Comparison of incidence of selected injuries in amateur boxing with and without formerly mandatory head gear.

A systematic review and meta-analysis.

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Abstract

Title Comparison and incidence of selected injuries in amateur boxing with and without formerly mandatory headgear

Objective The correlation between head gear and injury incidence and severity is not known to a satisfactory degree, making it impossible to decide whether head gear decreases the risk of injury or not.

Design A systematic review and meta-analysis. Stoppages due to blows of the head and knockouts in bouts with and without headgear were examined and compared. Incidence of facial lacerations and hand injuries in bouts with headgear were also compared to other bouts without headgear.

Methods Ten studies provided data from a total of 17 135,6 bouts from 1955 to 2015. The reported injuries were analysed and compared.

Main Outcome Measures Injuries per 1000 hours of boxing with and without headgear

Result The number of head injuries has essentially been halved without headgear. Total lacerations reported with headgear was 111, and 1716 without headgear, making an increase of 1,445.95 %. Total head injuries reported with headgear was 169 and 73 without headgear. Number of head injuries has decreased by 56,28% per 1000 hours of boxing without headgear. Injuries per 1000 hours of boxing with headgear is 476,8, compared to 800,7 injuries per 1000 hours of boxing without headgear.

Conclusion The amount of head injuries is significantly reduced without headgear, but the incidence of cuts has increased considerably. The total number of injuries has increased without headgear.

Sammendrag

Tittel Sammenligning av forekomst av utvalgte skader i amatørboksing med og uten tidligere påbudt hodebeskyttelse

Problemstilling Reduserer hjelm risikoen for hode- og kuttskader i amatørboksing?

Metode Systematisk gjennomgang og meta-analyse. Kampstopp grunnet slag til hodet og knockouts i kamper med og uten hjelm ble sammenlignet. Kutt- og håndskader i boksekamper med hjelm ble og sammenlignet med kamper uten hjelm.

Resultat Antall hodeskader har omtrent blitt halvert uten hjelm. Totalt antall rapporterte kuttskader med hjelm var 111, og 1716 uten hjelm. Dette utgjør en økning på 1,445.95%. Totalt antall hodeskader med hjelm var 169, og 73 uten. Antall hodeskader har sunket med 56,28% per 1000 timer boksing uten hjelm. Skader per 1000 timer i boksing med hjelm er 213,44, sammenlignet med 239,96 skader per 1000 timer boksing uten hjelm.

Konklusjon Antall hodeskader er tydelig redusert uten bruk av hjelm, men antall kuttskader har økt betraktelig. Det totale antall skader har økt etter avskaffelsen av hjelm.

Introduction

Boxing as a competitive sport has been dated back to the 3rd and 2nd millennia BC, and became an Olympic sport as early as 688 BC (Poliakoff, et al., 1999). Hieroglyphic captions tell stories about bare-knuckle fights in front of spectators and sets of rules for the fighters, and traces of organized fighting for sport, entertainment and even religious rituals can be found in every corner of the world in most time periods (Nakamura, 2019).

> "There's no evidence protective gear shows a reduction in incidence of concussion … In 1982, when the American Medical Association moved to ban boxing, everybody panicked and put headgear on the boxers, but nobody ever looked to see what the headgear did." (ESPN, 2013)

This statement was made by the Amateur International Boxing Association's (AIBA) Chairman of Medical Commission, Charles Butler, when the AIBA in 2013 decided to discard mandatory head gear in their competitions. Up until this point, helmets had been mandatory in Amateur Boxing since 1984, almost 30 years (ESPN, 2013). Although boxing has been an Olympic sport for over 2700 years, it is often perceived as dangerous by people outside the martial arts community and in the medical community particularly. However, it is an increasingly popular sport all over the world, with 89 nations competing in 2019's AIBA world championships for men and women respectively (AIBA 2019; AIBA 2019). With more active competitors in a sport with a reported risk of acute traumatic brain injury, there is a simultaneously growing patient group that needs attentive rehabilitation and medical care. Patients with neurological damage and brain trauma leading to cognitive and functional impairments are a patient group in need of individual and interdisciplinary care, from physicians and physiotherapists. The burden on tomorrow's health care system with a growing patient group calls for better knowledge on how to prevent head trauma in combat sports, this was the main objective of Shukla and Sharma's article (2018).

In the last century, several rule changes and safety measures have come in place to make the sport safer, like a set number of rounds in a bout (3x3 minutes in amateur boxing), mandatory mouthguards and thorough medical examinations before, during and after bouts (Bianco, et al., 2013). Several Medical studies on acute head injuries in boxing suggest that head gear doesn't necessarily decrease the risk of concussions in fighting, although a clear decrease in facial lacerations was seen after 1984 (Falvey and McCrory, 2015; Davis et. al. 2017). This decrease was expected, as the helmets that were introduced were the same professional boxers

used in sparring to avoid getting cut. However, when more thoroughly examined the studies lack evidence to determine head gears effect on boxers' safety. This was either due to a narrow selection of data (i.e. Either just a few, selected tournaments were compared, or injury incidence over a shorter time period), or because injuries were but a minor focus area in the studies, where the total activity profile of boxers and changes in technique were the main issue. Several case studies on active and former boxers have reported a risk of permanent brain injury, and how recurring concussions are degenerative to one's health, without being able to conclusively state that this risk is lower with head gear (Casson and Viano, 2019; Bianco, et al., 2013; Davis, Waldock, Connorton, Driver and Anderson, 2017; Falvey and McCrory, 2015; Blonstein and Clarke, 1957). According to Jordan (2000), repetitive concussions or sub-concussive blows to the head may lead to chronic traumatic brain injury. In order to reduce the risk of long-term consequences, decreasing acute injuries in boxing should be a priority.

