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Review article

A comparison of injury rates in organised sports, with special emphasis on American bull riding

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Abstract

Objective: The authors set out to determine which sport in the literature has the highest injury rates. **Data sources:** A systematic review of sports injury studies was performed using the PubMed database on the National Library of Medicine website, using the key words: "Injury Incidence" in combination with each of the sports: "boxing," "football," "hockey," "rodeo," "rugby," and "soccer." **Study section:** Using a 3-round selection process, 2021 papers were reviewed. Those papers that did not report injury rates as a function of time were excluded. **Data extraction:** Each paper underwent an independent review by two authors. Injury rates from the papers reporting the top 5 injury rates for each sport were recorded and placed into an electronic spreadsheet for comparison. All selected studies reported injury rates as a function of time, although the unit of time was not always the same; therefore, simple extrapolation was made for all studies to make the unit of time in hours. **Data synthesis:** The injury rate in bull riding was found to be 1440 injuries/1000 exposure hours; 1.56 times greater than amateur boxing, 1.75 times greater than semi-professional rugby, 10.3 times greater than American football, and 13.3 times greater than ice hockey. **Conclusions:** The authors conclude that injury rates vary widely between contact sports and that American bull riding is the most dangerous organised, spectator sport in the world. **Keywords**: sport injuries, injury rates, bull riding, sport injury epidemiology

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Introduction

Researchers in sports medicine and injury prevention today use injury epidemiological data and statistics to guide them in making recommendations to sporting organisations and promoters on improving rules, regulations, and equipment to make sports safer and more meaningful for participants and spectators. Injury epidemiological data in the medical literature allow for comparative analyses to be conducted on various sporting activities. Despite the availability of this data, evidence-based conclusions about which spectator sport is the most dangerous have yet to be made.

American rodeo is a truly American sport with roots deeply embedded in the Old West heritage of the working cowboy. (1) Rough stock events (i.e. bull riding, bareback riding and saddle bronco riding) have been shown to have the highest injury rates [2, 3, 4, 5]. Bull riding is a mainstay event in American competition rodeo; implicated in up to 31-37% of rodeo injuries, making it the most dangerous event in rodeo [6, 7]. The rate of injury associated with bull riding has been shown to be two times higher than with other major rodeo events (3.2 versus 1.39 per 100 competitor exposures) [8]. Bull riding participants frequently suffer head and neck injuries, sometimes resulting in permanent neurological sequelae or death [9, 10].

In an apparent effort to attract public attention and fan support, many sports and other activities have recently been referred to as *"extreme",* including bull riding. In order to determine which sports have the highest injury rates, this investigation was created to compare injury rates in such sports. Furthermore, in order to elucidate the differences between such sports, the importance of measuring injury as a function of exposure time, rather than as competitions or events, is illustrated in this present study. The hypothesis of this study is that bull riders have the highest reported injury rates per unit of time.

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Methods

This project involved conducting a systematic review of literature that has reported sport injury rates as a function of time, and the prospective collecting of exposure time data from American professional bull riding events. The athletes were professional bull riders in competitions at Professional Bull Riders events, or at the International Professional Rodeo Association events, including the International Finals Rodeo**.**

A. Systematic literature review

The purpose of the literature search was to systematically review, identify and compare studies reporting the highest injury rates for each of the various sports. Since the goal was to find the highest injury rates in sport, the authors did not restrict the search by gender, age, or classification of sport (i.e. extreme sports, contact sports, high velocity sports, individual or team sports), and included team sports with multiple positions, such as ice hockey or football. To allow comparison between the different sports, the authors sought reported rates of injuries as a function of time, usually per 1000 exposure hours, the most widely used system for reporting sport injury frequency [11]. No attempt was made to meta-analyse the data as the authors were only searching for studies that reported injury rates approaching those found in the sport of bull riding.

Round One: Round One of the literature search was to identify those publications in the English language that report on the rate of injury for six popular, organised sports: boxing, American football, hockey, roller hockey, rugby and soccer. These sports were chosen because they are popular contact sports and likely to produce the highest rates of injuries to athletes based upon the clinical and research experience of the authors. A literature search for sports injury studies was performed using the PubMed database on the National Library of Medicine website. This search was based upon the keywords: "Injury Incidence" in combination with each of the sports: "boxing," "football," "hockey," "rugby," and "soccer." The term "incidence" was used rather than "rate" in the search process because it consistently generated the greatest number of titles.

