Why Median Severity and Ordinal Scale Severity Values should not be used for Injury Burden Results: A Critical Review

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ABSTRACT

Injury burden is a composite measure of injury incidence and mean severity; this parameter has been reported as an output measure from injury surveillance studies in rugby for over 20 years. The benefits of reporting injury burden results have, more recently, been recognised in other sports. This wider use of injury burden as an output measure from injury surveillance studies has, however, highlighted misunderstandings about how to calculate, present and interpret injury burden data. The aim of this critical review is to explain why median severity and ordinal severity scales should not be used to calculate and report injury burden results in injury surveillance studies. Equations are presented to show how injury burden results should be calculated, and graphs and tables are presented to explain the errors that are introduced when median severity and ordinal scales of severity are used instead of mean severity. This critical review is intended to highlight the correct procedures for calculating, reporting and interpreting injury burden results in order to avoid incorrect results, conclusions and injury prevention recommendations being published.

Introduction

The impact of injuries on athletes varies from minor pain with no detrimental effect on their ability to train and compete to short-term, long-term, career-ending and catastrophic injuries [1] and long-term health conditions such as osteoarthritis [2]. Injuries in sport can be managed effectively using a risk management approach [3, 4] with the key stages of this approach being risk identification, risk assessment, risk evaluation and risk mitigation [3, 5]. Injury surveillance studies underpin the assessment stage of the risk management process and provide the evidence-base on which risk evaluations are undertaken and cost-effective injury prevention strategies are developed and justified [6]. Injury burden, which is a composite measure of injury incidence and mean injury severity [7], is an important parameter in several areas of sport, as the data are relevant to athletes' short and long-term health [8] and their ability to train and compete [9, 10]. Consensus statements for sports injury surveillance studies are well established and the recommended procedures and output measures enable injury burden values to be calculated in both athlete welfare [11–13] and athlete performance [9, 10] contexts. Although injury burden has been recognised and reported as an output measure from injury surveillance studies in rugby for over 20 years [14–16], the importance of injury burden information has only more recently been recognised and recommended for other sports [17].

The principles, practices and problems associated with recording and using injury burden values have been discussed previously [7, 18]. The increasing importance given to reporting injury burden values in injury surveillance studies has, however, been accompanied by errors and misunderstandings about how to calculate, present and interpret the data. For injury burden measurements to deliver their full range of benefits, it is essential that valid results are reported in order to avoid reaching incorrect conclusions and making invalid recommendations.

The objective of this review is to explain why median severity and ordinal severity scales should not be used to calculate and report injury burden results in injury surveillance studies.

Materials and Methods

A range of parameters is used to characterise and compare injuries sustained in sport. Typically, these parameters include injury location, type, nature (e. g. acute, gradual onset) and cause (e. g. contact, non-contact, competition, training) [11–13]. The primary output measures reported in injury surveillance studies are (i) the frequency with which injuries are sustained (incidence) and (ii) a central-tendency value for the severity of injuries sustained. Injury severity in a sample population may be reported as the mode, median or mean value, all expressed as the number of days-absence resulting from injury. If the severity data follow a normal distribution the three central-tendency measures return the same value [19]. Sports injury severity values, however, rarely follow a normal distribution and, while it is theoretically possible for injury severity data to be left-skewed, they most often follow a right-skewed distribution [18, 20–22]. This means that the three central-tendency values do not have the same value and their values will usually follow the sequence of mean > median > mode. Severity values can also be recorded using ordinal scales, such as those recommended in some sports injury surveillance consensus statements [12, 13].