Women, who debuted in Olympic boxing in the 2012 Los Angeles Olympic games, are still compelled to wear head gear. The ban of protective head equipment only accounts for men, as specified in AIBA's Technical and Competition rules (2019). There has not been a formal explanation as to why the ban is separated between sexes. Very few studies investigating female boxing and injury incidence exist as of today.

According to today's AIBA rules, a fighter wins an amateur boxing bout by points or if their opponent is unable to finish the round or is disqualified (AIBA, 2019). The ringside physician has the right to stop the bout for medical reasons, and the referee can stop the bout if they find one or both boxers unable to defend themselves, gets injured or is at risk of getting injured ((Jako, 2002). This is called a referee-stop contest (RSC). If a boxer is unable to continue within 10 s of a blow from an opponent, a knockout (KO) decision is recorded (Goodfellow, 2009). It is important to note that this does not only count if the boxer is left unconscious or severely concussed as popularly believed, a boxer can often be "knocked out" from shots to the liver or spleen. When a blow to the head leaves the boxer unable to defend themselves and shows signs of concussion, the referee can call an RSC head (RSCH) decision. If a boxer gets injured (i.e., a dislocation or a major cut) the referee and ringside physician can stop the contest and call an RSC injury (RSCI) decision.

The AIBA developed a scoring system based on the 10-point-must system from professional boxing, and a boxer wins a bout after each of the five judges allocated around the ring independently analyse each round following these criteria (Davis et al, 2017; AIBA, 2019):

- Number of quality blows on target area.
- Domination of the bout by technical and tactical superiority
- Competitiveness

Both competitors are dealt ten points, which is the maximum, and the judges then apply the following criteria to score each round:

- 10 vs. 9 – Close round
- 10 vs. 8 – Clear winner
- 10 vs. 7 – Total dominance

The ringside physician has the right to stop the bout for medical reasons if it is needed during the bout. The Medical handbook of Olympic Style Boxing gives guidelines the management follows in case of a knockout (Goodfellow, 2009). These guidelines provide information on pre- and post-bout medical examinations, how to handle various injuries in the ring, disqualifying conditions for a boxer, and minimum suspension periods for boxers after receiving a RSCH or KO verdict. The following grades of concussive symptoms have all been retrieved from Jako in cooperation with AIBA (2002):

Grade 1 - If there is no loss on consciousness and symptoms like confusion resolve in 15 minutes, the boxer will receive a thorough medical examination from the ringside physician. This is to determine the need for and possible nature of further medical examinations and possible suspension from competing and training.

Grade 2 – If there is no loss of consciousness, but the concussion symptoms last for longer than 15 minutes, the boxer will be taken to hospital for a neurological examination and a possible CT-scan.

Grade 3 – If there is any loss of consciousness the boxer is immediately transferred by ambulance to the nearest emergency department. This accounts whether the boxer is knocked out for mere seconds or a longer period (minutes). The severity of the concussion decides when the boxer can return to training and competing, but in these cases a 28-day rest period is a bare minimum. This accounts for all kinds of training. Before a boxer is allowed to train again, they must undergo examinations from both a neurologist and a CT-scan or MRI. The physician’s decision is noted in the boxer’s record book, a book all active boxers must have to be allowed to compete.

As recorded by Jordan in 2009, Punch drunk-syndrome and traumatic parkinsonism are two of the more severe results of boxing-related brain injuries, but it is important to note that most of these case studies are from the early half of the century, when safety measures in competitive boxing were completely different from today. Although studies indicate that amateur boxing is, by injury rates, a safer sport than several other contact and non-contact sports, the rule changes in amateur boxing demonstrate an aim to protect all athletes and reduce the relative risk of injury even more (Koh, Cassidy, & Watkinson, 2003). This can explain the increased rate of RSC (referee stop contest) decisions the last decades, as reported by Bianco et al (2013). After repeated KO or RSCH decisions for the same boxer, a 1-year rest period or even enforced retirement is mandatory (Jako, 2002).

The terms "head injury" and "brain injury" are used alternately in this study, because of the bout decision code RSCH and varying use of both terms in relevant literature. Several laboratory investigations and articles have shown that use of headgear does reduce head impact force and therefore risk of head injury (HIC), as confirmed by Bartsch, Benzel, Miele, Morr and Prakash (2012). Using different speeds, impact forces, headgears and angles, two different studies concluded that the current head gear used by amateur boxers can reduce the risk of traumatic brain injury and superficial injuries to a significant degree, and often more than halves the impact force (McIntosh & Patton, 2015; Dau, Chien, Sherman & Bir, 2006).

Loosemore et. al. (2017) made an important comment in their brief report about head gear use in AIBA boxing tournaments:

> "Head guards provide padding over the forehead but only a thin strap under the chin although blows to the forehead are seldom the cause of a knock-out. Padding cannot be added under the chin as this impedes breathing as the boxer keeps the chin tucked." (p. 87).

