Subject : presentation of advisory report
Your ref : S/BOA-981134
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Dear State Secretary,

At the request of your predecessor, formulated in letter nr S/BOA-981134, I herewith present you the report *Brain damage in boxers and soccer players*. It has been drafted by an Expert Committee of the Health Council and reviewed by its Standing Committees of Medicine, and Medical Ethics and Health Law.

The Committee has limited the report to brain damage resulting from intentional and accidental hits, blows, or kicks to the head or from collisions. Boxing has been selected as an example since it is the only fighting sport for which sufficient scientific data is available and because a large percentage of especially professional boxers develops chronic brain damage. This is a worrisome situation that justifies measures in my opinion. Similar to what has been demonstrated in boxing, also other fighting sports, such as kickboxing and free fight, will carry a great risk for acute and chronic brain damage. Measures to prevent that damage are also warranted in these sports. The second example, soccer, has been selected because it is the most important popular sport in the Netherlands, because heading is an important aspect of the game and the possibility exists that heading leads to brain damage. This has not yet been unequivocally demonstrated, but there are indications for it. Both in boxing and soccer, the Committee sees an important role of neuropsychological testing in the early detection of chronic brain damage, and with that in prevention of its further development. I share the concerns of the Committee and support its recommendations.

Yours sincerely,

Professor M de Visser

Brain damage in boxers and soccer players

to:

the State Secretary of Health, Welfare and Sport

No. 2003/19E, The Hague, 11 November 2003

The Health Council of the Netherlands, established in 1902, is an independent scientific advisory body. Its remit is “to advise the government and Parliament on the current level of knowledge with respect to public health issues...” (Section 21, Health Act).

The Health Council receives most requests for advice from the Ministers of Health, Welfare & Sport, Housing, Spatial Planning & the Environment, Social Affairs & Employment, and Agriculture, Nature and Food Quality. The Council can publish advisory reports on its own initiative. It usually does this in order to ask attention for developments or trends that are thought to be relevant to government policy.

Most Health Council reports are prepared by multidisciplinary committees of Dutch or, sometimes, foreign experts, appointed in a personal capacity. The reports are available to the public.

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Executive summary

Participation in sport can lead to physical injury. Brain injury is one of the most serious forms of injury that can occur. In soccer, players can suffer brain injury as a result of others infringing the rules, as a result of ‘accidents’, and possibly as a result of repeated or poorly executed heading of the ball. In boxing, there is an inherent risk of brain injury, since the sport’s ultimate aim is to knock out one’s opponent. Repeated acute brain injuries – concussions, for example – can lead to the development of chronic brain injury, and ultimately to dementia in the most serious cases.

Both in the world of sport and in medical circles, there has for some time been debate concerning ways of preventing sports-related brain injury. After questions on this subject had been raised in parliament, the State Secretary for Health, Welfare and Sport asked the Health Council to prepare an advisory report. In *Brain injury in boxers and soccer players*, a Committee of the Health Council focuses on the problems in the sports of boxing and soccer and addresses the following questions:

- How common is sports-related brain injury and what gradations of injury – both acute and chronic – may be distinguished?
 - How can brain injury be detected, and how valuable is neuropsychological testing as a diagnostic tool?
 - What can be done to prevent sports-related brain injury?
-

Incidence of brain injury

Not a great deal is known about the prevalence of brain injury in boxing or other fighting sports. Given that inflicting brain injury is one of the intrinsic aims of boxing in particular, little or no research has been conducted into the prevention of such injuries. No attempt has ever been made to quantify the incidence of acute brain injury in professional boxers. However, studies showed that one in eight amateur contests ends in concussion. Information from the Amateur International Boxing Association (AIBA) indicates that the percentage of contests at world championship and Olympic tournaments stopped because of brain injury has declined in recent decades, from about 10 per cent to no more than 3 per cent. This may indicate a fall in the incidence of concussion at such tournaments, but this possibility has not been investigated. It has been convincingly demonstrated that between 40 and 80 per cent of professional boxers suffer chronic brain injury. The seriousness of the abnormalities appears to be related to the number of bouts. Amateur boxers are also affected by chronic brain injury, but no data on the incidence is available and the evidence suggests that the problem is much less serious than among professional boxers.

With regard to soccer, the most informative research data indicates that there are six cases of concussion in every ten thousand men's matches/training sessions, and four cases in every ten thousand women's matches/training sessions. The average player has about a 50 per cent chance of suffering concussion at some point in his/her playing career. There is no evidence to suggest that heading the ball can cause concussion. The Committee knows of only one study reported to date that looked at the subject of chronic brain injury in ex-professional soccer players. Neuropsychological tests indicated that eight of the ten former players participating exhibited abnormalities (albeit mild in some cases). It is not clear to what extent the subjects are comparable with modern-day players, since various aspects of the game have changed over the years. Studies involving active soccer players have produced mixed findings; some have suggested that soccer is associated with chronic brain injury, while others have found no link. Notably, chronic injury has been observed only in players who have executed more than a thousand headers.

The interpretation of data on sports-related brain injuries is complicated by significant inter-study inconsistency in the definition of acute and chronic brain injury. In fact, the findings of the studies reported to date cannot properly be compared. If insight into the incidence of acute and chronic sports-related brain injuries is to be improved, further and more specific sports-epidemiological research is required.

The detection of brain injury

A preliminary on-the-spot diagnosis is normally required when an incident occurs in order to decide whether the individual in question is fit to continue with the game or contest. In the Netherlands, use is currently made of the symptom classification system set out in the *Richtlijnen voor de diagnostiek en behandeling van patiënten met licht schedel-hersenletsel (Guidelines on the Diagnosis and Treatment of People with Slight Cranial Brain Injury)*, published by the Netherlands Association for Neurology. However, this scoring system is intended for use by physicians and is consequently unsuitable for on-field use by lay people. The Committee therefore recommends adoption of the system developed by the American Academy of Neurology. This system uses clearly defined criteria and is more widely accepted than the other systems currently in use. Furthermore, the associated guidelines on minimising the consequences of acute brain injury lend themselves to application in the Dutch sporting context because of the clear criteria for the resumption of sporting activities.

If chronic brain injury is to be detected as early as possible, anyone suspected of such injury should undergo neurological and neuropsychological testing. In the context of such testing, it is always preferable to compare an individual's performance against his or her baseline data, rather than group averages. For this reason, the Committee considers it important that athletes should undergo tests as early in their careers as possible, in order to gather baseline data. It is not feasible to organise testing for the great mass of amateur athletes, but it should be possible to test professionals, who are at greater risk because of the time they devote to their chosen sport. In addition, the Committee recommends that neuropsychological testing forms an integral part of compulsory periodic check-ups for participants in sports associated with a high risk of brain injury. This would enable prompt action in cases where an individual's cognitive functions appeared to be deteriorating. An athlete thus found to be suffering from chronic brain injury should be advised to refrain from all sporting activities that might aggravate the injury. The systematic collection of neuropsychological data regarding athletes would have the added advantage of contributing significantly to scientific knowledge regarding the sensitivity and specificity of neuropsychological testing and thus facilitating their improvement.

Neuropsychological tests are uniquely capable of demonstrating acute brain injury and detecting chronic brain injury at an early stage of development. Such tests can reveal brain injuries at an earlier stage than is possible using imaging techniques. The use of neuropsychological tests is also preferable to the use of serum markers, which currently have little practical value in the detection of acute sports-related brain injuries. However, if the sensitivity and specificity of serum markers as indicators of brain injury

should ever be demonstrated, and if a kit were to become available, with which plasma levels could be determined on the spot, serum markers could perhaps be used for this purpose in the future.

The value of protective headgear

Helmets have been proven to be effective in the protection against acute brain injury. It is as yet unknown whether they also protect against chronic injury, but it is likely that reducing the risk for acute damage will have a preventive effect on long-term effects.

The head cap worn by amateurs in boxing and other fighting sports mainly prevents superficial injuries to the head. The forces acting upon the head are absorbed only to a limited amount. Such headgear offers insufficient protection to boxers' brains.

Studies into the effectiveness of protective headgear for soccer players have given mixed results. These devices also protect against superficial injuries, but protection against brain damage is doubtful.

The prevention of brain injury in boxing

Boxing inflicts health damage. It is the question whether the extent and severity of this damage justifies that the authorities interfere with the autonomy of the fighters and to impose limitations to boxing or even a ban. The Committee feels that this is indeed the case, specifically for professional boxing.

Professional boxing entails a great deal more risk than amateur boxing because no head protection is used and the bouts are longer; in addition, professional boxers generally spar more often and for longer. As a result, a professional boxer is at great risk of chronic brain injury. Furthermore, the sometimes-considerable financial incentives to win can induce a boxer to accept higher risks. These problems are exacerbated by the fact that the Dutch Boxing Association makes little or no provision for the medical supervision of professional boxers. The Committee believes that rule changes are required to reduce the risks associated with professional boxing. If it should not be possible to implement appropriate rule changes within a reasonable space of time, or if it should be concluded that rule changes are unlikely to have any significant effect on the occurrence of brain injury, the Committee strongly recommends the prohibition of professional boxing in the Netherlands. In various countries where professional boxing has been banned for some time, the experience has been that this does not give rise to practical problems. Consideration should also be given to outlawing participation in other fighting sports whose rules permit the infliction of brain injury. One option would be to make prohibition temporary, pending the development of suitable measures to minimise the risk of injury.

All people participating in boxing and other fighting sports should be fully informed about the short-term and long-term health risks associated with participation. No one should be allowed to participate competitively without first being made aware of and accepting the risks (i.e. participation only on the basis of informed consent). The Committee strongly recommends that young people under the age of sixteen should not be allowed to compete in boxing or other fighting sports that can inflict brain injury.

The annual physical examination that boxers are required to undergo should be made more rigorous; it should be made compulsory for all boxers – including non-competitive boxers – and all fighting sport participants, and it should include neuropsychological testing. Competitive boxers should also be examined using imaging and electrophysiological techniques. In the event of cognitive disorders being detected, the subject should be strongly advised to refrain from all sporting activities that involve a risk of brain injury. Where possible (where there is a supervisory medical committee), the person in question should be barred from participation in boxing and fighting sports for life.

If a boxer loses a bout following a KOH (knockout – head) or an RSC-H (referee stopping contest – head), he or she should undergo neuropsychological testing and neurological examination. The boxer should be suspended from competition until the symptoms of acute brain injury abate.

The Committee wishes to see adoption in the Netherlands of the comprehensive requirements made by the AIBA concerning the training of ringside physicians. Ringside physicians, referees and coaches should also receive regular refresher training.

A physician is bound by the Hippocratic oath to adhere to the principle of ‘beneficence’ (doing and promoting good). The physician therefore faces a dilemma in relation to boxing. Given the physician’s commitment to the principle of beneficence, one may reasonably ask whether it is right for a physician to act as a ringside doctor at a boxing contest or other such event. On the other hand, allowing participants to fight without adequate medical supervision might be regarded as an abdication of responsibility. The rules of the Dutch Boxing Association therefore prohibit a contest from taking place without a ringside physician. The Netherlands Association of Sports Medicine (ASM) has issued a guideline regarding boxing and other fighting sports: physicians should endeavour to establish preventive measures and by no means promote these sports activities. The Royal Dutch Medical Association has ruled that *all* physicians in the Netherlands are to observe the ASM guidelines.

The prevention of brain injury in soccer

Whenever brain injury is suspected, the Committee would like to see the guidelines developed by the American Academy of Neurology applied. The additional and more

specific advice given by the International Conference on Concussion in Sports ought to be followed in the Dutch sports setting because of the detailed step-by-step plan for a sportsperson's return to play following a brain injury. Appropriate care following brain injury can prevent aggravation of the damage.