Injuries that result in athletes being unable to train or compete are referred to as 'time-loss injuries'; those that do not prevent an athlete from training and competing are referred to as 'non-time-loss injuries' [12, 13]. Injury burden, which describes the total number of days that an athlete population is unable to train or compete, can be expressed as the total days-absence resulting from injuries sustained in a specified setting over a specified period of time. For non-time-loss injuries that might impact on an athlete's ability to train and/or compete at their normal performance level, days-absence can be replaced by the number of full-time-equivalent (FTE) days-absence based on the magnitude of the effect the injuries have on the athletes' activities [9, 10]. For example, an athlete only able to train at 80 % of their normal performance level for 10 days would be classified as having sustained {10 x (100–80)}/100 FTE days-absence, equal to 2 FTE days. Because the total number of days-absence recorded in a study is dependent on the sample size and the period of exposure, injury burden values are usually normalised and reported as the number of days-absence/1000 athlete-hours [7, 18]. Normalised injury burden values can be calculated in two ways: (i) as [total days-absence x 1000]/[total athlete-hours of exposure] or (ii) as [injury incidence (expressed as the number of injuries/1000 athlete-hours) x mean severity of injury (expressed as days-absence)]. Injury burden reported as days-absence/1000 athlete-hours of exposure is, therefore, directly related to the total number of days-absence, with the slope of the relationship equal to [1000/total athlete-hours of exposure]. Plotting mean injury severity values against injury incidence values within a risk matrix containing iso-risk contours provides a simple, visual method to present injury burden results and to highlight the highest and lowest-risk injuries in a particular setting [7, 18].

Results

▶ **Table 1** presents a lower limb injury data set for 25 (hypothetical) lower limb injuries sustained by one rugby team playing 25 games (15 players/game; 80 minutes/game; total exposure: 500 player-hours): these data equate to an overall incidence of lower limb injuries in the sample population of 50.0 injuries/1000 player-hours (25 × 1000/500). ▶ **Table 1** shows the number of player-days-absence associated with each of the 25 injuries together with the incidences and the mean and median severities of the injuries sustained at each injury location. In addition, injury burden values are presented for each injury location based on the incidence values and both the mean and median injury severity values for the locations. ▶ **Fig. 1** displays these two sets of injury burden values plotted against the corresponding total days-absence, for the five body locations. ▶ **Fig. 2** presents a risk matrix with the mean and median severities of injury plotted against the corresponding incidence values for the 5 injury locations (see ▶ **Table 1** for the data used).

Incidence, mean and median severities and injury burden values based on previously published rugby data [17], are presented for eight body locations (lumbar spine, hip/groin, wrist/hand, chest, lower leg, foot, ankle, thigh) in ▶ **Table 2**.

Four examples of ordinal scales used to record the consequences of injuries in clinical and performance-related contexts are shown in ▶ **Table 3**. While ▶ **Fig. 3** illustrates the consistency between these ordinal scales in terms of their rank order, it highlights the non-linearity of the scales in terms of days-absence. ▶ **Table 4** shows the injury severity data presented in ▶ **Table 1** after the days-absence values have been transformed into data based on the ordinal scales shown in ▶ **Fig. 3** and columns 1 and 2 of ▶ **Table 3**. ▶ **Table 4** also includes the corresponding mean and median severity values derived from these ordinal scale values and the corresponding injury burden values based on the mean and median ordinal severity scale values. ▶ **Fig. 4** plots the two sets of injury burden data shown in ▶ **Table 4** against the corresponding total days-absence values for the five body locations.

Discussion

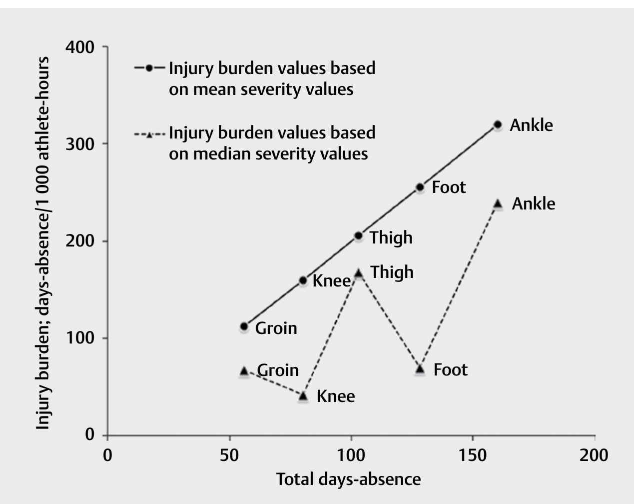
One-off injury burden measurements are normally used to report the level of injury risk experienced by a defined athlete population during specific competitions, events or over defined periods of time. Injury burden values can also be ranked as a function of, for example, injury location, type or causation to create injury risk spectra in order to identify priorities for injury prevention. Repeated, longitudinal measurements of injury burden are used to monitor long-term trends in injury risk or to measure injury risks pre- and post-interventions such as injury prevention strategies. Injury burden values can be displayed visually in risk matrices by plotting mean severity values against the corresponding injury incidence values [7, 18]. Whichever reporting method is adopted, however, it is essential that the data are calculated and presented correctly.