It is lateral blows to the jaw or head resulting in rotational and/or angular acceleration of the head that is believed to be the biggest factor in concussion or mild traumatic brain injury (King, Yang, Zhang, & Hardy, 2003). Knowing this, uppercut and hook punches to the jaw and chin are punches that statistically will lead to head injury most often, because of the head's acceleration and the lack of padding in said areas.

An obvious reason why there was a 3.3-fold reduction in facial lacerations after helmets were made mandatory in 1984, is that the helmets cover both the forehead and cheekbones, areas where the bones are raised, making them prone to cuts (Bianco, et al., 2013). Head gear has

been used by professional boxers in sparring for a long time, and still is, to reduce the incidence of cuts. When head guards for boxing were first made mandatory at the 1984 Los Angeles Olympic games, they used the same helmets as professional boxers. The head guards did exactly what they were designed for- reducing cuts but sadly did not protect boxers from brain injury to a significant degree (Loosemore P. M., et al., 2017).

Facial lacerations do not damage as severely as traumatic brain injury, yet they are in several studies on amateur and professional boxing injuries the most common or second most common reason for bouts ending before time (Loosemore, Lightfoot and Beardsley, Boxing injuries by anatomical location: a systematic review, 2015; Zazryn, McCrory and Cameron, 2009). Several studies, like Loosemore et. al 2015 citing Jordan and Campbell, state that the actual number of cuts in bouts are near impossible to know, as bouts often continue when the boxers get cut; «…attending physicians at boxing matches are less likely to record facial lacerations on injury forms unless they require sutures, which does indicate a lack of consistency." (p. 16.) This is also supported by Schmidt-Olsen, Jensen and Mortensen's Danish study from 1990. Nevertheless, recurring damage to the skin resulting in scar tissue formation can be unfortunate for the boxer's career, as scar tissue is less flexible and more likely to split open again.

Furthermore, where numbers on hand injuries could be obtained, the aim was to detect a possible link between hand injuries and headgear. Both modern headgear and boxing gloves are designed with shock absorbing material, a big improvement from the horsehair gloves used not many decades ago (Loosemore P. M., et al., 2017). Gloves must be 10 ounces (or 12 oz if the fighter weighs 69kg or more). The glove padding is designed to protect both the knuckles and head, the hand wraps are supposed to protect the bones of the hand and absorb shock, and the modern-day gloves have the thumb sewed or tied to the fist. The latter design is aimed to reduce the risk of boxers getting a thumb in their eye, and forced abduction causing the ulnar collateral ligament to tear, the most common injury in this area of the hand as reported in the biggest study of hand injuries in boxing (Noble, 1987). Sadly, few studies reported detailed head injuries, hand injuries, and stated whether headgear was used or not.

Method

This study is a systematic review and meta-analysis of injuries in amateur boxing exploring a possible effect of AIBAs 2013 rule change, discarding mandatory head gear use for male boxers. This study consists of ten different articles providing data from approximately 17135 amateur boxing bouts over a period of 60 years (1955-2015). Eight articles were found through PubMed and Google Scholar. The search terms “Boxing”, “Amateur boxing”, “Headgear”, “Head guard”, “Helmet” and “Injury/Injuries” were combined in different orders. One article was found through the citation list of a relevant article, and one was found through the reference list of a review that is not included in this study. The searches identified a total of 1138 studies in PubMed and 27 500 studies in Google Scholar, with additional 543 citations that were all evaluated. Articles were considered relevant based on their titles and abstracts. Potentially relevant articles were obtained and assessed according to the following criteria:

Inclusion criteria:

1. Articles written in English
2. Empirical studies
3. The boxers had to be on amateur level
4. Total number of injuries and bouts/rounds/hours of boxing had to be reported
5. Whether helmets were used or not had to be explicitly reported, or be within a time frame and in a situation where the use of headgear was a certainty
6. The severity of the head injuries had to be significant, either resulting in the ending of a bout or time out of training. Codes RSCH (Referee stop contest-head) and KO (Knock-out) were required.

Numbers of other relevant injuries, such as cuts and/or injuries of the hands and wrists were factored in as well in the selection of articles.

Exclusion criteria:

1. Articles written in any other language than English
2. Reviews, articles without reported numbers and articles where data of injuries cannot be separated between amateur and professional boxers, or competition and training.

Around half of the originally selected articles that provided data on injuries with and without headgear were discarded because they did not fulfil the set criteria for this study but helped

provide support when analysing the final data. After selecting the articles, all relevant data were gathered in Table 1. Where data was unobtainable, the areas are left blank, and where the studies state zero injuries, 0 has been noted. Chosen time measurements are number of bouts and hours of active boxing. Where number of rounds or other measurements were used, bout length and numbers were cross-checked with time period in boxing, to calculate as accurately as possible by hand. Figure 1 in "Amateur boxing in the last 59 years. Impact of rules changes on the type of verdicts recorded and implications on boxers' health» made these calculations possible (Bianco, et al., 2013). This also accounts for studies containing material with several bout lengths. In studies where the exact bout numbers were unobtainable, the approximate number given in the article was used, after the number of boxers was cross-checked from the same study. All hours of boxing not explicitly stated in studies were calculated by hand.