On-site provision should be made for the medical treatment of acute brain injury. Such provision is already made for all professional matches in the Netherlands. The medical personnel in attendance are all given instructions by the Royal Netherlands Football Association on how to respond in the event of a (suspected) brain injury. The Committee believes that compliance with these instructions should be mandatory. Amateur matches are too numerous to make the universal attendance of trained medical personnel practical. In the United States, an easy-to-use reference card has been developed, which lists signs and symptoms of concussion and sets out a number of simple but validated on-the-spot tests that can be used to assess the condition of someone who has received a blow to the head. The Committee recommends the development of a Dutch version of this reference card for on-field use in both professional and amateur sport. All referees and coaches should then be instructed, at least at the beginning of each season, in the use of the card. Wherever doubt exists regarding a player's fitness to continue following an incident, he or she should be withdrawn from the match and referred for medical examination. The Committee also recommends that professional players should undergo both an immediate on-field test, plus more thorough subsequent testing.

In the interests of brain injury prevention, strict enforcement of the rules of the game is also important. As well as advocating such enforcement, the Committee would like to see the rules modified in two respects. The FIFA is already seeking to outlaw use of the elbow when jumping to head the ball. The Committee's view is that use of an elbow should be outlawed in all phases of play as a matter of urgency. In addition, the Committee recommends that a team should be permitted to temporarily substitute an injured player to allow for more thorough examination off the pitch. This would enable a team to give an injured player proper attention without fear of weakening the team's position in the game.

The Committee believes that players should be instructed in appropriate heading techniques. The effect that heading has on the brain increases as the ratio between the mass of the player's head and the mass of the ball decreases. This implies that increasing the mass used in heading by tensing the muscles of the neck can reduce the risk of brain injury. Since the head-ball mass ratio is much lower in junior players than it is in adults, the risk of brain injury in children is higher. The Committee therefore supports the Dutch FA's view that players under the age of sixteen should not be trained to head the ball. The scarce data on possible chronic brain injury as a result of frequent heading is not equivocal. The Committee therefore presently does not believe that there are grounds for imposing other limitations to heading, or for recommending the use of pro-

tective headgear by soccer players. Further research is required, however, into the biomechanics of heading; there is a need to add to the existing knowledge in order to facilitate the possible development of protective gear.

It has been suggested that soccer players should wear mouthguards, which are already used in various other sports. However, the Committee does not feel inclined to recommend the use of mouthguards until there is evidence that they would actually be effective in soccer.

Concluding remarks

The Committee would like to see the creation of a knowledge centre to register brain injuries and to coordinate research into the effectiveness of preventive measures, not only for boxing and soccer, but for all sports which may result in brain injuries. The centre could also organise seminars and training courses for sports physicians, coaches and youth leaders. In this way, people in the sporting world could be provided with greater insight into brain injuries and taught what to do in the event of an incident that might involve such an injury. The seminars might vary from introductory outlines for amateur coaches to detailed explorations of the relevant issues for professionals such as sports physicians.

Introduction

Exercise and sport are generally regarded as healthy activities. However, playing sport can lead to physical injury. In certain sports, the risk of injury is quite significant; indeed, the object of fighting sports such as boxing is to overcome one's opponent by inflicting physical injury. Brain damage is regarded as one of the most serious forms of physical injury, because the brain plays a crucial role in physical and mental performance. Any chronic and therefore irreversible injury to this vital organ is a particularly serious matter. Both in the world of sport and in medical circles, there has for some time been debate concerning ways of making sport safer, preventing physical and in particular brain injury and identifying the early signs of brain injury. In this context, one particularly pertinent question is whether and, if so, how acute brain injury can lead to chronic injury. That both types of injury can occur in sport is not in doubt.

Around the world, several dozen studies have been conducted into brain injuries associated with sporting activities. Researchers have tended to focus particularly on those sports that involve robust physical contact between opponents, such as boxing, rugby, American football and ice hockey. It has been found that boxers sometimes suffer progressive degeneration of the brain, comparable in some respects to Alzheimer's disease. This condition is referred to as 'punch-drunk syndrome' or *dementia pugilistica*. In addition, boxers can be affected by Parkinsonism. Various studies have shown that the more often a boxer has suffered acute injury – such as concussion or a knockout – the more likely it is that a chronic condition such as punch-drunk syndrome or Parkinsonism

will develop. Training patterns also appear to play a role, in particular the intensity and the duration of sparring sessions.

In more recent years, several studies have looked at brain injury in soccer players. Soccer players' heads sometimes make sufficiently violent contact with the ball, an opponent or a goalpost as to cause brain injury. There is reason to believe that, as with boxers, the repeated occurrence of acute injuries, especially concussion, can lead to chronic brain injury. Researchers in the Netherlands and other countries have pointed to regular heading of the ball as a possible cause of chronic brain injury.

In the late 1990s, reports appeared in the media regarding research carried out by the Dutch neuropsychologist Matser into the dangers associated with heading in soccer. In the light of this research, the State Secretary for Health, Welfare and Sport was asked in parliament what action the government was taking to prevent sports-related brain injuries. The State Secretary accordingly asked the President of the Health Council to prepare an advisory report on this subject, to support the possible development of a more specific policy on prevention of sports-related brain injuries. In particular it was asked whether neuropsychological tests may play a role in diagnostics, since such tests might give indications for chronic brain injury at a much earlier stage than other techniques. The text of the State Secretary's letter is reproduced in annex A.

On 25 April 2002, the President of the Health Council set up the Sports-Related Brain Injuries Committee, whose members are listed in annex B. The Committee was asked to address the questions posed by the State Secretary on the basis of the scientific evidence currently available. To assist its deliberations, the Committee invited representatives of the medical committees of the Royal Netherlands Football Association and the Dutch Boxing Association to attend a meeting on 28 November 2002 and present their views on preventing and dealing with brain injury in their sports.

In the remaining chapters of this report, the Committee answers a number of the questions posed by the government:

- How common is sports-related brain injury and what gradations of injury – both acute and chronic – may be distinguished?
- How can brain injury be detected, and how valuable is neuropsychological testing as a diagnostic tool?
- What can be done to prevent sports-related brain injury?

The Committee's answers relate to boxing and soccer only.

In Chapter 2, a résumé is presented of the data available regarding the incidence of brain injury in boxers and soccer players, and regarding the gradations of injury distinguishable. Chapter 3 covers the diagnosis of the various gradations of brain injury and the value of neuropsychological testing. Chapter 4 looks at the role helmets can play in the prevention of brain injury. In Chapters 5 and 6, the Committee assesses the scope for brain injury prevention in each of the two focus sports, and makes practical recommendations regarding appropriate measures. The report concludes with proposals concerning ways of increasing and disseminating knowledge regarding sports-related brain injuries.

Incidence of brain injury in boxers and soccer players

In this chapter, the Committee presents a résumé of the most significant data available concerning the incidence of brain injury in boxers and soccer players. Information relating to the situation in a number of other sports appears in annex C. No data is available for sports not mentioned in this report.

2.1 Delineation

Brain injury may occur in all sports activities as a result of accidents. A systematic registration of this is missing and information of the incidence of such accidents is only scarcely provided in the scientific literature. In the Netherlands, the Injury Information System provides data on the number of cases treated in by emergency rooms in hospitals (109). These data present an incomplete picture, however, since only patients with serious injuries will report at emergency rooms. Moreover it is not possible to determine from this registration whether the injury is the result of an accident or caused by the sports activity itself. The Committee therefore deems these data not suitable for the determination of the incidence of brain injury. The focus in this report is on brain injury resulting from game-related sports activities.

The Committee specifically looked at brain injuries that are considered as minor or mild in traumatology and biomechanics. Serious brain injuries with an AIS* score of 3

* AIS = *Abbreviated Injury Scale*, a scaling of the severity of injury based on the extent of life-threatening, ranging from 0 (no injury), 1 (minor/mild), 2 (moderate), 3 (serious), 4 (severe), 5 (very severe), to 6 (virtually unsurvivable).

or higher are not dealt with in this report. Concussions are mainly minor or mild (AIS1) and in a very limited number of cases moderate (AIS2).

Although various researchers have published the findings of studies into brain injury in boxers and footballers, mutual comparison of the studies is difficult. One obstacle to comparison is that a variety of definitions of brain injury are used. This is probably why the incidences reported by American authors are higher than those reported in Europe. Another problem is that most of the studies involved quite small groups of athletes. Furthermore, many authors provide only sketchy information concerning the characteristics of the research population, the causes and nature of the injuries and the methods of registration. The data is consequently difficult to interpret. In fact, the findings cannot properly be described as comparable.

2.2 Boxing

2.2.1 *Acute brain injury*

Matser ⁽⁷²⁾ studied thirty-eight amateur boxers before and after a bout. In 13 per cent of cases, concussion was observed after the fight (sometimes involving loss of consciousness).

Porter ⁽⁹²⁾ observed 281 amateur fights; thirty-three (12 per cent) ended in a knock-out (KO) or in the intervention of the referee following blows to the head. This was regarded as mild cerebral brain concussion. Brain injury accounted for 52 per cent of all acute injuries. No brain injuries were observed during training.

Enzenauer ⁽³³⁾ reported hospital admission figures for boxers in the US army between 1980 and 1985. Brain injury accounted for 68 per cent of all injuries. This study was concerned with serious injuries only, so it is likely that the proportion of brain injury is higher than when all acute injuries would have been considered.

The Amateur International Boxing Association (AIBA) made unpublished data available concerning the percentages of senior world championship and Olympic fights since 1980 that have ended in KOH (knockout, head), RSCH (referee stopping contest, head) or RSCI (referee stopping contest, injury) (see table 1). The percentages for all three outcomes show a clear downward trend, both in world championships and in Olympic tournaments. This observation cannot readily be explained, but may be related to stricter regulation. In this context, it is worth noting that, since the early 1990s, a full-length fight has gone from being three rounds of three minutes, first to five rounds of two minutes and later four rounds of two minutes. The reason for this was that the heaviest blows (figuratively speaking) tended to be landed in the closing stages of each round.

Table 1 Percentages of stopped boxing contests during major international tournaments.

	KOH	RSCH	RSCI	Total
World championship, seniors				
Munich, 1982	5.9	3.9	12.7	22.7
Reno, 1986	4.9	6.3	0.0	11.2
Moscow, 1989	1.3	6.2	1.8	9.3
Sydney, 1991	1.5	3.5	1.5	6.5
Tampere, 1993	1.6	1.9	1.5	5.0
Berlin, 1995	1.7	0.6	1.4	3.7
Budapest, 1997	0.8	1.7	1.4	3.9
Houston, 1999	0.3	1.5	0.3	2.1
Belfast, 2001	0.3	0.6	0.9	1.8
Olympic Games				
Moscow, 1980	11.0	6.4	12.2	29.6
Los Angeles, 1984	5.8	10.1	1.6	17.5
Seoul, 1988	7.9	16.3	1.4	25.6
Barcelona, 1992	1.9	8.4	3.2	13.5
Atlanta, 1996	1.1	4.6	3.2	8.9
Sydney, 2000	0.6	3.3	1.0	4.9

According to Dutch Boxing Association figures, forty-eight amateur boxers and four professionals have been barred from fighting in the Netherlands since 1998. In eight cases, the decision as to whether a boxer should be allowed to fight was based upon the results of an electroencephalographic examination (EEG). No data is available either concerning the total number of contests taking place during the period in question or concerning the breakdown of the fighters by age and weight category. According to the Dutch Boxing Association there are approximately 1000 amateur and 25 professional boxers in the Netherlands.

2.2.2 *Chronic brain injury*

The reported incidences of chronic brain injury vary considerably. However, this is largely because of differences in the chronic injury definitions applied and in the detection methods used.

Roberts⁽⁹⁷⁾ examined 224 former professional boxers for neurological abnormalities. Signs of brain injury were found in roughly half the subjects, and Parkinsonism in 17 per cent.