Because the three central-tendency values of severity are rarely the same in injury surveillance studies, it is essential that the correct severity value (i. e. the mean value) is used to calculate injury burden. Instead of using mean severity of injury to calculate and present injury burden results, some publications have used the median severity of injury [20–22]. The first section of this review, therefore, explains why median severity values should not be used to calculate or present injury burden results. The results presented in ▶ **Table 1** and ▶ **Fig. 1** show that injury burden results based on the median severity of injury under-estimate the true injury burden. ▶ **Fig. 1** also demonstrates that, while a linear relationship exists

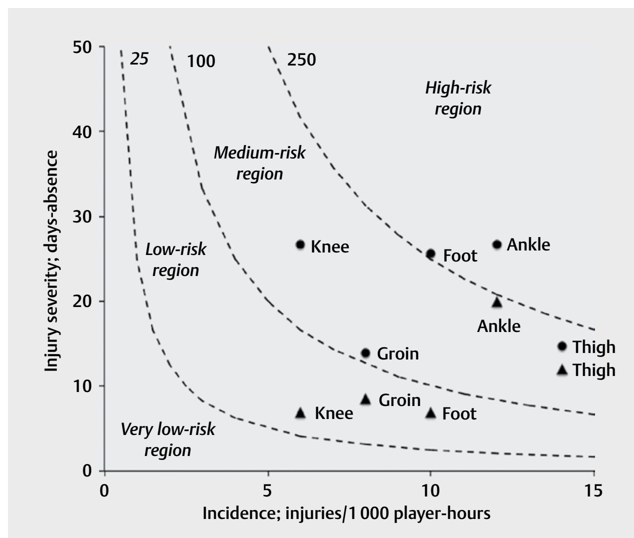
▶ **Table 1** Hypothetical lower limb injury data set for a rugby team playing 25 games (15 players/game) of 80 minutes duration (total match exposure: 500 player-match-hours).

	Injury location (number of injuries); days-absence				
	Thigh (7)	**Ankle (6)**	**Foot (5)**	**Groin (4)**	**Knee (3)**
1	2	10	2	4	3
2	3	12	4	7	7
3	6	16	7	10	70
4	12	24	40	35	
5	20	43	75		
6	25	55			
7	35				
Match exposure (player-hours)	500	500	500	500	500
Total days-absence (days)	103	160	128	56	80
Incidence(i)	14.0	12.0	10.0	8.0	6.0
Mean severity, days-absence	14.7	26.7	25.6	14.0	26.7
Median severity, days-absence	12.0	20.0	7.0	8.5	7.0
Burden (mean severity) (ii)	206	320	256	112	160
Burden (median severity) (ii)	168	240	70	68	42

(i): Incidence reported as injuries/1000 player-hours; (ii): Burden reported as days-absence/1000 player-hours.



▶ **Fig. 1** Relationships between injury burdens, for 5 injury locations, calculated using mean and median severity values and the total days-absence shown for the injury locations in ▶ **Table 1**.



▶ **Fig. 2** Risk matrix showing mean and median injury severity values plotted against corresponding incidence values for the 5 lower limb injury locations (based on data shown in ▶ **Table 1**). The risk contours represent injury burden values of 25, 100 and 250 days-absence/1000 player-hours; (● mean injury severity values; ▲: median injury severity values).

between total days-absence and injury burden values based on the mean severity of injury, no such linear relationship exists when using the median severity of injury. Hence, using median severity values to calculate and present injury burden results can be seen to have no mathematical validity will inevitably give rise to misleading conclusions and recommendations.