The main outcome measurement chosen is injuries with and without headgear per 1000 hours of boxing. In Table 1, total number of injuries per 1000 hours of boxing is stated as well.

Several different bout lengths and vague reports on where and how injuries occurred in some studies are limitations to this study. However, the studies were found detailed enough to be included, many other studies that possibly could have provided useful numbers could not be included because of inadequate reports on injuries and helmet use. One example of this is Schmidt-Olsen et. all's study from 1990, on injuries in Danish amateur boxing with and without helmets, that could not be included because it was not concretely stated how many injuries occurred with and without headgear (Schmidt-Olsen, Jensen, & Mortensen, 1990).

A further limitation to this study is that there were more studies and reports on fight injuries with headgear than without. This is partly because of the extent of time headgear has been mandatory in amateur boxing, and because several studies had to be excluded because headgear use was impossible to determine. Several studies reported hand injuries without separating the different areas of the upper extremities, combining shoulder, wrist and hand injuries. Where this is the case, areas of the upper extremities in the numbers are said in paragraphs. This results in inaccurate numbers and is a clear limitation of this study. It is not specified whether injuries occurred in competition or in training in Siewe et. all's study from 2015, however it is specified all injuries occurred wearing head guards. The limitation it could have to this study was considered of small significance to the final numbers and were therefore included. Davis et. all's study from 2015, there was a lack of information about the injuries and reasons for referee stoppage. The writers did not have access to the full data, only

using official numbers in their study. Only table 1 was used in Loosemore et all's study from 2017. The rounds with and without headgear were first converted into hours, used separately in their respective calculations with injuries, and then combined when the total of hours and total injuries per 1000 hours were calculated. Where total numbers are first reported, followed by numbers from bouts, the latter has been used in calculations as it is injuries per 1000 hours of active boxing that is the measurement, and most studies used numbers from bouts. Numbers from training make a more unreliable study, as there are no set rules for gloves, hand wraps, helmet types or bout lengths. In Table 1 the studies are sorted chronologically, with the two studies that compared injuries with and without headgear on the top, then studies are ranged from earliest to most recent period of time that boxers were studied.

Most studies have stated that they have gotten WMA's Declaration of Helsinki- covering ethical principles for medical research involving human subjects. No studies reported any conflicts of interest.

Results

The data consists of 17135,65 bouts fought by amateur boxers between 1955 and 2015. This estimates 2397,26 hours of active boxing. The total injury count from these hours is 1405. There are 575 reported injuries with headgear from the included studies, and 954 injuries without headgear. Out of the total, the number of hours of boxing with headgear is approximately 1205,8, and 1191,4 hours without headgear. Table 1 shows that the number of injuries has increased without headgear. Total lacerations reported with headgear is 111, and 1716 without headgear, making an increase of 1,445.9 %.

Total head injuries reported with headgear is 169 and 73 without headgear. Number of head injuries with headgear per 1000 hours of boxing is 140,1. The approximated number of head injuries without headgear per 1000 hours of boxing is 61,2. The amount of head injuries has decreased by 56,28% per 1000 hours of boxing without headgear. In total, injuries per 1000 hours of boxing with headgear is 476,8 compared to 800,7 injuries per 1000 hours of boxing without headgear.

The total number of hand injuries recorded from these studies are 151.

Study	Sex	Bouts	Hours of boxing	Injuries in total	Injuries per 1000 h of competition	Situation	Injuries with headgear	Injuries without headgear	RSCH/KO/Head trauma	Cuts	Hand injuries	Period (years)	Injuries with headgear per 1000 h	Injuries without headgear per 1000 h
Loosemore M, et al. (2017)	Male	7744,4	1440,1	334	231,9	Competition	88	246	66 (43 with, 23 without)	268 (45 with, 223 without)		3	118,3	353,4
Davis P, et al. (2017)	Male	79	11,85 (approx.)	10	843,8	Competition	0	9	2	8		2	0	1199,97
Blonstein J.L. & Clarke, E. (1957)	Male	3000 (approx.)	450	642	1425,24	Competition		642	29	600	11			1425,24
Blonstein J L, OBE (1974)	Male	252	37,8	57	1507,65	Competition		57	19	27	2	1		1507,65
Estwanik JJ, et al. (2016)	Male	547	82,05	85	1035,95	Competition	85		48	14	19		1035,95	
Porter & O'Brien (1996)	Male	843	69,5	64	920	Competition	64		33	4	13 (hand and wrist)	0,4	920	
Massimiliano B, et al. (2009)	Female	1337	178,26 (approx.)	50	280	Competition	50		31		11 (hand, wrist and shoulder)	7	280	
Siewe J, et al. (2015)	Male (42) and female (2)	121	18,15	192 (67 in competition)	3691,03	Competition and training	192		8	42	30 (in hand and wrist)	1	3691,03	
Loosemore M, et al. (2015)	Male	3187,5	106,25	297 (88 in competition)	828	Competition and training	88		5 (in competition)	5 (situation unknown)	32 (in competition) (31 in wrist)	5	828	
Zazryn T, et al. (2006)	Male (30) and female (3)	24,75	3,3	8	1221,4	Competition and training	8		1	1	2	1	1221,4	
TOTAL		17135,65	2397,26	1405	586,0857813		575	954					476,8381072	800,7386268