Casson ⁽¹⁹⁾ conducted neurological and neuropsychological tests on eighteen former and active boxers, and also performed EEGs and computer tomographic (CT) scans. In thirteen of the fifteen professional boxers (87 per cent) at least two of the four tests resulted in abnormal findings. The author concluded that this was indicative of chronic brain injury. All fifteen professional boxers and the three amateurs registered abnormal scores in at least one of the neuropsychological tests.

Jordan ⁽⁶⁰⁾ carried out brain CT scans on 338 active professional boxers. Definite abnormalities were observed in twenty-five boxers (7 per cent) and possible abnormalities in another seventy-five (49 per cent). There was no difference between the boxers with clear abnormalities and the rest of the group in terms of age, or in terms of the number of bouts fought, won or lost, or in terms of EEG abnormality type. Of the boxers with definite CT abnormalities, 68 per cent had suffered one or more KOs, compared with 49 per cent of those with possible abnormalities and just 37 per cent of those without abnormalities.

In another study, Jordan ⁽⁶¹⁾ tested thirty professional boxers using neurological and neuropsychological methods. Chronic abnormalities of a slight to serious nature were observed in nineteen of the subjects (63 per cent). The severity of the abnormalities was related to the number of bouts.

Haglund ^(45,46,48,84) examined fifty amateur boxers and compared them with two control groups: soccer players and track and field athletes. Among the boxers, slight to moderate EEG abnormalities were observed. They also scored less well than the control subjects in one of the neuropsychological tests. The authors concluded that there was no evidence to suggest that amateur boxers suffered serious chronic brain injury through participation in their sport, but that some did exhibit slightly impaired brain function and mild neurocognitive dysfunctions.

Zhang ⁽¹²⁵⁾ compared twenty-four professional boxers with fourteen healthy control subjects. Using a special magnetic resonance imaging (MRI) technique called diffusion-weighted imaging, signs of microstructural brain injury were observed in the boxers. Notably, these injuries could not in all cases be detected using conventional MRI techniques. A good correlation was found between the observed abnormalities and the number of hospital admissions following traumatic brain injury. The authors attributed the observed damage to chronic traumatic brain injury. Unfortunately, the possibility of a link with other medical problems or cognitive performance was not considered.

2.2.3 *Conclusion: scarcity of reliable data on brain injury in boxers*

The high percentage of brain injury cases in boxers is related to the fact that inflicting brain injury is an intrinsic part of the game: the goal is to eliminate the opponent and one of the most important methods (and the most popular one with the spectators) is the

knockout. Because contracting brain injury invariably goes with the sport, little or no research has been conducted into its incidence. One in eight amateur contests ends in concussion. Information from the Amateur International Boxing Association (AIBA) indicates that the percentage of contests at world championship and Olympic tournaments stopped because of brain injury has declined in recent decades, from about 10 per cent to no more than 3 per cent. This may indicate a fall in the incidence of concussion at such tournaments, but this possibility has not been investigated. No attempt has ever been made to quantify the incidence of acute brain injury in professional boxers, but it has been convincingly demonstrated that between 40 and 80 per cent of professional boxers suffer chronic brain injury. The seriousness of the abnormalities appears to be related to the number of bouts. Amateur boxers are also affected by chronic brain injury, but no data on the incidence is available and the evidence suggests that the problem is much less serious than among professional boxers. There are no known cases of *dementia pugilistica* amongst amateur boxers.

2.3 Soccer

2.3.1 Acute brain injury

In the United States, Powell⁽⁹³⁾ asked coaches at 235 US high schools to keep records of concussion incidents associated with various sports. Any incident in which a player was withdrawn from a match or training session for examination of suspected brain injury was classed as involving Mild Traumatic Brain Injury (MTBI). It is therefore likely that the reported figures overestimate the actual incidence of MTBI. For soccer the incidence was 0.57 MTBIs per thousand boys' matches and 0.71 MTBI per thousand girls' matches.

Another American researcher, Boden⁽¹⁴⁾, asked the coaches of seven men's teams and eight women's teams in the eastern United States to record incidents of concussion over two seasons. A total of 163 male players and 188 female players were involved in the study. The recorded incidences were 0.6 cases of concussion per thousand matches/training sessions among men and 0.4 cases per thousand matches/training sessions among women. In most cases (72 per cent), the concussion was slight (grade 1). The remaining 28 per cent of cases involved moderate concussion (grade 2). In no case was heading the ball recorded as the cause of the injury.

Barnes⁽¹⁰⁾, another researcher in the United States, used a thorough interview technique to investigate the incidence of concussion among 137 soccer players (participants at the U.S. Olympic Sports Festival in 1993). An injury was classified as concussion only if the subject clearly remembered that it led to, for example, treatment by a doctor or the player being unable to participate in subsequent matches or training sessions. This

criterion was applied in order to reduce the risk of recall bias. Of the 72 men interviewed, 39 had suffered concussion at least once during their soccer careers. This gave an overall incidence of 74 cases in 939 player-years, 24 resulting from collision with another player. Of the 65 women, 23 had suffered a total of 28 concussions in 924 player-years. Twenty of the female concussion incidents involved collisions.

In the Netherlands, Matser⁽⁷¹⁾ sought to establish the incidence of concussion among amateur soccer players by interviewing players and their family doctors. The research method was designed to minimise the risk of recall bias. Concussion was defined as *commotio cerebri* (concussion accompanied by unconsciousness: category 2 or 3 under the classification system developed by the Netherlands Association for Neurology⁽²⁴⁾, or grade 3 concussion under the American system). Of the 33 players interviewed, sixteen (49 per cent) had suffered concussion at some time while playing soccer.

2.3.2 *Chronic brain injury*

Tysvaer studied 37 former professional soccer players, subjecting them to neurological and neuropsychological tests⁽¹¹⁶⁾ and performing EEGs⁽¹¹⁵⁾. EEG abnormalities were significantly more common among the ex-soccer players than among members of a control group. The neuropsychological tests revealed that thirty of the thirty-seven (81 per cent) had impaired brain functions. Performing CT scans on players from the same group, Sortland⁽¹⁰⁵⁾ found that nine out of thirty-three former professionals (27 per cent) exhibited central cerebral atrophy.

Various researchers have studied soccer players who still actively participated in the sport. The findings suggest a higher but – due to lack of data – non-quantifiable incidence of chronic brain injury.

Comparing a group of ninety-six professional players with a control group, Tysvaer⁽¹¹⁶⁾ found that the soccer players' EEGs exhibited more abnormalities. These were greatest among young players.

Matser compared neuropsychological test results obtained from 33 amateur soccer players⁽⁷¹⁾ and 53 professionals⁽⁷³⁾ with results from 27 swimmers and track athletes. The soccer players achieved lower scores than the controls in planning and memory tests. The discrepancies could not be attributed to differences in educational background: the soccer players were on average slightly better educated than the control athletes. Furthermore, there appeared to be a link between the number of times a soccer player had been concussed during his career and his performance in certain of the tests. Among the professional players, there was also an association between neuropsychological performance and the frequency of heading the ball.

In another study, Matser performed neuropsychological tests on 84 Dutch professional soccer players. The test results were then analysed against the frequency with which the players were required to head the ball during matches, and against the number of times they had suffered concussion while playing ⁽⁷⁴⁾. The more heading of the ball a player did (particularly in relation to an apparent threshold at about a thousand headers) and the more often he had been concussed, the greater the impairment of his cognitive performance. Interestingly, however, heading and concussion appeared to be linked to the impairment of different functions.

Janda ⁽⁵⁸⁾ looked at cognitive performance in a group of 57 youth players (average age 11.5 years). Comparing the players' scores against standard data, no significant abnormalities were found, except that high frequencies of heading were associated with reduced ability to learn new words. However, 49 per cent of the subjects reported suffering headache after heading the ball.

Guskiewicz ⁽⁴³⁾ was not able to observe any difference in neuropsychological test performance between a group of 91 active soccer players, a group of 96 other sportspeople and a group of 53 control subjects (all students).

2.3.3 *Conclusion: half of all soccer players suffer concussion at some time in their playing careers*

The most informative research data indicates that there are six cases of concussion in every ten thousand men's matches/training sessions, and four cases in every ten thousand women's matches/training sessions. The average player has about a 50 per cent chance of suffering concussion at some point in his/her playing career. There is no evidence to suggest that heading the ball can cause concussion.

The Committee knows of only one study reported to date that looked at chronic brain injury in ex-professional soccer players. Neuropsychological tests indicated that eight of the ten former players participating exhibited abnormalities (albeit mild in some cases). It is not clear to what extent the subjects are comparable with modern-day players, since various aspects of the game have changed over the years. In particular, modern footballs are very different from those used in the past; in wet conditions they absorb less moisture and do not therefore become so heavy. This did happen with the old-fashioned footballs and this may well have had an influence on the effect of heading. Some studies involving active soccer players indicated the occurrence of chronic brain injury, while others did not. Notably, chronic injury has been observed only in players who have executed more than a thousand headers.

2.4 Concluding remarks: insufficient sports-epidemiological research data available

The interpretation of data on sports-related brain injuries is complicated by significant inter-study inconsistency in the definition of acute and chronic brain injury. In fact, the findings of the studies reported to date cannot properly be compared. If insight into the incidence of acute and chronic sports-related brain injuries is to be improved, further and more specific sports-epidemiological research is required.

The detection of brain injury

In the previous chapter, several references were made to gradations of brain injury. The point was also made that the various gradations of brain injury are by no means consistently defined throughout the studies. Both for scientific purposes and for practical sporting purposes, a generally accepted set of brain injury gradation definitions is required.

3.1 Systems for the classification of symptoms

3.1.1 Concussion

If the consequences of a sports-related brain injury are to be minimised, it is important to determine how serious the injury is. A preliminary on-the-spot diagnosis is normally made when an incident occurs in order to decide whether the individual in question is fit to continue with the game or contest. It is therefore desirable that diagnosis may be made by relatively straightforward means, by reference to a readily applicable brain injury gradation system. In the Netherlands, use is currently made of the symptom classification system set out in the *Richtlijnen voor de diagnostiek en behandeling van patiënten met licht schedel-hersenletsel (Guidelines on the Diagnosis and Treatment of People with Slight Cranial Brain Injury)*, published by the Netherlands Association for Neurology⁽²⁴⁾. However, this scoring system is intended for use by doctors and is not suitable for on-field use by lay people. The Committee believes that the system developed by the American Academy of Neurology (AAN)⁽³⁾ is more appropriate for such

use than the system advanced by the Netherlands Association for Neurology, or the McGill University system adopted by the Royal Netherlands Football Association ⁽⁶⁶⁾. The AAN system uses clearly defined criteria and is more widely accepted than either of the other two systems. Furthermore, the associated guidelines on minimising the consequences of acute brain injury lend themselves to application in the Dutch sporting context because of the clear return-to-play criteria (see 3.3).

Concussion is an acute brain injury, which may be subdivided into three gradations:

- Grade 1
 - Transient confusion
 - No loss of consciousness
 - Symptoms of concussion or mental status abnormalities disappear within fifteen minutes
- Grade 2
 - Transient confusion
 - No loss of consciousness
 - Symptoms of concussion or mental status abnormalities persist for more than fifteen minutes
- Grade 3
 - Any loss of consciousness, either brief (seconds) or prolonged (lasting up to fifteen minutes)

If unconsciousness lasts more than fifteen minutes, the condition is described not as concussion but as contusion (*contusio cerebri*).

3.1.2 *Second Impact Syndrome*

Like concussion, Second Impact Syndrome is a form of acute brain injury. The condition is life-threatening and is liable to occur if a person resumes sporting activities before the symptoms of an earlier concussion have disappeared. If a second blow to the head is received following premature activity resumption, it can lead to immediate loss of cerebrovascular autoregulation ^(9,99). This can have fatal consequences within minutes. It is therefore very important not to resume sporting activities until all symptoms of concussion have abated. In 3.3 the Committee gives specific return-to-play recommendations.

