Assessing Potential Risk Factors of Concussion using Three-Year Collegiate Athletes Data

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Overview

Introduction: Background and Motivation

What is concussion?

Definition

1. A type of traumatic brain injury caused by a bump, blow, or jolt to the head that can change the way your brain normally works.
2. Also referred to as a type of mild Traumatic Brain Injury(mTBI)[**biausa**]

Concussion has been labeled as a major public health issue due to acute and potential long term effects associated with this injury[**collins**]

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Athletes are population at high risk of concussion, and cumulative effects of repeated concussions can have long term consequences[**eva**, **gro**, **main**].

Some Statistics

According to University of Pittsburgh's Brain Trauma Research Center:

1. More than $300,000$ sports-related concussions occur annually in the US.
2. The likelihood of suffering a concussion while playing a contact sport is estimated to be as high as 19 percent per year of play
3. More than $62,000$ concussions are sustained each year in high school contact sports

and more ...

Introduction: Background and Motivation

Our goal in this study is to detect the association between concussion incidence and other potential risk factors among NCAA athletes.

Goals

1. We follow a previous study on athletes between the $1997 - 1999$ academic year[**main**].
2. the previous study only focused on the gender difference.
3. Attempt to reproduce their results with our method.
4. Conduct further analyses on the other risk factors, including types of sport, game settings (competitive game or practice), and academic years, as well as the potential interactions between different factors.

We will get into details in the method section.

Data and Method – Competitive Games Data

The following table shows data for concussion occurrences during competitive games

		Males			Females		
Year	Sport	Concussion Cases	Athlete Exposures	Incidence Rate	Concussion Cases	Athlete Exposures	Incidence Rate
1997	Soccer	34	30966	1.0979	51	24981	2.0489
	Lacrosse	19	13486	1.4089	12	8762	1.3696
	Basketball	8	27706	0.2887	16	29413	0.5439
	Softball/ Baseball	22	51351	0.4284	9	26834	0.3354
	Gymnastics	0	227	0	1	8903	0.1123
1998	Soccer	27	19142	1.4105	47	22934	2.0494
	Lacrosse	15	9514	1.5766	7	7122	0.9829
	Basketball	21	39367	0.5334	30	38174	0.7859
	Softball/ Baseball	6	49207	0.1219	10	44280	0.2258
	Gymnastics	0	221	0	0	822	0
1999	Soccer	40	25636	1.5603	60	27167	2.2086
	Lacrosse	17	12177	1.3961	7	8531	0.8205
	Basketball	20	32836	0.6091	26	28992	0.8968
	Softball/ Baseball	25	80215	0.3117	28	75355	0.3716
	Gymnastics	0	1179	0	0	2083	0
	Total	254	393230	0.6459	304	354353	0.8579

Table 1. Total Game Concussions and Concussion Rates (per 1,000 Athlete Exposures) by Sport, Year, and Gender
Source: Covassin et al. [11]

Data and Method – Practice Sessions Data

The following table shows data for concussion occurrences during practice

		Males			Females		
Year	Sport	Concussion Cases	Athlete Exposures	Incidence Rate	Concussion Cases	Athlete Exposures	Incidence Rate
1997	Soccer	10	127013	0.0787	12	87442	0.1372
	Lacrosse	11	76246	0.1443	14	33342	0.4199
	Basketball	16	118905	0.1346	24	104872	0.2289
	Softball/ Baseball	10	129623	0.0772	7	45291	0.1546
	Gymnastics	0	3897	0	4	31006	0.1290
1998	Soccer	8	77769	0.1029	9	77286	0.1165
	Lacrosse	4	56201	0.0712	3	31048	0.0966
	Basketball	31	164607	0.1883	26	140817	0.1846
	Softball/ Baseball	9	130988	0.0687	7	76076	0.0920
	Gymnastics	0	3265	0	0	9253	0
1999	Soccer	4	106241	0.0377	13	100855	0.1289
	Lacrosse	14	74115	0.1889	5	37765	0.1324
	Basketball	22	140637	0.1564	25	108480	0.2305
	Softball/ Baseball	9	213674	0.04212	17	129155	0.1316
	Gymnastics	0	9867	0	0	2083	0
	Total	148	1433048	0.1033	167	1032517	0.1617

Table 2. Total Practice Concussions and Concussion Rates (per 1,000 Athlete Exposures) by Sport, Year, and Gender
Source: Covassin et al. [11]

Data and Method – Contingency Table

We first conduct our study by analyzing the contingency table(non-model method):

Analysis of Contingency Tables

1. Analyze the distribution of response(concussion) and risk factors (gender, sports and game setting).
2. Analyze the marginal association between response and risk factors (gender, game setting, sports type, and year) using χ^2 tests.
3. Analyze the association between response and gender for a single type of sport using χ^2 test.
4. Analyze the conditional association between response and gender, also between response and game settings conditioned on academic years, for each single type of sport using the CMH tests.

Data and Method – Logistic Model

We will also build a logistic model to analyze the associations between incidence of concussion and risk factors:

Logistic Model:

$$\text{logit}(\pi(\vec{\mathbf{x}})) = \alpha + \vec{\beta} \cdot \vec{\mathbf{x}}$$

$\vec{\mathbf{x}}$ is a vector, the length depends on how many risk factors we are considering.