Discussion

While the final numbers of injuries per 1000 hours of boxing with and without headgear in Table 1 might make it seem like removing headgear in boxing is more harmful to the boxers, it is important to emphasize the difference in character and severity of the injuries making up most injuries with and without headgear. Without headgear, the majority of the injuries recorded are facial lacerations, and the risk of head injury has plummeted**.** The data on total injuries in competition show a general decrease after the mid-80's, which can be explained by the headgear usage decreasing cuts especially. The results in this study are like earlier studies with the same objective reporting more injuries after headgear was banned, with cuts being the reason for said increase (Bianco et. al. 2013; Davis, Waldock, Connorton, Driver and Anderson, 2017; Loosemore, P. M. et. al. 2017). With an isolated consideration of RSCH and KO decisions, the risk of a boxer injuring their head and brain is lower without a headguard on.

The little data obtained on the head injury rate among female boxers suggest a lower incidence compared to their male counterparts (Bledsoe, Li, & Levy, 2005). One reason as to why this might be, is the fact that female boxers usually do not have the same punching force as male boxers. Following the principal gender differences in muscle morphology, women are weaker and lighter than men (McArdle, Katch, & Katch, 2010). Women's head mass is also on average 15% less than men, as stated by Vorland Pedersen and Stalsberg (2019) citing Tierney et. al., which would cause a bigger relative impact to a female boxer's head, seeing as the same rules apply for glove size and other equipment between sexes (Tierney, et al., 2008). However, several studies comparing the injury rate in other sports, like soccer, softball, basketball and tae kwon do, report that female athletes are more prone to injuries in general (Koh, Cassidy and Watkinson, 2003; Powell and Barber-Foss, 2000). The lack of data on female boxing, and different studies on injury incidence of female athletes in contact and non-contact sports provide equivocal numbers. This makes it impossible to conclude that there are any sex-related differences in injury incidences in amateur boxing.

What makes this study reliable is the careful selection of previous studies and data. Several other studies have reported injury rates and risk factors, and a few studies have looked at amateur boxing injuries with the same objective as this study. Yet their sample size or selected time period left them with equivocal conclusions on whether headgear does reduce the risk of head injury or not. This is the first study of its data size to look at amateur boxing with this objective, making its result and conclusion more reliable than earlier studies'.

Important factors that make this study reliable, are the careful selection and thorough analysation of studies and the data they provided. The total time of boxing, total amount of injuries, and the total injury rate per 1000 hours respectively were manually calculated several times to cross-check the study's validity.

Studies reporting incidence of hand injuries turned out to be quite hard to find, as the criteria involved that the studies had to state whether head gear was or was not used as well as reporting head injuries, in order to detect a possible link. The hypothesis that headguards physically protects the hands better from injuries could not be confirmed or denied. The hypothesis argued that hand injuries could increase without headgear for two reasons; One less layer of shock-absorbing protecting gear, and fewer bouts ending in a RSCH or KO decision, leaving more time for boxing resulting in more punches thrown and a bigger strain on the hands. This wear and tear on a boxer's hands could be thought to increase the rate of hairline fractures, or stress fractures. With numbers arguing against this assumption, Davis et. al. announced in their article that punches thrown in total decreased after helmets were discarded, as well as punches landed (2017). This again shows how amateur boxing is starting to bridge the gap between amateur and professional boxing. The punch frequency and overall activity volume is lower in professional boxing per round, and an immediate change in amateur boxing towards a lower volume has already been recorded (Davis, Connorton, Driver, Anderson and Waldock, 2018; Falvey and McCrory, 2015). Furthermore, defensive moves like blocks and parries were used more frequently without headgear in place, and movement around the ring increased, making the boxer's risk of injury (be it in the head or hands) lower (Davis, Connorton, Driver, Anderson, & Waldock, 2018). In addition to this, international competition rules have been set for the length of hand wraps and gauze used under the boxing gloves, as well as rules for taping. This is an important factor to hand injuries in competition vs. in training, where most boxers are free to use as much and little wrapping as wanted and heavier gloves. Longer wraps and heavier gloves provide more support and shock absorption, resulting in better protection of the hands and wrists. Set rules for padding, wrap length and glove weight are arguably to avoid "weaponization" of the gloves, seeing as heavier gloves make a bigger impact force, and tape and wraps can be used to make the fists harder.

A final argument against the first assumption is that resistance exercise and mechanical strain on bones and tissue that exceeds everyday life impacts is proved to improve the preservation of bone and muscle mass (Ram Hong & Wan Kim, 2018). Because of the lack of data, numbers where hand injuries were reported have been included, but cannot be used to strengthen or

weaken a hypothesis. Determining how to reduce hand injuries is desirable, as it is often the first or second most common reason for athletes losing training time due to injuries (Loosemore, et. al. 2015; Timm, Wallach, Stone and Ryan III, 1993). When separated from head injuries and headgear use, there are many studies looking at risk factors contributing to hand injuries in amateur and professional boxing, thoroughly covering both incidence and severity. These studies could not be used here however, as the possible link to head injury was the main objective around hand injuries, to make a stronger argument in the direction of a safer contact sport for all.