3.1.3 *Chronic brain injury*

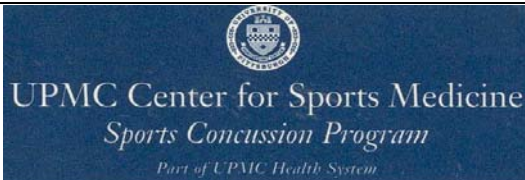
Chronic brain injury may be defined as a generally progressive brain condition that initially manifests itself in the form of slight cognitive disorders⁽⁹⁶⁾. The more blows are received to the head, the greater the cognitive disorders become and the greater the risk of motor changes (typically Parkinsonism); as the condition progresses, psychiatric symptoms may also arise (difficulty controlling impulses and paranoia). Mendez⁽⁸³⁾ wrote in a review that psychiatric symptoms had been observed in boxers who displayed signs of chronic brain injury. The condition may ultimately develop into dementia (Alzheimer's disease). Three gradations of chronic brain injury may be distinguished, based on the cognitive disorders involved⁽¹²⁴⁾:

- Type 1 – Memory impairment (short and long-term) only
- Type 2 – Memory impairment, accompanied by impairment of at least one other higher brain function, although having no significant influence on day-to-day activities
- Type 3 = dementia – Memory impairment, accompanied by impairment of at least one other higher brain function, to a degree that has a significant influence on day-to-day activities.

3.2 **On-field cognitive testing**

The Center for Sports Medicine at the University of Pittsburgh has developed an easy-to-use reference card that lists signs and symptoms of concussion and sets out a number of simple on-the-spot tests that can be used to assess the condition of someone who has received a blow to the head (figure 1).

Using this quick on-field test, it is possible to determine within a few minutes whether a player suspected of having a brain injury is or is not fit to continue. The test makes use of new learning techniques (e.g. asking the subject to repeat a series of numbers) and is specific and effective, even in the assessment of fatigued subjects. The reliability of the tests is greater if baseline data is available for comparison. The test can be used during a match or contest to establish whether it is safe to allow the subject to continue. McCrea⁽⁷⁵⁾ reports the use of a test of this type for the assessment of a large series of athletes, but unfortunately the study methodology used leaves something to be desired^(42,76).



UPMC Center for Sports Medicine
Sports Concussion Program
Part of UPMC Health System

Concussion Signs and Symptoms Evaluation
412-432-3670

Or call UPMC MedCall and request assistance from the Sports Concussion Program
1-800-544-2500

<p>Signs observed by staff</p> <ul style="list-style-type: none"> • appears to be dazed or stunned • is confused about assignment • forgets plays • is unsure of game, score, or opponent • moves clumsily • answers questions slowly • loses consciousness (<i>even temporarily</i>) • shows behavior or personality change • forgets events prior to hit (<i>retrograde</i>) • forgets events after hit (<i>anterograde</i>) 	<p>Symptoms reported by athlete</p> <ul style="list-style-type: none"> • headache • nausea • balance problems or dizziness • double or fuzzy vision • sensitivity to light or noise • feeling sluggish • feeling "foggy" • change in sleep pattern • concentration or memory problems
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*Symptoms may worsen with exertion.
Athlete should not return to play until symptom-free.*

Cognitive Testing

Orientation

Ask the athlete the following questions.

What stadium is this? What month is it?
 What city is this? What day is it?
 Who is the opposing team?

Anterograde amnesia

Ask the athlete to repeat the following words.

Girl, dog, green

Retrograde amnesia

Ask the athlete the following questions.

What happened in the prior quarter/period?
 What do you remember just prior to the hit?
 What was the score of the game prior to the hit?
 Do you remember the hit?

Concentration

Ask the athlete to do the following.

Repeat the days of the week backward (starting with today).
 Repeat these numbers backward:
 63 *(36 is correct)* 419 *(914 is correct)*

Word list memory

Ask the athlete to repeat the three words from earlier. (Girl, dog, green)

*Any failure should be considered abnormal.
Consult a physician if the athlete exhibits any signs or symptoms.*

Figure 1 On-field reference card for the assessment of a player suspected of having concussion.

Although on-field testing will require validation in a Dutch setting, the Committee recommends the development of a Dutch version of the UPMC reference card for use in both professional and amateur sport. In addition, coaches and referees should be instructed in the use of the test. The Committee also recommends that, for professional athletes, on-field testing should be followed by more thorough neuropsychological testing⁽²³⁾.

3.3 Return-to-play guidelines following brain injury

3.3.1 Acute brain injury

The guidelines of American Academy of Neurology (AAN)⁽³⁾ have been tightened up by the International Conference on Concussion in Sport (ICCS)⁽⁷⁾ such as that if a player exhibits any sign or symptom of concussion, he or she should be withdrawn from

the match or contest and should not take any further part in sporting activities for the rest of the day. Rehabilitation should take place gradually over a period of days, under medical supervision. Each successive step towards a full resumption of activities should be dependent on the individual being free of all brain injury-related complaints and symptoms. The Committee endorses the recommendations of the ICCS and AAN. The advice linked to each gradation of acute brain injury is set out below:

- Grade 1
 - Remove from contest; return to play not allowed.
 - Examine immediately and at 5 minute intervals for the development of mental status abnormalities or post-concussion symptoms at rest and with exertion.
 - Gradually build up rehabilitation (every next step after 24 hours):
 - no activity, complete rest until symptoms have disappeared
 - light aerobic exercise such as walking or stationary cycling
 - sport specific training, for example running in soccer
 - non-contact training drills
 - full contact training after medical clearance
 - game play.

 - Grade 2
 - Remove from contest; return to play not allowed.
 - Examine on-site frequently for signs of evolving intracranial pathology.
 - A trained person should reexamine the athlete the following day.
 - A physician should perform a neurologic examination to clear the athlete for return to play after 1 full asymptomatic week at rest and with exertion.
 - Return-to-play should be build up gradually according to the guidelines of the ICCS (see Grade 1).
 - CT- or MRI scanning is recommended in all instances where headache or other associated symptoms worsen or persist longer than one week.
 - Following a Grade 2 concussion, return to play should be deferred until the athlete has had at least two weeks symptom-free at rest and with exertion.
 - Terminating the season for that player is mandated by any abnormality or CT or MRI scan consistent with brain swelling, contusion, or other intracranial pathology.

 - Grade 3
 - Transport the athlete from the field to the nearest emergency department by ambulance if still unconscious or if worrisome signs are detected (with cervical spine immobilization, if indicated).
-

- A thorough neurologic evaluation should be performed emergently, including appropriate neuroimaging procedures when indicated.
- Hospital admission is indicated if any signs of pathology are detected, or if the mental status of the athlete remains abnormal.
- If findings are normal at the time of the initial medical evaluation, the athlete may be sent home. Explicit written instructions will help the family or responsible party observe the athlete over a period of time.
- Neurologic status should be assessed daily thereafter until all symptoms have stabilized or resolved.
- Prolonged unconsciousness, persistent mental status alterations, worsening post-concussion symptoms, or abnormalities on neurologic examination require urgent neurosurgical examination or transfer to a trauma center.
- After a brief (seconds) Grade 3 concussion, the athlete should be withheld from play until asymptomatic for 1 week at rest and with exertion.
- After a prolonged (minutes) Grade 3 concussion, the athlete should be withheld from play until asymptomatic for 2 weeks at rest and with exertion.
- Following a second Grade 3 concussion, the athlete should be withheld from play for a minimum of 1 asymptomatic month. The evaluating physician may elect to extend that period beyond 1 month, depending on clinical evaluation and other circumstances.
- Return-to-play should be build up gradually according to the guidelines of the ICCS (see Grade 1).
- CT or MRI scanning is recommended for athletes whose headache or other associated symptoms worsen or persist longer than 1 week.
- Any abnormality on CT or MRI consistent with brain swelling, contusion, or other intracranial pathology should result in termination of the season for that athlete and return to play in the future should be seriously discouraged in discussions with the athlete.

3.3.2 *Chronic brain injury*

In order to detect chronic brain injury as early as possible, neurological and neuropsychological testing is required. An athlete thus found to be suffering from chronic brain injury – as indicated by, for example, slight cognitive disorders – is advised to refrain from all sporting activities that might aggravate the injury.

Neurological and neuropsychological testing is always best done against an individual's own baseline data, rather than against group averages. For this reason, the Committee considers it important that athletes should undergo tests as early in their sporting careers as possible, for the purpose of gathering baseline data. It is not feasible to test the

great mass of amateur athletes, but it should be possible to test professionals, who are at greater risk because of the time they devote to their sport.

3.4 The value of neuropsychological testing

Neuropsychological testing can reveal brain injuries at an earlier stage than is possible using imaging techniques. Furthermore, the tests now available enable one's condition to be assessed very quickly. The reliability of neuropsychological testing has been studied on various occasions ^(11,22,32,42,52,63). Nevertheless, little is known about the sensitivity or specificity of such testing. For test batteries used to assess acute injury, researchers have reported sensitivities of between 75 and 87.5 per cent and specificities of 77 to 90 per cent ^(23,51). These figures were calculated using clinical examination as the 'gold standard'. On the basis of the reported data, Grindel ⁽⁴²⁾ asserts that acute brain injury can be detected by neuropsychological testing (although there is a one-in-four chance that a diagnosis of brain injury will not be made at the appropriate time), but that such tests cannot be used to confirm the subject's recovery from the injury.

However, the Committee does not feel that MRI can be regarded as the 'gold standard' for the detection of brain injury; it is the Committee's belief that neuropsychological testing can reveal abnormalities at an earlier stage of development than is possible using imaging techniques. The validity of neuropsychological testing cannot therefore be determined in terms of sensitivity and specificity. Under such circumstances, one must find an alternative way of pronouncing something abnormal, a way that takes account of the biological variation within a 'normal' standard population. So, for example, one might decide that a value that deviates from the average by more than twice the standard deviation may be regarded as abnormal. Normal neuropsychological test results for the US population have been reported by Lezak ⁽⁷⁰⁾.

No data is available regarding the sensitivity or specificity of neuropsychological testing as a means of detecting chronic brain injury. However, when assessment is based upon data obtained using the alternative method referred to above, neuropsychological testing is clearly a valuable tool for the early detection of chronic injury. In the United States, therefore, neuropsychological tests are now used as a matter of routine in some professional sports.

3.4.1 *Studies on boxers*

Several studies have been published on neuropsychological testing of amateur and professional boxers. The design of several of these studies was inadequate, however, for instance because of the lack of a proper control group. The results of these studies are therefore of no value. The available data has been summarized in annex D. The studies

involving professional boxers indicated that a professional boxing career is associated with a fair chance of permanent brain injury. Lack of control groups or baseline data means no firmer conclusions can be drawn, however.

A great deal more research has been done with amateur boxers. The relevant studies indicate that memory functions in particular can be impaired shortly after a fight, but there is no strong evidence of any lasting memory impairment.

3.4.2 *Studies on soccer players*

Similar data relating to soccer players has been summarized in annex E. The neuropsychological test seems to be a sensitive method to detect brain damage in these athletes at an early stage. It is necessary, however, to include adequate controls in the study and to determine baseline values.

The available data indicates that a deterioration in cognitive performance can occur, linked to the number of times a player has been concussed. This is not a surprising finding and is consistent with the data on chronic brain injury in other sports obtained by different methods.

The research by Matser ⁽⁷³⁾ would appear to indicate a link between chronic brain injury and heading amongst professional soccer players. No such association was found where amateurs were concerned ⁽⁷¹⁾. Janda found no correlation between the frequency of heading the ball and (slight) cognitive abnormalities in junior players ⁽⁵⁸⁾.