Inclusion criteria: The primary criteria for selection were the reporting of data on the rate of injuries as a function of exposure time (usually reported as 1000 exposure hours). Each selected paper met the following inclusion criteria:

1. Focused on one of the six contact sports mentioned above;
2. Looked at all injuries occurring in the specific sporting activity in question;
3. Reported the injury rate of the specific sporting activity as a function of time.

Exclusion criteria: All titles were reviewed to exclude papers that did not report the injury rate of a sport, were not in English, or did not have abstracts. All remaining abstracts were then reviewed to exclude those that were not reporting sport injury rate as a function of time. Papers with any of the following exclusion criteria were rejected:

1. Reported on any sport not included in the group of contact sports listed above;
2. Looked only at one or a select group of injury types;
3. Did not use exposure time as a denominator in reporting the rate of injury.

All titles were reviewed by each author to select qualifying studies. Papers were excluded from each round of consideration if both authors agreed that exclusion had been met; otherwise, the paper was promoted to the next round.

Round Two**:** Round Two involved reviewing the abstracts of those titles promoted from Round One. Upon reviewing the abstract, if both authors made the determination that the paper did not meet selection criteria then it was excluded from further consideration.

Round Three**:** Round Three was the selection of those abstracts reporting the highest injury rates in each sport followed by the full article review. Reviews were completed on the full manuscripts of those studies reporting the highest injury rates in each sport in a time-dependent manner. If criteria for selection were met after each reviewer read the paper, then the reported rate of injury was recorded as a result for comparative analysis (Table 1). Injury rates were converted to 1000 exposure hours (EH). The studies reporting the top 5 injury rates from each sport were selected and used in comparison to the injury rate data for bull riding. If a particular sport is represented in the literature by less than 5 papers, then reporting of these rates was limited to the available data.

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Table 1: The highest injury rates found in a systematic review of the medical literature, including the rates of data subsets (i.e. defenders in ice hockey).

Sport	Highest Injury Rates (Injuries/ 1000 EH)	Design	Country	Reference
American Bull Riding	**1440**	**Prospective**	**Canada/ USA**	**Butterwick DJ, Hagel B, et al.** [8]
Amateur Boxing	920	Retrospective	Ireland	Porter M, O'Brien M. [12]
Female Boxing	680	Retrospective	USA	Bledsoe GH, Li G, et al. [13]
American Football (High School)	140	Prospective	USA	Anderson BL, Hoffman MD, et al. [14]
American Football	16	Prospective	Germany	Baltzer AW, Ghadamgahi PD, et al. [15]
American Football (High School)	3	Retrospective	USA	DeLee JC, Farney WC [16]
Roller Hockey	304.9	Retrospective	USA	Varlotta GP, Lager SL, et al. [17]
Ice Hockey	78.4 107.8 defense	Prospective	Sweden	Lorentzon R, Wedren H, et al. [18]
Hockey (High School)	96.1	Prospective/ Retrospective[a]	USA	Smith AM, Stuart MJ, et al. [19]
Ice Hockey	66	Prospective	Finland	Molsa J, Airaksinen O, et al. [20]
Youth Ice Hockey (ages 9-19)	50.9 M 64.8 M varsity high school	Prospective	USA	Roberts WO, Brust JD, et al. [21]
Semi-Professional Rugby	824.7	Prospective	Australia	Gabbett TJ [22]
Amateur Rugby	694[b]	Prospective	Australia	Gabbett TJ [23]
Elite Rugby (High School)	405.6 (<19 yrs)	Prospective	Australia	Estell J, Shenstone B, et al. [11]
Amateur Rugby	182.0 forwards	Prospective	Australia	Gabbett TJ [24]
English Professional Rugby	139	Prospective	UK	Stephenson S, Gissane C, et al. [25]
Soccer	44.4 57.9 M	Prospective	USA	Putukian M, Knowles WK, et al. [26]
Soccer	50.4 M 50.3 F	Prospective	USA	Lindenfeld TN, Schmitt DJ, et al. [27]
Asian Football	64.7[d] 154.2[e]	Prospective	Korea	Yoon YS, Chai M, et al. [28]
Professional Soccer	41.8[f] 24[g]	Prospective	Sweden	Walden M, Hagglund M, et al. [29]
Professional Soccer	35.3	Prospective	USA	Morgan BE, Oberlander MA [30]