In 1964, the year of the first world amateur boxing championship, the first important modification to amateur boxing rules occurred. The standing-count rule allows the referee to start an eight second count if a boxer is in difficulties for any reason, if the athlete has not been knocked to the canvas (Jako, 2002). Ironically, the KO rate did not decrease significantly, but injuries (especially facial lacerations) increased dramatically (Bianco et. al, 2013). The standing-count rule was supposed to increase the safeguarding of the boxers' health, yet the numbers on KO, RSCH, RSC and RSCI incidence indicate that standing counts did not contribute to an intended reduction, but rather that head guards did when they were made mandatory in 1984. The 1984 Olympics made it clear that head guards reduce the incidence of cuts by approximately 90% and reduce the KO rate. However, the rate of RSCH and RSC balanced out the injury reduction, resulting in an altogether significant increase in bouts ending before their time limit with headguards in place (Bianco et. al, 2013)

Referring to the concern expressed by the medical community, as mentioned in the introduction, the health risks in boxing have been a topic of discussion many a time. Articles from the last century have reported a noticeable risk of traumatic brain injury and late onset cognitive impairments, such as traumatic parkinsonism and pugilistic dementia, in former boxers (Casson & Viano, 2019). However, as underscored by Bianco et. al., the reports referred to a set of few athletes competing many years ago, before safety rules like the standing count and medical supervision had been introduced. Secondly, the boxing bouts in the earlier decades of the last century could last countless rounds, and the bouts were only ended if they were abandoned by a competitor or if they were knocked out (2013, p.4). This results in the competitors suffering far more blows to the head throughout the bouts, than they would in a modern-day bout with 3-5 rounds. This makes it difficult to compare numbers of injuries in the earlier days of boxing as we know it, with numbers from modern-day bouts and getting reliable results. The cases' lifestyles post boxing career were not reported, and

important contributing factors like alcohol consumption cannot be ruled out in the reports of neurological and cognitive impairments. When looking at the data in this study, it is important to bear in mind the aforementioned information on earlier amateur boxing and the way in which it varies from modern boxing in both rule set and medical care. One may argue that the injury rates are not completely comparable to modern-day boxing injury rates because of these differences. Yet amateur boxing seems to be moving in the direction of becoming more similar to professional boxing, with a new scoring system more like the one in professional boxing, and new demands to the amateur boxers' styles. Loosemore et.al. among others reported this change, by comparing AIBA amateur tournaments to WSB-tournaments, as well as looking into head injury incidence with and without headgear (2017). This change is also a result of several new rules regarding protective gear, illuminating the importance of reflecting on why injury rates in earlier amateur boxing were as they were.

Third, the protective gear used in the earlier decades of the last century are another contributing factor to the number of KOs and more severe head traumas, in addition to more facial lacerations, as seen in the data. In the old days, boxers used to fight with bare fists or very light gloves (2-6 ounces) whereas today's boxers fight with minimum 10-ounce gloves (Bianco, et al., 2013). The boxers fought without gum shields and helmets. Today, gum shields are mandatory not just in competition, but are in many gyms also mandatory in training and sparring. The material filling today's gloves is designed to be as shock-absorbing as possible, to protect the hands as much as possible (Bianco, et al., 2013). Data from Blonstein & Clarke's study supports these hypotheses, where 600 of a total 642 injuries in approximately 3000 rounds were cuts, arguing that the lack of padding and shock absorption in boxing gloves heightens the risk of cuts (1957).

In Bartsch, Benzel, Miele, Morr and Prakash's study, impacts to the head were compared using MMA-gloves (4 oz) to a bare head, boxing gloves (10 oz) to a bare head, and boxing gloves to a head with a boxing helmet on (2012). Note that the helmet used was of the brand Tuf-Wear, which is not on the list of AIBA-approved boxing gear and therefore would not have been used in an official amateur boxing bout and is also slightly heavier than approved headguards (180g heavier) (AIBA, 2019). In other words, the AIBA approved headguards will presumably provide less shock absorption than the helmet used in this study. The study found that even though the theoretical risk of brain injury was heightened regardless of padding used, the combination of boxing glove and headguard provided the most significant reduction of impact and argued that it will provide the best head and neck protection for

competitors. This is also applicable to hand injuries, where one can argue that a double layer of shock-absorbing protection will help reduce the risk of head and hand-injuries keeping active competitors out of training. The MMA-gloves used in this study are comparable to the old fashioned boxing gloves used in the early half of the last century, because of their weight, and because the impact dosage data was tested with a dummy with a bare head, just like amateur boxing before the 1984 rule change. A discovery in this study was that the head and neck impact dosage accumulate fastest in MMA and boxing bouts without protective headgear, in other words the impact force is higher and will theoretically cause more harm for hands and head. This find stresses the need for a change in the technical style of amateur boxing: If getting hit in the head is more harmful without a helmet on, more frequent use of defensive moves and overall head movement and movement around the ring is necessary to reduce total impacts to the head. It is arguable that the gloves' purpose first and foremost is not to protect the head- but to protect the knuckles, however the risk of injuring the knuckles would logically increase the thinner the gloves are padded (i.e. lighter), and with thinner padding between knuckles and target comes a higher risk of local injuries like contusions and lacerations.