3.5 **Other means of detecting brain injury**

3.5.1 *Serum markers*

Neuronal injury serum markers are substances normally found only in the central nervous system, but which can enter the bloodstream following a trauma. The most extensively studied biochemical marker that is relevant in relation to brain trauma is S-100B. This calcium-binding protein normally occurs only in the astroglial cells of the brain. Following a brain injury, it can pass through the blood-brain barrier; raised serum levels of S-100B can even be detected after a slight brain trauma ⁽⁵⁶⁾. However, raised levels of such serum markers are not necessarily indicative of brain trauma; athletes have also been found to have increased marker levels following a long-distance run ⁽⁸⁸⁾.

The half-life of a serum marker is typically short, certainly if no secondary injury occurs. Although no data is available directly relating to the half-life of S-100B following a slight brain injury, research involving coronary bypass patients indicates that something in the order of thirty minutes may be expected ⁽¹¹⁴⁾. In other words, this marker can probably serve as an indicator of such an injury only if a blood sample can

be taken shortly after the trauma. The blood would then have to be separated from the plasma and the latter frozen for subsequent analysis. Because of their short half-lives, serum markers are not suitable for the detection of chronic injury.

Given the complexity of the blood sampling and preparation processes, and the length of time that elapses before a result is available, biochemical markers are of little value in the assessment of an athlete in the immediate aftermath of a trauma. Indeed, also their value in a clinical setting remains unclear pending further research ^(95,114).

3.5.2 *Genetic testing*

There are strong indications that the presence of the gene for apolipoprotein E ϵ -4 is a risk factor in the development of Alzheimer's disease ^(5,12). It also seems that the consequences of acute brain trauma may be more serious for carriers of this gene ^(54,111). Athletes who carry the gene and suffer acute brain injury are more likely to develop chronic brain injury than non-carriers. It might therefore be useful to screen (prospective) participants in contact sports for the apolipoprotein E ϵ -4 gene, with a view to identifying those who might be at increased risk. However, the possible introduction of such screening raises a variety of social, legal and ethical issues ^(20,77). The Committee does not consider it appropriate to pass judgement on the desirability of such testing, wishing only to highlight the possibility.

3.6 **Conclusion: the neuropsychological test rates highest**

The Committee feels that the value of neuropsychological testing in indicating the presence of acute brain injury and in the early detection of chronic brain injury has been sufficiently demonstrated. The Committee recommends that neuropsychological tests form an integral part of the periodic check-ups compulsory for participants in sports associated with a high risk of brain injury. This will in due time lead to the availability of baseline values for all relevant athletes and to better determine whether an athlete's cognitive functions are deteriorating. This will allow to take measures early in the process, by recommending an athlete to refrain from all sporting activities that might aggravate the injury when type 1 cognitive disorders have been demonstrated.

In the Committee's view, there is currently little to be gained from the application of serum markers in the detection of acute sports-related brain injuries. However, if the sensitivity and specificity of these markers as indicators of brain injury should ever be demonstrated, and if a kit were to become available, with which plasma levels could be determined on the spot, serum markers could perhaps be used for this purpose in the future.

Head protection

Helmets are used in numerous sports, including American football, motorsport, baseball, bobsleighbing, climbing, equestrian sports, ice hockey, motorcycle sport, skateboarding and skiing. Furthermore, an increasing number of people wear a helmet when travelling on the road. The main purpose of a helmet is to mitigate the effects of external forces acting upon the head, thus reducing the likelihood of skull fractures, scalp injuries and brain injuries. In a literature survey, Vriend ⁽¹¹⁸⁾ convincingly demonstrated the effectiveness of cycle helmets in the prevention of such head injuries. Similar research has been conducted into the benefits of using crash helmets, but little data is available on the use of helmets in sport. Nevertheless, there is good reason to believe that head injuries can be prevented by wearing a helmet.

4.1 Helmet standards

Within in the European Union (and therefore in the Netherlands), helmets are covered by the Personal Protective Equipment Directive. In accordance with this directive, the protective value of a helmet must be demonstrated by objective – i.e. measurable – means. Van Mechelen and Hlobil ⁽⁸¹⁾ found considerable inconsistency between the standards used to determine the effectiveness of sports helmets. Not only did different sports apply quite different standards, but also the standards used within a given sport often varied significantly. Beusenbergh ⁽¹³⁾ compared thirty-four helmet standards, eleven of them being sports helmet standards (for cycling, motorcycle sport, equestrian

sports and skiing). All the standards required the effectiveness of a (sports) helmet to be demonstrated in terms of:

- Resistance to penetration
- Shock-absorbing capacity
- Resistance to compression
- Strength of the fastening system.

Of these factors, only shock-absorbing capacity is relevant in relation to the prevention of the types of brain injury with which this report is concerned. However, all standards are currently written with a view to the prevention only of serious forms of brain injury (i.e. injuries that involve a significant threat to life). This is related to the biomechanical knowledge available concerning the causation of brain injury and the ability to calculate the likelihood of such an injury.

4.2 Biomechanical research into the effectiveness of helmets

In recent decades, a great deal of research has been carried out on cadavers and using mathematical and physical models, with a view to improving scientific understanding of the mechanisms involved in impact-related brain injury and the protective effect of helmets (in various contexts). The studies in question have all focused on acute brain injury, rather than on chronic injury resulting from repeated impact. Most researchers agree that the risk of acute brain injury can be cut by reducing the accelerating forces to which the head is subjected. For this reason, almost all helmet standards involve measurement of the accelerating forces to which the head is subjected during a collision. However, it is only very recently that the same principle has been used in the context of research into the prevention of – acute – Minimal Traumatic Brain Injury in American football players^(86,87). For the present purposes, the most significant findings of this research were as follows:

- The combination of linear and rotational accelerating forces was studied, leading to the definition of an effective criterion (maximum Head Impact Power, or HIP_{max}) that correlates with the likelihood of MTBI. Thus, the acceleration measurements have been validated on the basis of the likelihood of sports-related injury.
- The HIP_{max} has been used for the definition of new guidelines (not yet a standard) for the design of American football helmets; a new helmet designed in accordance with the guidelines has been in use since 2001. No epidemiological data is yet available concerning the effectiveness of this new helmet.

4.3 Head protection in boxers and soccer players

In boxing and some other fighting sports it is sometimes compulsory, mainly for amateurs, to wear a head cap made of soft material. Such caps mainly prevent against superficial injuries to the head. The forces acting upon the head are absorbed only to a limited amount. Such headgear offers insufficient protection to the brains of boxers^(72,91,100).

Studies into the effectiveness of protective headgear for soccer players are receiving increasing scientific attention^(69,78,85,126). Studies performed have given mixed results, however. In general, it can be concluded that these devices protect soccer players against superficial injuries in case of heavy impacts (for instance with other players or with goal posts), but protection against brain injury is doubtful. It should be mentioned that the methods and parameters used in these studies to determine the relationship between brain injury risk and impact stress have only limited validity.

4.4 Conclusion: helmet-wearers suffer fewer brain injuries

The limited scientific data concerning the effectiveness of current head protection gear in boxing and soccer do not indicate a protective affect against infliction of brain injury. The effectiveness of helmets in the prevention of acute, serious brain injury, on the other hand, is not in doubt. In addition, it has recently been demonstrated that helmets offer protection against less serious brain injuries. Methods have accordingly been developed to enable this knowledge to be used in the design of helmets for use in sports other than American football.

Nothing is yet known about the effectiveness of helmets in the prevention of chronic injury, although it is reasonable to suppose that by reducing the risk of acute injury, one is likely to also reduce the risk of long-term effects. Further research is required to demonstrate that this is indeed the case in those sports for which helmets are already used and which involve frequent head contact, such as ice hockey and American football.

The prevention of brain injury in boxing

The head cap that amateur boxers are obliged to wear protects mainly against superficial injuries; it offers only modest protection against impact-related injuries. However, there are other ways to reduce the risks associated with boxing. These range from the use of additional protective gear, through revision of the rules of the game (e.g. outlawing blows or kicks to the head), to a complete ban. Professional boxing has been banned for several decades in Sweden, Norway, Iceland, North Korea and Cuba. Organisations representing physicians have called for boxing to be banned in other countries as well (4,8,16,123).

In this chapter, the Committee gives recommendations regarding ways of preventing brain injury in boxing. This is followed by a short discussion of the ethical dilemma that physicians face concerning their involvement in boxing.

5.1 Arguments for and against restricting or outlawing boxing

Although numerous sporting activities involve an element of health risk, various authors have argued that there are special reasons why boxing (and implicitly other fighting sports as well) is a special case that justifies taking strict measures.

Boxing is a regulated form of violence

Although people are periodically hurt and even killed in various sports, boxing differs from the majority in that the rules allow a participant to inflict serious injury on an oppo-

ment. Many authors have suggested that the intrinsic object of boxing is morally provocative or even immoral (25,25,49,89,103,107,110). Unlike sports such as rugby, American football and ice hockey, boxing is a sport that legitimises violence (89,107,110). Whereas violence is against the rules of most sports, overcoming one's opponent by means of violence is an inherent feature of boxing.

While it is true that the dangers of boxing are well known and that there have been sensible changes in the organisation of the sport, such as a move towards earlier intervention by the referee, coach or ringside doctor, and (amongst amateurs) the introduction of compulsory head protection, the *intrinsic* object of boxing remains unchanged. On the other hand, it could be argued that, particularly where younger amateur boxers are concerned, the emphasis is more on self-defence than on attack. Similar arguments can be made regarding other fighting sports.

High incidence of chronic injury in boxing compared with other relatively high-risk sports

Chronic injuries are a particularly serious problem in boxing, compared with other relatively high-risk sports. As indicated elsewhere in this report, the incidence of such injuries in other fighting sports is not clear. However, it may be expected that any sport involving blows or kicks to the head comparable in their intensity with those received by boxers is likely to involve a similar risk of chronic head injury.

Relatively high incidence of brain injury

The number of people participating in boxing is relatively small compared with many other high-risk sports (according to the Dutch Boxing Association there are approximately 1000 amateur and 25 professional boxers in the Netherlands). As a result, while the absolute number of sports-related injuries is lower in boxing than in many other activities, the relative frequency of such injuries is considerably higher (16). The risk per hour of participation is therefore considerably greater than in, for example, rugby, American football or ice hockey.

The following arguments are put forward against restriction of the sport.

Participants take a different view of their sport

While boxing and other fighting sports appear to be intrinsically violent, the participants are much less inclined to regard their sport as violent or immoral than many (sports) theorists and sports ethicists. Research by Wacquant (119) indicates that boxers associate

their sport with a sense of freedom and autonomy, with independence and with the exploration of one's personal limits and capabilities; they also associate it with 'masculine qualities', such as toughness, courage, determination and strength, as well as with 'militaristic values', such as discipline and self-sacrifice.

The numbers of injuries and fatalities in boxing is not that high

The point is often made that fatal accidents are relatively rare in boxing. In England and Wales, 'only' three boxing deaths were recorded between 1986 and 1992⁽¹²¹⁾. Fatalities in other sports during the same period were much higher: 77 deaths in motorcycle sport, 69 in airborne sports, 54 in mountaineering, 40 in ball sports and 28 in equestrian sports. However, the validity of such comparisons is questionable. First, there are considerable differences in the numbers of people participating in the various sports concerned. Second, fatal accidents in boxing and other fighting sports are the result of blows to the head deliberately inflicted by the opponent (albeit not with the intention of causing death), whereas the fatal accidents in other sports are the consequence of equipment failure or human error.

A ban on boxing would force the sport underground

Warburton⁽¹²¹⁾ considered the prohibition of boxing undesirable on the grounds that it would drive the sport underground; people would box illegally, without any proper medical supervision. However, this argument is not supported by the practical experience of countries such as Sweden, Iceland and Norway, where boxing has been banned for several decades⁽¹⁶⁾.

5.2 Moral principles: autonomy and nonmaleficence

A reasoned stance with regard to the possible restriction or prohibition of boxing and other fighting sports needs to take account of the moral principles of 'respect for individual autonomy' and 'nonmaleficence'^(49,65,121).