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[a]. Parents were responsible for reporting player injury to the doctor
[b]. 4th tournament match
[c]. Matches lost
[d]. Injury definition = loss of playing time
[e]. Injury definition = complaints reported by athletes
[f]. Match injury by English/Dutch teams
[g]. Match injury by other teams
F = Female
M = Male

B. Data collection

Definition of bull riding exposure

The most recent prospective collection of injury data in American rodeo reported injury rates in a five-year prospective study of the Canadian Professional Rodeo circuit [8]. In this article, Butterwick reported injury rates from 30564 competitor exposures (CE) to a variety of rodeo sporting events. The definition of competitor exposure in that study was not time-dependent; rather, it was defined as each time that one competitor competed (attempted) in one event at a rodeo (i.e. one bull ride). This definition did not measure the duration of the exposure. The present comparative analysis requires such a definition

Injuries in bull riding are known to occur as early as when the rider first sits atop the animal while still in the bucking chute (although this is infrequent), thus the authors believe that the exposure time should begin at that moment. For the same reason (injuries infrequently occur to riders after a successful disengagement from the animal), the exposure time was concluded only after either the animal exited the arena or the rider reached the fence.

Units of measurement: The duration of an exposure in bull riding is a matter of only seconds and the reported injury rates are relatively high; therefore, the units of injury rates initially were recorded and are 1000 "Exposure Seconds" (1000 ES). Data from other sports reported in scientific citations were stated in "Exposure Hours" (EH). The bull riding data were easily computed into EH units for comparative analyses using a ratio of 1/3.6.

Bull riding exposures: The authors prospectively recorded the time of exposure in seconds during 452 independent bull rides. Each bull ride was performed by a professional bull rider, at a sanctioned professional bull riding event. Overall, there were 30 different professional bull riding events at which they collected data. Initially, one timer was used to time the bull ride and to record the time. However, this resulted in lost data as a second ride could start (bull rider first sits atop a bull) prior to the completion of the current ride. It is unknown how many instances of lost data occurred. However, for the last 22 events the authors used two teams of timers, thus ensuring that there was no lost data. Therefore the average duration of a bull riding exposure was determined by prospectively timing 452 professional bull riding exposures. This portion of the study was not designed to collect injury data. Thus the authors combined the mean exposure time in this study to the injury rate in a five-year epidemiological study which included bull riding data, to determine the injury rate per unit of time for bull riding [8].

Results

A. Systematic Review

A total of 2021 titles were reviewed independently by two authors. A total of 354 abstracts were reviewed. The breakdown of the abstracts reviewed was as follows: Boxing - 12, American Football - 133, Hockey - 46, Roller Hockey - 3, Rugby - 86 and Soccer - 74. The highest three reported injury rates within the reviewed papers were selected to represent the highest rates of the sport.

Table 1 presents a comparison of sports with the highest reported injury rates in six sports. Some of these sports were presented as subsets (i.e. defencemen in ice hockey). In addition, the search for "hockey" presented an article on "roller hockey" which met the inclusion criteria and is therefore presented. This information is presented as time-dependent exposure rather than as per practice, game, or event.

Bull riding injuries per event were found to occur at a rate 32.2 injuries per 1000 exposures in Butterwick's five-year prospective study. Using the average exposure time of 80 seconds, the rate of injuries is calculated to be 0.0004 injuries/ES or 1440 injuries/1000 EH. Other sports with high injury rates are presented for comparison.

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B. Bull riding exposure

Four hundred and fifty-two bull riding exposures were timed and recorded prospectively. The timed exposures assumed a normal distribution with mean exposure duration of 80 seconds and a standard deviation of 33.94 (Figure 1).