The increase in facial lacerations after headguards were removed can be unfortunate for the boxers' careers. More bouts end by the RSCI-decision, and because of sheer tissue physiology, one can assume that the number of cuts will grow exponentially if boxers do not alter their style of boxing. This is because scar tissue is less elastic, which increases the risk of the skin re-opening from blows to the area. This can have an unfortunate effect on boxer's health and career and even though stitches, a broken nose or a hand injury can keep you out of training for a long period of time, it is not nearly as taxing as recurring concussions and head trauma. One could argue that the changes in injury rates in amateur boxing after discarding headgear are positive. Even though there are more injuries statistically, the severe injuries have been reduced. The next aim should then be to reduce the total relative risk of injury in boxing, both on amateur and professional level. Another element pointing amateur boxing in the direction of the professional side, is the 2008 introduction of WSB, AIBA's World Series of Boxing-tournament that were early in the discarding of headgear, and increased bout-lengths to 5x3 minutes (AIBA, 2018). The international tournament allows amateur boxers to maintain Olympic eligibility at the same time as bridging the gap between amateur and professional boxing, which can arguably be positive for the start of a boxer's professional career.

Koh, Cassidy and Watkinson found that even though the concussion rate in boxing is lower than team sports like ice hockey, soccer and rugby, they also reported that boxing had the highest rate of concussions in the three individual sports accounted for (2003). Coincidentally, the studies used to provide these data were all from a time when headgear was mandatory for amateur boxers. Koh et. all used numbers from studies on both professional and amateur boxers, and one of these studies are also used in Table 1. Friedrich Unterharnscheidt shared a reflection in his article; in other sports, injuries are an unfortunate consequence and is wished to avoid at all costs, while in combat sports, the aim is to injure (Unterharnscheidt F. , 1995;23). Though this might sound barbaric and brutal, the truth is that the point scoring system in boxing today, with scoring criteria like number of clean blows to the target area, is in truth a toned-down illustrative way of demonstrating that the athlete would be hurt if this was not a controlled situation. This is seen in other sports like fencing, where a lamé, an electrically conductive material worn over the protective clothing, is used to determine whether a hit landed within the target area or not. The point of this argument is that a higher rate of injuries in a sport where the sole purpose is to outscore or disarm your opponent using physical violence is to be expected, even though avoiding injury as best possible is one of the main aims in competitive sport where there is a risk of injury. If we look at Butler et. all's unpublished data from 2013, discarding head gear in amateur boxing helps reduce the risk of injury. 7352 rounds of boxing with headgear had a 0.38% concussion rate, while without head gear, the concussion rate from 7545 rounds was at 0.17% (Seifert, 2017). This supports both Loosemore et all's and Davis et all's data in Table 1, proving that the head injury rate and risk is decreased without helmets (2017;2017).

Regarding combat sports with injuries treated at emergency departments, boxing is not the sport to come out as most injury ridden, according to a US study stretching over 5 years (Pappas, 2007). The author inspected the incidence and anatomical placements of injuries from three different combat sports and reviewed whether combat sports have a higher rate of injuries than non-combat sports. This publication actually supports Loosemore et al.'s declarations, reporting that only 1.6% of the 7290 injuries that were treated in emergency departments required hospitalization, the rest did not need admission (2015). Only 10.3% of the injuries that resulted in hospitalization were boxing related, while 59.8% percent came from wrestling. The remaining 29.9% were related to other, unspecified martial arts. 23.3% of the boxing related injuries were concussions or face injuries, and over 60% of the injuries

were in the upper extremities (2007, p.59). Pappas found that combat sports do not have a higher injury rate than non-combat sports (2007).

A case study following a 22-year old male boxer who suffered an acute subdural haematoma after an AIBA-competition supports the argument that the general style of amateur boxing has adapted to headgear usage, where the headgear is a useful tool physically and mentally in this style of boxing (Falvey & McCrory, 2015). Ultimately, amateur boxing will then need to change into a more similar style to professional boxing, where headgear isn't used by international rules. Video analysis of three bouts where the same two amateur boxers competed against each other over a three year time period supplied data with and without protective headgear in place, and finally without headgear and set-up approximating professional boxing, scored for number of impacts to the head and head clashes, among others. Falvey and McCrory's data show that impacts to the head in the two first amateur bouts increased with 8 percentage points of the total without the headgear in place. Moreover, the number of head clashes also increased, but decreased by almost 80% from 2014's bout to 2015's bout with a more professional outline (2015). It is important to note that the study reported recurring head clashes to be the reason for the boxer's subdural haematoma, and not punches to the head. The boxer then had to follow the medical guidelines as mentioned earlier in this study, with a thorough clinical examination, SCAT3 assessment and MRI of the brain finally diagnosing him with a concussion and haematoma (Falvey & McCrory, 2015). One could argue that the number of impacts to the head and head clashes staying similar regardless of headgear use is due to the style of boxing amateur boxers have learnt, that has now changed.