The question is: are people always entitled to autonomously decide how they organise their lives and which activities they will take part in? In the civilised world, complete autonomy is never granted; one is not free to act entirely as one pleases, insofar as one is not free to harm others. However, the rules of boxing and other fighting sports are such that a participant *is* permitted to inflict injury on an opponent. This is not contrary to the principle of nonmaleficence, as long as both parties are aware of the risks that the activity entails and accept the permissibility of inflicting injury. Under such circumstances, there is no reason for the government to restrict an activity, unless it involves the inflict-

tion of fatal injury, the curtailment of freedom or the serious infringement of another person's physical integrity.

An important point of consideration thus is the extent and seriousness of the injuries inflicted. If these exceed certain limits, it might be justifiable for the government to intervene in order to protect people from themselves. Various precedents exist for safety-related governmental actions that limit the individual freedom of citizens. Motor cyclists and moped riders are obliged to wear helmets, for example, and car drivers have to use seatbelts. However, these measures serve to protect very large groups of people and are therefore very important for public health; furthermore, the measures compromise the freedom of the individual to a modest extent only. More comparable to a restriction on boxing and fighting sports is the very longstanding prohibition on duelling. Respect for individual autonomy does not extend to the government permitting citizens to settle disputes by fighting to the death, even with their mutual consent.

In light of the considerations set out above, the question that the government must address is as follows: are the degree and seriousness of the injuries inflicted in boxing and other fighting sports sufficient to justify the legislature acting to limit the autonomy of those who wish to participate in such sports, by restricting or possibly prohibiting such participation? The answer of the Committee to this question is positive.

5.3 Preventive measures presently taken in the Netherlands

Whether government intervention is justified depends partly on the sport's own willingness and ability to minimise the risk of physical injury.

The Dutch Boxing Association (NBB) requires all amateur and professional boxers to undergo annual physical examination. The examination that amateur boxers go through is less demanding than that which the professionals undergo. In addition to the tests given to amateurs, the professionals are given an HIV test, a retina examination and a CT or MRI brain scan. However, the examination does not involve electrophysiological or neuropsychological testing. The professionals' examination used to include a neuropsychological test, but this was dropped because its application proved problematic. None of the subjects passed the test, with the result that Dutch boxers simply circumvented the rules by taking out foreign licences that allowed them to box in the Netherlands. The whole situation had disagreeable implications for various parties involved, leading to a decision to abandon neuropsychological testing.

About a decade ago, the maximum length of an amateur bout was reduced from five rounds to four, and the use of protective gear, including a head cap, was made compulsory. Furthermore, modern boxing gloves are not as heavy as those used in the past. As a result, brain injuries are less common than a generation ago (see also the AIBA data pre-

sented in subsection 2.2.1), but the sport has also become less attractive to the public, with spectator numbers declining.

The requirements concerning the use of protective gear do not apply in relation to sparring. It is not known to what extent such gear is nevertheless used for this purpose.

The rules designed to protect professional boxers are much less strict and also less clear. Matters are complicated by the fact that not all professional boxing in the Netherlands takes place under the auspices of the NBB; contests are also organised under the umbrella of the Netherlands Professional Boxing Foundation (SBBN). The professional section of the NBB has no Medical Committee and no arrangements for coordination with regard to medical matters.

The NBB maintains a register of competitive boxers and any orders excluding them from competition. The doctors who examine boxers are appointed by the NBB. Various items of equipment have to be kept at the ringside during every contest; these are a first-aid kit, a stretcher and oxygen apparatus. Furthermore, the ringside doctor has the authority to stop a contest. There are no guidelines concerning special training for ringside doctors, referees or coaches, except that coaches are required to possess a first-aid qualification.

5.4 Conclusions and recommendations

The Committee takes a positive view of the measures put in place by the NBB to prevent injury, but does not consider them sufficient. In particular, the high risk of chronic brain injury resulting from an intensive career in boxing (or any other fighting sport involving risk of brain injury) is felt to warrant further action. Hence, the Committee makes the following recommendations, drawing partly on the proposals made by Sports Medicine Australia, the umbrella organisation for sports medicine in Australia ⁽¹⁰⁶⁾:

5.4.1 *Revision of the rules*

With a view to reducing the risks associated with participation, the rules of boxing and other fighting sports that allow blows or kicks to the head should be changed in the Netherlands – and ultimately in an international context.

Informed consent

All people participating in boxing and other fighting sports with a risk for brain injury should be fully informed about the associated health risks, in particular the risk of chronic brain injury. Participation in contests should only be allowed when the risks are known and accepted (informed consent).

Restriction on participation by juniors

The Committee would like to see that competitive participation in boxing and other fighting sports with a risk for brain injury should not be permitted for young people under the age of sixteen. This is in line with the recommendation that junior soccer players should not be given training in heading of the ball.

Competitive suspension for boxers with symptoms of acute brain injury

If a boxer loses a contest following a KOH (knockout – head) or an RSC-H (referee stopping contest – head), he or she should undergo neuropsychological testing and neurological examination as a matter of course. The boxer should be suspended from competition until the symptoms of acute brain injury abate.

More thorough periodic examinations

The annual examination that boxers are required to undergo should be made more rigorous; all boxers – including non-competitive boxers – and all fighting sport participants should be obliged to undergo an examination, which should include neuropsychological testing as a matter of course. In the event of type 1 cognitive abnormalities being detected, the subject should be strongly advised to refrain from all sporting activities that involve a risk of brain injury. Where possible (where there is a supervisory medical committee), the person in question should be barred from participation in boxing and fighting sports for life.

Better training

Ringside physicians, referees and coaches should receive regular refresher training, with particular emphasis on the prevention of brain injury and its aggravation, and on ways of detecting brain injury.

In addition, the Committee wishes to see adoption in the Netherlands of the comprehensive requirements made by the AIBA concerning the training of ringside physicians (82).

5.4.2 *Prohibition*

If it should not be possible to implement the measures outlined above within a reasonable space of time, or if it should be concluded that the recommended rule and procedure changes are unlikely to have any significant effect on the occurrence of brain injury, the

Committee strongly recommends the prohibition of at least professional boxing in the Netherlands. Its reasoning is that professional boxing entails a great deal more risk than amateur boxing because no head protection is used and the contests are longer; in addition, professional boxers generally spar more often and for longer. As a result, a professional boxer is at great risk of chronic brain injury. Furthermore, the sometimes-considerable financial incentives to win can induce a boxer to accept higher risks. These problems are exacerbated by the fact that the Dutch Boxing Association makes little or no provision for the medical supervision of professional boxers. As indicated above, the Committee believes that curtailment by the legislature of the individual's freedom to participate in injurious activities (even if such participation is on the basis of mutual consent) is justifiable where the injuries inflicted are potentially serious. The chronic health impairment that professional boxers risk is in the Committee's view sufficiently serious to warrant the curtailment of individual freedom.

Consideration should also be given to outlawing (amateur and professional) participation in other fighting sports whose rules permit the infliction of brain injury. Because scientific data concerning the risks associated with such sports is lacking, it will be necessary for the risks to be estimated by experts. One option would be to make prohibition temporary, pending the development of suitable measures to minimise the risk of injury.

In various countries where professional boxing has been banned for some time, the experience has been that prohibition does not give rise to practical problems. In Norway, for example, participation in professional boxing contests, demonstrations or training camps has been against the law since 1981, as has the organisation of, or cooperation with such activities. In 2001, the Norwegian law was extended to cover all fighting sports in which knockouts are permitted (see annex F).

5.5 Involvement of physicians with fighting sports

A physician is bound by the Hippocratic oath to adhere to the principle of 'beneficence' (doing and promoting good) ⁽¹²²⁾. For a physician, therefore, cooperating with or facilitating boxing or another fighting sport is problematical. Given the potentially injurious nature of such sports, it is reasonable to expect that a physician, in adherence to the principle of beneficence, would oppose participation because of the hazards involved. Thus, in relation to fighting sports, a physician has a choice between two courses of action: to distance him/herself from them entirely, or to work towards their prohibition or reform.

Several medical organizations, such as the American Medical Association, the Australian Medical Association, the British Medical Association (BMA) and the World Medical Association have for some years been calling for boxing to be banned ^(4,8,16,123). The BMA argues that rule changes, such as the introduction of shorter rounds and the use of head and mouth protection do not change the fact that the ultimate aim of

boxing is to knock out one's opponent. Changing the rules to outlaw blows to the head would not resolve the issue. Not only would this completely change the nature of sport, but the problem would simply be shifted to other areas and organs of the body. According to the BMA, requiring informed consent would not be a solution either, because the decision as to whether to box would still rest with the individual would-be participant – however well informed by a physician. Consequently, the BMA believes that there is only one position a physician may adopt that is consistent with the principles of the profession, namely to distance him/herself entirely from boxing ⁽¹⁶⁾.

The Netherlands Association for Sports Medicine (ASM) has stated in its 1995 guidelines ⁽¹¹⁷⁾: “The physician is aware that those sporting activities where the deliberate (temporary) knocking out of vital bodily functions of the opponent contributes directly to the result of the sport, are at odds with important medical and ethical principles, specifically when these activities are allowed under the rules of the sport.” The ASM recommends that physicians speak up wherever and whenever possible in favour of limiting boxing-inflicted injury. According to the ASM this means that physicians should endeavour to establish preventive measures and by no means promote these types of sport. In 1996 the General Assembly of the Royal Dutch Medical Association determined that *all* physicians in the Netherlands have to observe the guidelines of the ASM.

Given the physician's commitment to the principle of beneficence, one may reasonably ask whether it is right to act as a ringside physician at a boxing contest or other such event. The dilemma for a physician is often the fear that, if cooperation is withheld, participants will fight without adequate medical supervision. However, the rules of the NBB prohibit a contest from taking place without a ringside physician being present.

The prevention of brain injury in soccer

Green & Jordan⁽⁴¹⁾ set out a series of proposals aimed at preventing acute and chronic brain injury in soccer players and at preventing the aggravation of existing brain injuries. More recently, the Royal Netherlands Football Association has published guidelines for all medical staff and coaches in *Topzorg*, the newsletter of the Association's Sports Medicine Centre. Below, these guidelines are compared with Green & Jordan's proposals.

On-site provision should be made for the medical treatment of acute brain injury

Such provision is made for all professional matches in the Netherlands. The medical personnel in attendance are all given instructions by the Dutch FA on how to respond in the event of a (suspected) brain injury. The Committee believes that compliance with these instructions should be mandatory.

Amateur matches are too numerous to make the universal attendance of trained medical personnel practical. Nevertheless, the Committee suggests that all referees and coaches should be instructed, at least at the beginning of each season, in the use of simple methods (such as the on-field test described in section 3.2) for the assessment of players involved in incidents that might give rise to brain injury. Wherever doubt exists regarding a player's fitness to continue following such an incident, he or she should be withdrawn from the match and referred for medical examination.

A player who suffers concussion should always undergo thorough medical examination, including neuropsychological testing

The Dutch FA does not recommend this. The Committee feels that such a response is unnecessary in cases of grade 1 concussion. However, as indicated earlier in this report, the Committee does believe that professional players should undergo an immediate on-field test, plus a more thorough subsequent neuropsychological test. Further recommendations for follow-up are given in chapter 3.

Return to play following brain injury should be regulated

The McGill University guidelines that the Dutch FA currently applies include advice on return-to-play. However, as indicated in chapter 3, the Committee recommends the adoption in the Netherlands of the guidelines produced by the American Academy of Neurology, supplemented by the proposals of the International Conference on Concussion in Sport. These guidelines also include rules on the return-to-play.