If median injury severity values are used, instead of mean severity values, to present injury burden data in a risk matrix, the resultant graphs generate incorrect risk profiles, which will again lead to misleading conclusions and recommendations; see ▶ **Table 1** and ▶ **Fig. 2**. In this case, the injury burden results derived from the mean severity values place two body locations (ankle, foot) in the ‘ high-risk region’ of the risk matrix, three body locations (thigh, knee, groin) in the ‘medium-risk region’ and no body locations in the ‘low-risk region’. If median injury severity values are used, no body locations are placed in the ‘high-risk region’ of the matrix, two injuries (ankle, thigh) in the ‘medium-risk region’ and three injuries (foot, groin, knee) in the ‘low-risk region’. Of the five body locations, only the results for the thigh appear in the same injury risk region (medium-risk) when using both the mean and median severity-based injury burden results.

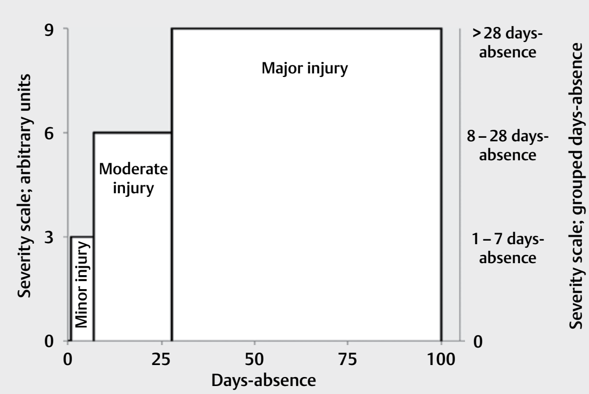
The results presented in ▶ **Table 2** demonstrate that the conclusions presented above are not merely an inherent factor of the hypothetical data set used in this review. Reviewing the injury bur-

▶ **Table 2** Incidence, median severity, mean severity and injury burden based on median and mean severity of injuries sustained by rugby players at eight body locations. Data derived from Table 6 in [17].

Injury location	Incidence;	Injury severity, days		Injury burden; days-absence/1000 player-hours	
	injuries/1000 player-hours	Median	Mean	Based on median severity	Based on mean severity
Lumbar spine	1.5	10	44.0	15	66
Hip/groin	1.9	9	43.2	17	82
Wrist/hand	4.5	10	43.1	45	194
Chest	3.8	13	19.7	49	75
Lower leg	4.0	17	47.5	68	190
Foot	1.9	37	44.2	70	84
Ankle	6.9	15	46.4	104	320
Thigh	6.4	14	26.7	90	171

▶ **Table 3** Examples of ordinal scales used for recording injury consequences in clinical and performance-related contexts.

Arbitrary scale values	Clinical context		Performance context
	Grouped days-absence	Treatment/ rehabilitation	
0	No days-absence	No treatment or rehabilitation required	No reduction in athletic performance
3	1 to 7 days-absence	Minor treatment and/or rehabilitation required	Minor reduction in athletic performance
6	8 to 28 days-absence	Moderate treatment and/or rehabilitation required	Moderate reduction in athletic performance
9	>28 days-absence	Major treatment and/or rehabilitation required	Major reduction in athletic performance



▶ **Fig. 3** Relationships between ordinal consequence scales (see ▶ **Table 3**) and days-absence from injury.

den results based on median severity (▶ **Table 2**, column 5) would lead to the following incorrect conclusions:

- Injury burden values for lumbar spine (15) and hip/groin (17) injuries are similar;
- Injury burden values for wrist/hand (45) and chest (49) injuries are similar;
- Injury burden values for lower leg (68) and foot (70) injuries are similar; and
- Injury burden values for ankle (104) and thigh (90) injuries are similar.

If these injuries are compared correctly using injury burden values based on mean severity (▶ **Table 2**, column 6), it can be seen that the correct conclusions are:

- Injury burden for hip/groin injuries (82) is ~25 % higher than that for lumbar spine injuries (66);
- Injury burden for wrist/hand injuries (194) is almost three times higher than that for chest injuries (75);
- Injury burden for lower leg injuries (190) is more than twice that for foot injuries (84);
- Injury burden for ankle injuries (320) is almost twice that for thigh injuries (171).