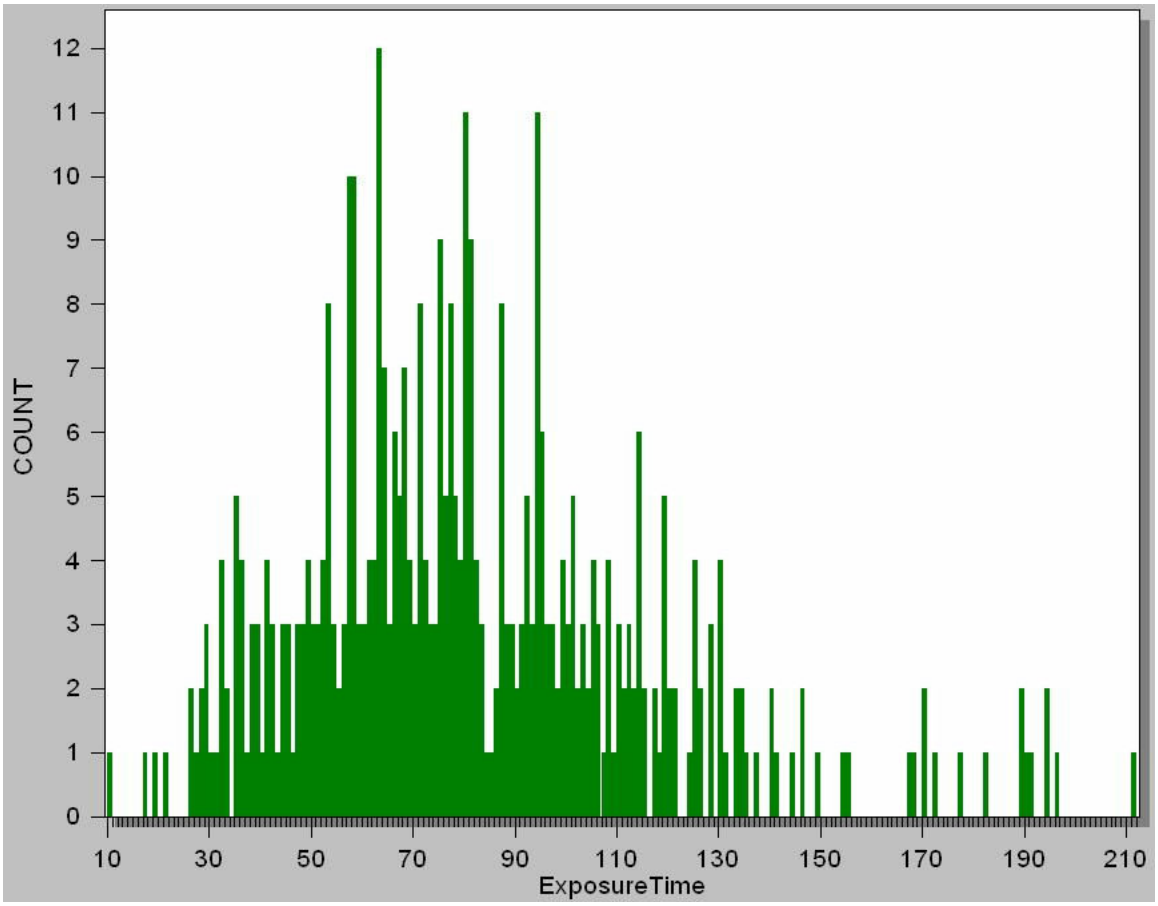

Figure 1: Four hundred and fifty-two bull riding exposures were timed and recorded. The timed exposures assumed a normal distribution with a mean exposure duration of 80 seconds and a standard deviation of 33.94.

Relative rates of injury data (Table 2) illustrate that none of the sports studied exhibit injury rates that are as comparatively dangerous as bull riding. In particular, bull riders are approximately 10 or more times more likely to sustain injury than are participants in team contact sports, such as ice hockey and football, and about 36% more likely to sustain injury when compared to amateur boxing.

Table 2: The highest relative injury rates for each selected sporting activity are summarised using the highest reported rates compared to published bull riding data.