The rules of the game should be strictly enforced

Enforcement of the rules is regarded as a priority by the Dutch FA. Given that deliberate contact with an opponent (involving use of the elbow, for example) is one of the main causes of brain injury ⁽⁷³⁾, strict enforcement of the rules of the game, combined with harsher sanctions against players whose misbehavior endanger others, can in the Committee's view have a preventive effect. The Committee would draw attention to the fact that in the event of a serious breach of the rules resulting in brain injury, the offender is not only liable to incur the disciplinary sanctions provided for in the context of the sport, but may also face a civil claim for damages from the victim.

The Committee is aware that the FIFA is seeking to outlaw use of the elbow when jumping to head the ball. The Committee's view is that use of an elbow should be outlawed in all phases of play as a matter of urgency.

The Committee also recommends that the rules on the substitution of players should be revised. A team should be permitted to temporarily substitute an injured player to allow for more thorough examination off the pitch. This would enable a team to give an injured player proper attention without fear of weakening its position in the game; as things stand, when a player is taken off the pitch for treatment, there is always pressure for him or her to resume play as soon as possible so that the team is once more at full strength, giving rise to a danger that the examination will not be as thorough as it might be.

Appropriate heading techniques should be taught

Research has shown that professional soccer players suffer heading-related brain injuries less often than amateurs. That this should be the case in spite of the greater intensity of the play may reflect the greater technical expertise of the professionals. On the basis of biomechanical research, Lees and Nolan ⁽⁶⁷⁾ concluded that the effect of heading on the brain increases as the ratio between the mass of the player's head and the mass of the ball decreases. This implies that increasing the mass of the head by tightening the neck muscles can reduce the risk of brain injury. The Committee therefore believes that players should be instructed in appropriate heading techniques. Lees and Nolan also point out that the head-ball mass ratio is lower in children than it is in adults, which may be expected to increase the risk of brain injury. The Committee therefore supports the Dutch FA's view that junior players should not be trained to head the ball; the Association recommends that such coaching should not begin until from the age of sixteen.

The limited data on possible chronic brain injury resulting from frequent heading as discussed in 3.4.2 is not equivocal. The Committee therefore sees no reason to limit heading in other respects or to recommend the use of head protection gear.

Padding goalposts

The Dutch FA makes no reference to padding goalposts. Drawing on data published by Boden and Frenguelli ^(14,35), Green and Jordan ⁽⁴¹⁾ report that relatively few brain injuries result from collisions with a goalpost. However, they point out that research by Janda ⁽⁵⁷⁾ demonstrated that injuries could be eliminated altogether by the use of padded goalposts, without affecting the nature of the game. The introduction of padding for the frame of the goal would therefore appear to be effective in the prevention of injury, but is unlikely to significantly reduce the incidence of brain injury. In consequence, the Committee believes that goalpost padding would not be of great value.

Use of mouthguards

The Dutch FA has no published view on this topic either. A literature survey carried out by Vriend ⁽¹¹⁸⁾ revealed that in many contact sports wearing a properly-fitting mouthguard not only protected the player's teeth, but also reduced the risk of brain injury. No data is available on the use of mouthguards in soccer, but Delaney and Drummond ⁽²⁷⁾ suggest that soccer players would benefit from the use of such devices. The Committee does not presently believe that there is sufficient evidence to justify recommending the use of mouthguards in soccer. Research into their effectiveness is required before such a recommendation can be made.

More research should be carried out

The Committee fully supports this proposal. However, a number of comments are made with regard to the various types of research suggested by Green and Jordan:

- Research into the incidence of head injury and neurological injury in soccer players: a prerequisite for such research is a proper definition of brain injury.
- Large-scale epidemiological research into the incidence of concussion in soccer players: concussion should be covered by the definition of head injury used for the research mentioned at the previous bullet; in addition, research should not be confined to soccer, but should include other contact sports.
- Detailed research into the biomechanics of heading: little more is known about this subject than what is reported by Lees and Nolan ⁽⁶⁷⁾; there is an urgent need to add to this knowledge to facilitate the possible development of protective gear.

The development of chronic brain injury should be countered

The recommendation made in the previous chapter, namely that a person who develops a type 1 cognitive disorder (impairment of long-term and short-term memory) should refrain from participation in any sporting activity that might aggravate his/her condition, applies equally in the context of soccer. This is the only way to counter the further development of chronic brain injury.

Concluding remarks

In the interests of boxers, soccer players and other athletes, the Committee would like to see the creation of a knowledge centre to register sports-related injuries and coordinate research into the effectiveness of preventive measures.

The centre could also organise seminars and training courses for sports physicians, coaches and youth leaders. In this way, people in the sporting world could be provided with greater insight into brain injuries and taught what to do in the event of an incident that might involve such an injury. The seminars might vary from introductory outlines for amateur coaches to detailed explorations of the relevant issues for professionals such as sports physicians.

The centre could also play a part in possible (mass-media) public information campaigns.

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Annexes

Ministerial commission

On 16 July 1998, the then State Secretary for Health, Welfare and Sport wrote as follows to the President of the Health Council, asking for the preparation of a report:

Brain injuries are generally serious by comparison with injuries to other parts of the body. This remains the case where injuries received in the context of sporting activities are concerned, as illustrated by data from the Injury Information System operated by Consumer and Safety. In view of this fact, both the government and the governing bodies of the relevant sports favour measures designed to reduce risk, such as rule changes and the use of protective materials and equipment.

Certain sports are of particular significance in relation to brain injury. Principal among them are pugilistic sports, such as boxing, and sports that involve frequent use of the head, as in soccer, where the ball is often played with the head. Brain injuries can also occur in high-altitude mountaineering, where lack of oxygen may be a factor, and among regular divers, where barotrauma may play a part. In the latter sports, damage to the brain usually occurs gradually.

In 1987, a report entitled *Veiligheid Boksen (Safety in Boxing)* was published, exploring a number of issues, including the ethical acceptability of the sport. In response to this report, the Medical Committee of the Dutch Boxing Association (NBB) sought to establish a system of (medical) supervision, in the context of which boxers were to be screened using the neurological testing methods available at the time, with a view to detecting early signs that they are at risk of permanent (chronic) brain injury.

The pilot project revealed, however, that the neurological test methods of the day were not sufficiently sensitive for the intended purpose. Attention therefore shifted to neuropsychological testing techniques, which it was believed could be used both to assess a boxer's recovery from an acute injury and to detect degenerative chronic injury in good time.

In 1994, the NBB accordingly introduced neuropsychological testing as part of the periodic examination that boxers are obliged to undergo. The tests were withdrawn again the following year, however, because their effect was to exclude from competition a very high percentage of professional boxers. The high failure rate was felt to bring the validity of the tests into question. Furthermore, such testing was not internationally supported, as a result of which Dutch boxers who failed the tests were able to continue fighting in this country by taking out licences abroad.

In 1997, questions were raised in parliament regarding brain injury in general and in particular regarding the use of neurological testing in the prevention of (degenerative) injury (see appendix).

In view of the potentially serious consequences of brain damage, it is very important to know what scope there is for brain injury prevention and how effective the various preventive measures now possible are likely to be. It would also be helpful to supplement the acute brain injury data already available from the Injury Information System with information regarding chronic brain injury. I would therefore be grateful if you could address the questions set out below and provide me with an advisory report by the end of 1999:

- 1 How common are acute brain injury and chronic brain injury in sport, and in which sports are such injuries most common?
- 2 What gradations or phases of seriousness may be distinguished in relation to acute and chronic brain injuries respectively?
- 3 Are there particular categories, gradations or phases of injury, in the event of which victims should be temporarily or permanently advised against (or excluded from) further participation?
- 4 What is presently known about the prevention of (the relevant categories of) such injuries?
- 5 How effective would the neurological and neuropsychological test methods now available be in the early detection and prevention of such injuries, particularly in the sport of boxing? If you do not anticipate that such test methods would be very effective in their present form, how readily do you believe any of the methods could be adapted for use in the way described?

Thank you in anticipation for your help.

The State Secretary for Health, Welfare and Sport,
[signed]
Erica Terpstra

The Committee

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- Professor J Troost, *Chairman*
Neurologist, Maastricht University Hospital
 - Dr EJ Matser
Neuropsychologist, St Anna Hospital, Geldrop
 - AGH Kessels
Epidemiologist, Maastricht University Hospital
 - Dr CR van den Hoogenband
Surgeon, St Anna Hospital, Geldrop; Club Physician, PSV Eindhoven
 - Professor D Swaab
Director, Netherlands Institute for Brain Research, Amsterdam
 - Dr PAM Hofman
Neuroradiologist, Maastricht University Hospital
 - Dr J Steenbergen
Researcher/advisor, Amsterdam
 - Dr J van Hoof
Physicist, TNO Road Transport, Delft
 - M Beusenberg, *Advisor*
Physicist, TNO Road Transport, Delft
 - JPM Hogenbirk, *Advisor*
Ministry of Health, Welfare and Sport, The Hague
 - Dr E van Rongen, *Secretary*
Health Council of the Netherlands, The Hague
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Incidence of brain injury in other sports

Taekwondo

Pieter⁽⁹⁰⁾ monitored a total of 1665 men and 742 women participating in a number of Taekwondo tournaments in the United States. Among the men there were 7.04 cases of concussion per thousand contests, and among the women 2.42 cases per thousand contests.

Feehan⁽³⁴⁾ interviewed 48 people taking part in a Taekwondo tournament in New Zealand regarding Taekwondo-related injuries suffered in the twelve months prior to the tournament. Brain injury accounted for 5 per cent of all reported injuries. However, it is likely that the reported incidence of concussion was influenced by recall bias.

Hockey

The only research that has provided data on the incidence of brain injury in hockey was the study by Powell⁽⁹³⁾ in the USA. Among female high school students, the incidence of MTBI was 0.29 cases per thousand matches. However, as indicated earlier, the definition of MTBI used means that this figure may be an overestimate.

American Football

For American football, Powell⁽⁹³⁾ reports an incidence of 2.82 cases of MTBI per thousand matches (boys only, of course).

In another study of high school American football players, Langburt⁽⁶⁴⁾ found that 110 of the 233 players (47.2 per cent) claimed to have been concussed at least once during the season. Some 87.8 per cent of the incidents involved grade 1 concussion, 9.9 per cent grade 2 and 2.4 per cent grade 3.

On the basis of reports submitted by 242 high school and college coaches, relating to a total of 17,459 players, Guskiewicz⁽⁴⁴⁾ calculated that 5.1 per cent had been concussed at least once during the season.

Delaney⁽²⁸⁾ interviewed 289 players in Canada's American football competition. Of these players, 44.8 per cent had been concussed at least once during the 1997 season.

Australian Rules football

Shawdon⁽¹⁰²⁾ monitored 80 players belonging to a particular association over the course of a season. The incidence of concussion was 14.4 cases per thousand player hours.

Dicker⁽²⁹⁾ calculated that, in Australian Rules football, concussion accounted for 5 per cent of all injuries. Seward⁽¹⁰¹⁾ arrived at a broadly similar figure, i.e. 4 per cent. The findings of a study by McMahon⁽⁸⁰⁾ add further weight to these figures: concussion was found to account for 5 per cent of all injuries in ten-to-fifteen-year-olds and 1 per cent of injuries to younger players, equating to, respectively, 0.2 and 0.01 cases of concussion per thousand player hours. The research also revealed that 16 per cent of the 1253 players monitored suffered some form of injury.

Ice hockey

Goodman⁽⁴⁰⁾ found that among players competing in the British Columbia Junior Hockey League during the 1998-1999 and 1999-2000 seasons, there were 4.63 to 5.95 cases of concussion per thousand player hours.

On the basis of a literature survey, Honey⁽⁵³⁾ concluded there were between 0.0 and 6.6 concussion incidents per thousand player hours. Furthermore, the incidence of concussion increased at higher levels of competition.

Tegner⁽¹¹²⁾ monitored 227 top ice hockey players in Sweden over a period of four seasons. Each team suffered at least one case of concussion per year. The average incidence was 6.5 concussion incidents per thousand hours of play.