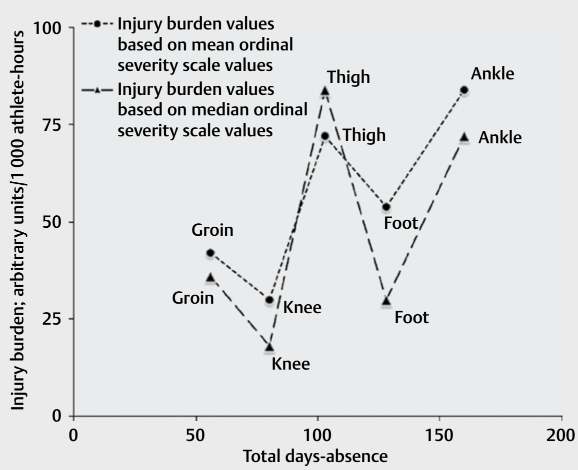
A further source of error arises when injury burden values based on median severity values are presented and assessed in risk matrices containing iso-risk contours based on mean injury severity values. Comparing the injury burden results shown in ▶ **Table 1** and ▶ **Fig. 2** based on mean severity leads to the following conclusion regarding the rank order for the risks of injury: Ankle > Foot > Thigh > Knee > Groin. Using injury burden values based on the median severity of injuries, however, leads to a different conclusion regarding the rank order of injury risks: Ankle > Thigh > Foot > Groin > Knee.

The second section of this review explains why ordinal scales of injury severity should not be used to calculate or present injury burden results. While ▶ **Fig. 1** confirmed the expected linear relationship between total days-absence and injury burden values based on mean severity using days-absence, ▶ **Fig. 4** shows that linear relationships do not exist between total days-absence and injury burden values when both mean and median severity values derived from ordinal severity scales are used. As injury burden provides a ratio scale of injury risk, the injury incidence and injury severity values used to calculate injury burden must both be based on ratio scales. The requirements for ratio scales are that they include an absolute zero and equal interval scale values: these criteria enable ratio scale values to be added, subtracted, multiplied and divided

▶ **Table 4** Injury data presented in ▶ **Table 1** after severity values have been transformed into ordinal scale values (based on the scales shown in ▶ **Table 3**, columns 1 and 2).

	Injury location (number of injuries); ordinal scale severity values (i)				
	Thigh (7)	**Ankle (6)**	**Foot (5)**	**Groin (4)**	**Knee (3)**
1	3	6	3	3	3
2	3	6	3	3	3
3	3	6	3	6	9
4	6	6	9	9	
5	6	9	9		
6	6	9			
7	9				
Match exposure (player-hours) (ii)	500	500	500	500	500
Total days-absence (days) (ii)	103	160	128	56	80
Incidence (iii)	14.0	12.0	10.0	8.0	6.0
Mean severity (ordinal scale) (iv)	5.1	7.0	5.4	5.3	5.0
Median severity (ordinal scale) (iv)	6.0	6.0	3.0	4.5	3.0
Burden (mean severity) (v)	71	84	54	42	30
Burden (median severity) (v)	84	72	30	36	18

(i): See ▶ **Table 2**, columns 1 and 2; (ii): See ▶ **Table 1** for exposure value and total days-absence; (iii): Incidence reported as injuries/1000 player-hours; (iv): Severity derived from the ordinal scale values (▶ **Table 2**); (v): Burden based on the incidence of injury and the mean and median severity ordinal scale values.



▶ **Fig. 4** Relationships between total days-absence and injury burden values calculated using mean and median ordinal scale severity values (see ▶ **Table 4**).