Competition bull riding	1.0
Amateur boxing	0.64
Semi-professional rugby	0.57
Female boxing	0.47
Professional roller hockey	0.21
Asian soccer	0.11
Ice hockey (Defenders)	0.075
High-school American football	0.097

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Discussion

The authors present the highest reported injury rates for the six sports selected in this study, including those of data subsets, such as defencemen in ice hockey, in Table 1. Since one goal of the study was to ensure that sports with the highest reported injury rates were included, there was no restriction on data collection by gender, age, classification of sport, or to team sports without individual position differences in injury rate. This enabled the authors to report those sports with the highest injury incidence, regardless of such characteristics.

Most of the published reports on football injury rates do not report data based upon exposure hours, but rather on exposure events; in other words, injuries per player-per game. The current method of reporting exposure regards the time a player was actually on the field. In other words, a player who spent only 5 minutes on the field was counted as an exposure in the same way as a player who spent 50 minutes on the field. It is therefore difficult to compare football data to other football data and to other sports that typically report injury rates based upon exposure hours (EH). Despite this, the highest rates of injury reported for American football were: 140[14], 16[15], and 3[16] EH respectively.

The authors are also aware that examining only those studies that used exposure time as the denominator eliminates some studies that have investigated sport injury rates using other measurements; however, it is simply impossible to compare one study type (i.e. exposure time) to another type (i.e. exposure game or players). The authors believe that this particular point is of paramount importance to the future of sport injury epidemiology research. They believe that the methodology used to study sport injury rates should become standardised at the international level and should utilise the exposure time as the denominator when reporting injury rates in future studies. This would enable valid and reliable meta-analyses to be conducted, without having to eliminate large numbers of otherwise high-quality studies from the review.

The authors do not exclude the possibility or even the probability that there are outliers (i.e. those studies with the highest injury rates) and that they might represent bias or study errors. These studies represent outliers for each sport and no studies report higher rates; therefore they represent the highest known possible injury rates for each given sport. The data presented in this study with regard to bull riding, represents the sum total of epidemiologic data available on total athlete injuries sustained in the sport, while the same is not true for the other sports against which bull riding was compared. The authors did not attempt to average or meta-analyze the data from the other sports; therefore the reader is cautioned not to draw conclusions about the mean or average rates of injury for these other sports. Comparing the outlying (at the higher end) sport injury rates of these other sports to the data this study has on bull riding is the extent to which the authors went to show that the injury rate in bull riding is significantly greater than the rates in the comparison of sports.

The bull riding data collection lost data when one timer/recorder was used, because a second bull rider's time could theoretically start prior to the completion of the current ride. This was acknowledged by the individuals who were recording the times; the authors then started to use teams of timers/recorders. The potential for an effect on results is mitigated by the normal distribution of the timed exposures in Figure 1.

No attempt was made to control for sample sizes in the reports of injury rates. Although some of the data presented in Table 1 are from very small sample sizes, the most likely effect of these small sample sizes is to overestimate injury rates. Moreover, because the authors only used the outlier studies of sport injury rates in the comparison to bull riding injury rates, it is almost certain that the mean injury rates of these other sports are far lower. Thus the overall presentation of data in Table 1 supports the hypothesis that bull riding has the highest injury incidence as a function of exposure time, or per 1000 EH.

Conclusion

Until now, there have been no published reports on the exposure time of American rodeo rough stock events; therefore this study presents the first such precise observation that an average bull riding exposure is 80.26 seconds. Using published injury rate data and assuming an average 80-second exposure time, the injury rate for that bull riding study is 1440 injuries per 1000 EH.

The next highest injury rate found in the literature search was amateur boxing, with an injury rate of 920 per 1000 EH, while the second and third highest reported injury rates were 825 and 680 injuries per 1000 EH in semi-professional rugby and female boxing, respectively. According to these data, the bull rider is 1.56 times more likely to be injured than the amateur boxer, 1.75 times

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more likely than the semi-professional rugby player, and 2.1 times more likely to be injured than a female boxer (Table 2).

As a result of these analyses, it is a simple matter to conclude that there is a universal difference in the injury rates between bull riding and most other sports; and these authors, therefore, are compelled to declare the sport of bull riding to be the most dangerous organised sport in the world.

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