Discussed in more detail from page 15, the need for a technical and tactical style change is undisputable when looking at the heightened impact dosage to the head and neck with a boxing glove to a bare head condition. As Davis et. al. demonstrated in their study last year, this change is already happening (2018). They found that several rear hand punches were used less post-2013, possibly because bigger movements are required to land a rear hand punch. The boxer needs to rotate their body and either step towards their opponent and/or duck down to hit their opponent in the body, leaving the attacking boxer more exposed to punches from the opponent (Davis, Connorton, Driver, Anderson, & Waldock, 2018). A possible reason for rear hand punches being used less post-2013 could be that the boxers assessed the risk from throwing rear hand punches and found it too big without a helmet, and instead stayed in a safer distance, sticking to front hand punches. Movement around the ring increased by 20%,

also supporting the argument that the boxer's evaluate risks differently without headgear. This is also a sensible argument as to why professional boxing on average has a lower intensity volume than amateur bouts per round and could help explain the decrease in RSCH and KO decisions after the 2013 rule changes, as seen in Table 1.

In a study by Zazryn, Cameron and McCrory, injury rates in training and competing for both amateurs and professionals respectively were compared over a 12-month period (2006). The authors found that, even though training accounted for 99.9% of the participation time during the study, over half of the injuries sustained in the same period were in competition. Injuries in training were 42.9% of the injury total. When examining aspects of activity that separates competition and training, the numbers of injury incidence make more sense. In training, activity patterns and drills are structured and there is a degree of closedness of drills. This means situations where the outcome of the athletes' choices of both attacking and defensive moves are limited by set drills, so the possibilities of what you can do in order to perform a set task are limited. When sparring in training you, as a boxer, are up against a semi-passive, semi- aggressive or completely passive and not aggressive opponent. In competition, you have a completely resistant and fully aggressive opposition without the closedness of drills, giving both more and less possibilities to what you can do to attack and defend at the same time. This creates a need for more efficient decision making and the risk of the technique dropping to a point where the punch can be harmful even to the attacking athlete. If repeated punching increases bone density, as established by Ram Hong and Wan Kim, hand fractures could be assumed to occur when the punch connects to a hard surface in an angle, making an impact in a direction where the bone is fragile (2018). Furthermore, whether the technique and performance of the punches thrown are good or not, you punch with more intent on average in competition. In these situations, the athlete intends to harm or knock the opponent out, whilst in training they usually don't punch with force against their opponent or training partner. Punching with force in training happens mostly when hitting pads or bags and is in a more controlled and calm setting. Boxers often spar and do light bag work with open fists in their gloves to reduce the punching force, and instead focus on i.e. speed. With a more pressured and stressed situation as competition is, and against an active and aggressive partner without structured limitations as in drills, a higher risk of injury is inevitable.

Further arguments against headguards in boxing as mentioned by Bianco et al among others, is the possible psychological effect the helmet has on both boxers (2013). Knowing that they are wearing an extra layer of protection can give false confidence and make the boxer more

reckless in their style of boxing, exposing themselves to blows that they maybe would have avoided before headgears became mandatory. This is supported by the numbers in Davis et al.'s study, that clearly stated less defensive headgear also enlarges the target, making the boxer easier to hit (2018). Peripheral vision is also reduced with the headgear on, making it harder for the boxer to defend and attack. This concerns lateral blows especially, increasing concern for the boxer's health when lateral acceleration of the head is one of the main factors in many concussive blows or blows leaving the boxer unconscious, as previously stated (King, Yang, Zhang, & Hardy, 2003).

A study on amateur boxers in Denmark in the 80's compared incidence of RSCH, KO and RSC decisions in 5272 bouts (over 790 hours of boxing), and found that headguards and set measures of boxing wraps did not affect the frequency of bouts being stopped because of blows to the head (Schmidt-Olsen, Jensen, & Mortensen, 1990). It should be noted that the exact number of athletes wearing headgear was not clearly stated but approximated to be 60% of the boxers in a one-year period. This contradicts the data from this study, showing that injuries per 1000 hours of boxing is reduced on average with headgear use, the incidence of RSCH/KO-decisions is higher with headgear, and facial lacerations increasing noticeably without headgear.

The discoveries in this study support most of the few other studies on the same subject. Earlier studies could not confirm that the headgear influenced injury incidence and severity in amateur boxing and stated that their results were equivocal at best because of lack of material. As it is still a short time after the 2013 rule changes, the lack of data on injuries without headgear in the last six years is a clear limitation to this study as well. However, this study has collected the largest amount of data on this subject so far, and the results confirm others' implications. As previously noted, there were several articles that could not be used to provide data in this study but were still used to support the results, as these studies provided similar results.

Conclusion

This study has provided details on injury incidence and risk factors obtained from the analysis of a comprehensive amateur boxing database from 1955 to 2015 of bouts all over the world. The rates are based on over 17000 bouts over a 60-year period. One thousand four hundred and five injuries were reported by coaches, physicians or boxers. This study emphasised the effect of headgear use in amateur boxing and discussed whether it should still be banned or reinstated in AIBA tournaments and bouts based on injury rates and pros and cons of the headgear itself. As traumatic head injury is of greater severity than facial lacerations, concluding remarks reinforce the argument for the discontinuing of headgear in amateur boxing. Further research should aim to confirm or contradict the results of this study, and document injury incidence and severity in amateur boxing after 2013, where data are scarce. In the future it is desirable to reduce the rate of lacerations, and both alterations in amateur's style of boxing as well as new medical measures and protective gear can play important roles in this required reduction.

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