[19]. Injury severity values based on days-absence meet the criteria for a ratio scale and these values can, therefore, be averaged to provide mean injury severity values. Injury severity values derived from ordinal scales, which do not have equal scale values (see ▶ **Table 3** and ▶ **Fig. 3**), can be used for ranking purposes but the values cannot be added, subtracted, multiplied or divided [19]. Ordinal scale severity values cannot, therefore, be used to calculate meaningful injury burden values. Although applying numerical scale values, such as 0, 3, 6, 9, to ordinal scales, (see ▶ **Table 3**, column 1) may (i) give an illusion that the intervals are equal and (ii) create the impression that mathematical calculations can be carried out using the values, there is no mathematical justification for this.

▶ **Fig. 3** highlights the non-linearity of ordinal scales and the disproportionality of the scale intervals in terms of days-absence. Ordinal scale severity values should, therefore, not be used in injury surveillance studies for calculating injury burden results, as they introduce the potential for errors in the conclusions and recommendations presented. For example, from the ordinal scales presented in ▶ **Table 3** and ▶ **Fig. 3**, it can be seen that if one athlete in an injury surveillance study sustained a minor injury requiring 2 days-absence (ordinal severity scale value: 3) and a second athlete in the study sustained a moderate injury requiring 8 days-absence (ordinal severity scale value: 6), the total time-loss from athletic activity would be 10 days (mean severity: 5 days-absence). These two injuries, however, would lead to a mean severity score in the study of 4.5 if based on the arbitrary ordinal scale. If in a second study, one athlete sustained an injury that did not result in time-loss (ordinal severity scale value: 0) and a second athlete in the study sustained an injury that resulted in 100 days-absence (ordinal severity scale value: 9), the total time loss from athletic activity would be 100 days (mean severity: 50 days-absence). These two injuries would, however, also lead to a mean severity score of 4.5 when based on the ordinal severity scale. Therefore, presenting the injury burden results from these studies based on ordinal scale severity values implies that the injury burden outcomes from the two studies were identical, even though the actual injury burden in the second study was ten-times higher than the injury burden in the first study.

Using ordinal scale mean and median severity values both lead to the incorrect ranking of injury risks. For example, the results presented in ▶ **Table 4** show that injury burden derived from mean values of the ordinal scales rank the risks as: Ankle > Thigh > Foot > Groin > Knee, while injury burden values derived from median values of the ordinal scale rank the risks as: Thigh > Ankle > Groin > Foot > Knee. Neither of these rank orders of injury burden agrees with the correct evaluation based on mean days-absence, which is shown above.

When injury consequences are assessed in a performance-related context, injury consequences are often recorded on a daily or weekly basis as a 'daily/weekly severity score'. These individual daily/weekly ordinal scale values are summed to produce a 'total severity score' for the duration of the athlete's adverse health condition. The 'total severity score' values recorded for all cases of the adverse health condition are then averaged to produce a 'mean severity score' for the adverse health condition. These 'mean severity scores' are then often plotted against the incidences of the adverse health conditions within a risk matrix. The same arguments regarding the non-validity of using ordinal scale values that were discussed above also apply in these cases. Furthermore, this approach is compounded further if several ordinal scale values are used to provide a number of injury severity outcome measures, which are then summed to derive a 'daily/weekly severity score' for an adverse health condition.

The discussion and examples presented above illustrate why ordinal scale severity values produce incorrect injury burden values and why these will in turn also lead to incorrect and inconsistent conclusions and recommendations from injury surveillance studies.

Injury burden data derived from injury surveillance studies provide important information about athletes' risks of injury; this information enables injury risks to be quantified and evaluated and injury prevention priorities to be identified [7, 18]. Unfortunately, in many of these studies, the principles associated with collecting, calculating, reporting and presenting injury burden data have not been fully understood. As a consequence, median severity values and/or ordinal scales of severity have been incorrectly employed to calculate and present injury burden values in a range of sports, including: football [20–22], ice hockey [23–25], athletics [26, 27], gymnastics [28] and Paralympics [29, 30].

The discussion and examples presented here have demonstrated the nature of the errors associated with using median severity and ordinal severity scales to calculate and present injury burden results. It is recommended that researchers intending to publish injury burden results are familiar with the correct procedures for calculating, reporting and presenting injury burden results in order to avoid presenting incorrect injury burden results, conclusions and recommendations.

Conflict of Interest

The author has no conflicts of interests associated with this publication.

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