Rugby

Although there are dozens of studies on rugby-related injuries, only one reports the percentage accounted for by concussion. In the 1992 season in Australia, Seward⁽¹⁰¹⁾

monitored injuries at 26 Australian Rules football and rugby clubs. In the two rugby competitions, concussion accounted for 5 and 8 per cent of all injuries.

Generally speaking, head and neck injuries are relatively common in rugby. Adams⁽²⁾ reported that such injuries accounted for 14 per cent of a thousand injury incidents investigated. Regarding amateur rugby players, Gabbet⁽³⁶⁾ arrived at a figure of 25 per cent. Gissane⁽³⁹⁾ investigated whether, among professional players, the player's positional role in the team was significant. Among forwards, head and neck injuries were more common than among backs, the respective figures being 53.9 cases and 25.0 cases per thousand player hours. Roux⁽⁹⁸⁾ reported a study in which the rugby teams of 26 South African high schools were monitored over the course of a season, revealing that 29 per cent of all injuries were head and neck injuries.

Cycling

Cyclists often have accidents, but almost no data on the incidence of brain injury has been reported in the academic press. Most publications that give brain injury percentages are based on hospital admissions and relate to accidents arising from everyday cycle use, rather than sports accidents. No data is available on the incidence of brain injuries among professional racing cyclists.

In Ontario, Canada, Hu⁽⁵⁵⁾ found that among bicycle-using children of between five and fourteen years old, 8.1 boys and 3.4 girls per thousand per year reported having a cycling accident. Roughly half of these incidents involved head injuries.

In a study of cycling accidents in Sweden involving serious injury or death, Bostrom⁽¹⁵⁾ established that each year 57 people per hundred thousand were hospitalised in connection with a cycling accident. Some 46 per cent of the accidents involved head or brain injuries.

A great deal of research has been carried out into the protective effect of cycle helmets^(6,118). From this research, it is clear that the seriousness of head injuries is reduced considerably by wearing a helmet.

In the Netherlands, the use of a crash helmet is obligatory in all competition. The International Cycling Union (UCI) has recently decided to make helmets compulsory for all races⁽¹⁾. The Committee strongly supports this move.

Equestrian sports

Horse-riding accidents occur frequently. Gimsing⁽³⁸⁾ estimated that between 1989 and 1999, there were between 850 and 890 such accidents a year in Denmark.

In a study in British Columbia, Canada, Sorli ⁽¹⁰⁴⁾ found that, between 1991 and 1996, the incidence of horse-riding accidents was 0.49 per thousand hours' riding. Some 60 per cent of the accidents (0.3 per thousand hours) involved head injury.

Christey ⁽²¹⁾ interviewed 557 horse-riders below the age of twenty-five. The incidence of accidents was 0.6 per thousand hours' riding. Head injuries occurred in 27.5 per cent of the accidents, equating to an incidence of 0.17 per thousand hours' riding.

In a prospective study, Gierup ⁽³⁷⁾ established an incidence of 0.7 accidents per thousand riding events, with 11 per cent (0.08 per thousand riding events) entailing brain injury.

Waller ⁽¹²⁰⁾ studied professional jockeys and found that, between 1993 and 1996, the incidence of accidents was 606 per thousand jockey-years. Head injuries occurred in 18.8 per cent of the accidents (114 per 1000 jockey-years).

Dekker recorded data on a group of 88 patients admitted to Groningen University Hospital with horse-riding injuries between 1990 and 1998. Of these patients, five (8 per cent) exhibited intracranial injuries ⁽²⁶⁾. It is not possible to calculate incidence figures from this data.

Neuropsychological testing of boxers

Various researchers have studied the neuropsychological testing of amateur and professional boxers. Some of the results are invalidated, however, by flaws in the study design, such as the failure to include a proper control group. The available data is summarised in the table below.

Authors	Number of boxers and control subjects	Methodology	Findings	Comments	Does study say anything about brain injury in boxers?
<i>Acute brain injury</i>					
Butler 1993 (18)	68 amateurs; controls: 31 water polo players and 47 rugby players	NP tests immediately before and immediately after contest and up to 2 years later	No difference between boxers and control subjects	Head injuries also common amongst control subjects. Control subjects selected from inappropriate sports.	No
Heilbronner 1991 (50)	23 amateur boxers	NP tests immediately before and after tournament	Performance in memory tests worse after contests; motor abilities improved	Consistent with research by Matser (72)	Yes: short-term injury
Matser 2000 (72)	38 amateur boxers; control group: 28 amateur boxers	NP tests before and after fights; control subjects tested before and after exertion	Performance in memory tests worse after contests		Yes: short-term injury
<i>Chronic brain injury</i>					
Johnson 1969 (59)	15 ex-boxers	NP tests	Abnormal results recorded in at least one test by 11 of the 15	No control group; no criteria for abnormality	No

Roberts 1969 ⁽⁹⁷⁾	224 ex-professional boxers	Neurology, NP tests	Approx. 50% showed signs of brain injury	No controls or baseline values	No
Thomassen 1979 ⁽¹¹³⁾	53 ex-boxers; control group: 53 ex-soccer players	Neurology, EEG, NP tests	No difference with controls	Soccer players probably not a good control group	No
Kaste 1982 ⁽⁶²⁾	14 ex-boxing champions: 6 professionals, 8 amateurs	Neurology, CT, EEG, NP tests	CT: abnormalities in 4/6 professionals and 1/8 amateurs; abnormal NP test results in 2 professionals	No control group; no criteria for abnormality	No
Casson 1984 ⁽¹⁹⁾	18 active and retired professional boxers	NP tests	In 14 boxers (78%) clear signs of brain injury; 100% registered abnormal scores in at least one NP test		Yes: long-term injury
Drew 1986 ⁽³¹⁾	19 professional boxers 10 control subjects (basketball and baseball players)	NP tests	Boxers scored significantly worse than control subjects	Strong correlation with number of professional bouts, even though average age is just 23.4 years	Yes: medium-term injury
Brooks 1987 ⁽¹⁷⁾	29 amateur boxers 19 matched control subjects	NP tests	No difference	No complex memory tasks included, therefore conclusions regarding brain injury not possible	No
Levin 1987 ⁽⁶⁸⁾	13 amateur boxers 13 control subjects Retesting of 10 boxers and 10 control subjects after six months	NP tests	No difference; equal improvement in performance in both groups after six months	Intensity of boxing not reported; nature of control group not stated	No
McLatchie 1987 ⁽⁷⁹⁾	15 active amateur boxers	Abnormal NP test results recorded by 9 of the 15 (60%)	NP the most sensitive method for detecting brain injury	No controls	Yes: long-term injury
Murelius 1991 ⁽⁸⁴⁾	50 ex-amateur boxers; control group: 25 soccer players, 25 athletes	Standard NP tests	Significant difference between boxers and control subjects in one test only	Soccer players probably not a good control group	Yes: long-term injury
Haglund 1993 ⁽⁴⁷⁾	50 ex-amateur boxers; controls: soccer players and athletes	NP tests	Slight difference between boxers and control subjects	Soccer players probably not a good control group	Yes: long-term injury
Stewart 1994 ⁽¹⁰⁸⁾	484 boxers at the start of their careers; 393 two years later	Baseline NP and two years later	No relation with number of fights / sparring sessions	Follow-up perhaps too soon – trend for correlation between performance and number of fights before baseline test	Yes: medium-term injury
Porter 1996 ⁽⁹²⁾	20 experienced amateur boxers; 20 matched control subjects	Prospective NP study, 15-18 months	No difference between boxers and control subjects		Yes: medium-term injury

Neuropsychological testing of soccer players

Authors	Number of soccer players and control subjects	Methodology	Findings	Comments	Does study say anything about brain injury in footballers?
<i>Acute brain injury</i>					
Putukian 2000 ⁽⁹⁴⁾	44 male, 56 female college soccer players	Battery of NP tests before and after training with heading	No acute effects associated with heading		Yes: short-term injury
Echemendia 2001 ⁽³²⁾	29 college athletes (including 3 soccer players) with concussion 20 control athletes	Battery of NP tests; baseline and 2 hrs, 48 hrs, 1 wk and 1 month after concussion	Lower overall score in victims after 2 hrs and 48 hrs; after 1 wk, differences in one or two test scores, after 1 month in one test score		Yes: short-term injury
<i>Chronic brain injury</i>					
Murelius 1991 ⁽⁸⁴⁾	50 ex-amateur boxers Control group: 25 soccer players, 25 athletes	Standard NP tests	No difference between soccer players and athletes		Yes: long-term injury
Tysvaer 1991 ⁽¹¹⁵⁾	37 ex-professional soccer players	Extensive battery of NP tests	Abnormalities in 81%	No matched control subjects; nature of game has changed since subjects were playing (lighter balls that don't soak up water)	Yes: long-term injury

Matser 1998 (73)	53 active professional soccer players; control group: 27 participants in non-contact sports	Battery of NP tests	Memory and planning abilities impaired in soccer players; relationship with number of concussions and frequency of heading	Yes: long-term injury
Matser 1999 (71)	33 amateur soccer players; control group: 27 amateur swimmers and athletes	Battery of NP tests	Memory and planning abilities impaired in soccer players; relationship with number of concussions	Yes: long-term injury
Janda 2002 (58)	57 soccer players, average age 11.5 yrs	4 NP tests; before and after season; with 1 team (10 players), also after 2nd season	No difference in average scores before and after season; after 2nd season, deterioration in word-learning test score; no relationship with frequency of heading; 49% complained of headache	No control group; small number of players tested in 2nd season Yes: medium-term injury
Downs 2002 (30)	26 amateur soccer players and 6 professionals; control group: 29 swimmers	Battery of NP tests	Soccer players scored worse in conceptual thinking test; older players also scored worse in reaction tests and concentration tests; association with estimated brain trauma	Yes: long-term injury
Guskiewicz 2002 ⁽⁴³⁾	91 college soccer players, 53 control subjects	6 NP tests	No difference, despite an average of 15.3 years of soccer play; no association between number of concussions and NP test performance	Yes: long-term injury

Norwegian legislation prohibiting boxing

STATUTE 1981-06-12 no. 68: Professional Boxing Prohibition Act.

Cf. statute no. 73 of 15 June 2001.

Section 1. Any person who in this country knowingly participates in a professional boxing contest, demonstration or training camp, shall be punished by a fine or by imprisonment for up to three months.

Section 2. Punishment in the form of a fine or imprisonment for up to three months shall be given to any person who knowingly:

- organises or provides financial support or physical accommodation for a boxing event, as referred to in section 1
- acts in the capacity of a manager, closes a contract or abets the closure of a contract for a boxing event, as referred to in section 1
- acts as a referee or helper at a boxing event, as referred to in section 1.

Section 3. This act shall come into force at a time specified by the King.

STATUTE 2001-06-15 no. 73: Act regulating organised fighting sports whose rules permit knockouts.

Cf. statute no. 68 of 12 June 1981.

Section 1. No contest in, demonstration of or training camp for a fighting sport whose rules permit knockouts shall take place without royal consent. In this

context, a knockout is deemed to be competitive elimination brought about by blows to the head.

The availability of royal consent shall depend in part upon the adequacy of the steps taken within the sport to protect the health and safety of participants.

The king may make his consent for a fighting sporting event conditional upon the satisfaction of detailed safety requirements.

Section 2. Punishment in the form of a fine or imprisonment for up to three months shall be given to any person who knowingly and without consent:

- organises, participates in, or provides financial support or physical accommodation for a fighting sporting event, as referred to in section 1, clause 1
- closes a contract or abets the closure of a contract for a fighting sporting event, as referred to in section 1, clause 1
- acts as a referee or helper at a fighting sporting event, as referred to in section 1, clause 1.

Section 3. This act shall be effective throughout this country, including Spitsbergen.

Section 4. This act shall come into force at a time specified by the King.