Data and Method – Dummy Variables

We also create our own dummy variables for sports type, to make it easier for us to analyze individual type of sport later on.

dummy variables

$$T_1 = \begin{cases} 1 & \text{if soccer} \\ 0 & \text{if baseball/ softball} \end{cases} \qquad Y_1 = \begin{cases} 1 & \text{if academic year 1997 – 1998} \\ 0 & \text{if academic year 1998 – 1999} \end{cases}$$

$$T_2 = \begin{cases} 1 & \text{if lacrosse} \\ 0 & \text{if baseball/ softball} \end{cases} \qquad Y_2 = \begin{cases} 1 & \text{if academic year 1999 – 2000} \\ 0 & \text{if academic year 1998 – 1999} \end{cases}$$

$$T_3 = \begin{cases} 1 & \text{if basketball} \\ 0 & \text{if baseball/ softball} \end{cases}$$

We need to point out that gymnastic is not considered in our study anymore, since there is almost no concussion incidence in this sport.

Data and Method – Predictor Selection

We implemented forward, backward, and stepwise selection procedures using `PROC LOGISTIC`.

Fitted Model:

$$\text{logit}(\pi) = \alpha + \beta_1 G + \beta_2 S + \beta_3 T + \beta_4 S * T$$

where $G =$"gender", $S =$"Game Setting", $T =$"Sports Type", and $Y =$"'year'

Results – Frequency Distribution of Counts

Frequency distribution of responses and risk factors conditioned on academic year:

Variable	Academic Year			Total
	1997 – 1998	1998 – 1999	1999 – 2000	
Concussion Status				
Yes	275 (0.03%)	260 (0.03%)	332 (0.03%)	867
No	935958 (99.97%)	984272 (99.97%)	1201499 (99.97%)	3121729
Gender				
Males	575296 (61.45%)	546795 (55.54%)	685531 (57.04%)	1807622
Females	360937 (38.55%)	437737 (44.46%)	516300 (42.96%)	1807622
Game Setting				
Game	213499 (22.80%)	229740 (23.33%)	290909 (24.21%)	734148
Practice	722734 (77.20%)	754792 (76.67%)	910922 (75.79%)	2388448
Type of Sport				
Soccer	270402 (28.88%)	197131 (20.02%)	259899 (21.63%)	727432
Lacrosse	131836 (14.08%)	103885 (10.55%)	132588 (11.03%)	368309
Basketball	280896 (30.00%)	382965 (38.90%)	310945 (25.87%)	974806
Softball/ Baseball	253099 (27.03%)	300551 (30.53%)	498399 (41.47%)	1052049
Total	936233	984532	1201831	3122596

Table 3. Frequency Distribution of Variables Across Different Academic Years (Percentages Are Across Each Year)

Results – Gender vs. Concussion

Table of Gender by Status			
Gender(Gender of Atheletes)	Status(Concussion Status)		
	Yes	No	Total
Female	465 0.04	1314509 99.96	1314974
Male	402 0.02	1807220 99.98	1807622
Total	867	3121729	3122596

Results – Game Setting vs. Concussion

Table of Setting by Status			
	Status(Concussion Status)		
Setting(Setting)	Yes	No	Total
Game	557 0.08	733591 99.92	734148
Practice	310 0.01	2388138 99.99	2388448
Total	867	3121729	3122596

Results – Test of Independence

Assess marginal association between concussion and other variables:

	Pearson's X^2		**Likelihood-Ratio G^2**	
Variable	Observed Statistic	P-Value	Observed Statistic	P-Value
Gender	47.2255	< 0.0001	46.4949	< 0.0001
Game Setting	800.1651	< 0.0001	648.5783	< 0.0001
Sport Type	130.5350	< 0.0001	132.8899	< 0.0001
Year	1.5334	0.4646	1.5279	0.4648

Results – Test of (Marginal) Independence

Assess marginal association between concussion and gender for each type of sport:

	Our Result		Covassin et al. [5]	
Variable	Observed Statistic	P-Value	Observed Statistic	P-Value
Soccer	25.2377	< 0.0001	12.9900	0.0003
Lacrosse	0.5579	0.4552	1.6300	0.2017
Basketball	9.0881	0.0026	5.1400	0.0233
Softball/ Baseball	8.6754	0.0032	0.9900	0.3197

Table 5. Comparison of Pearson Chi-square X^2 Test of Marginal Association between Concussion and Gender for Each Type of Sport using Two Different approaches to Compute Theoretic Expected Values

By saying marginal we mean 'marginal' across different academic years.

Results – Test of (Conditional) Independence

Homogeneous association between concussion and gender/game setting (Breslow-Day test), as well as conditional independence between concussion and gender/game setting (CMH test) for individual type of sport, conditioned on academic years.

	X Variable			
	Gender		Game Setting	
Sport	Breslow-Day Test	CMH Test	Breslow-Day Test	CMH Test
Soccer	0.6548	< 0.0001	0.4240	< 0.0001
Lacrosse	0.0653	0.4064	0.1268	< 0.0001
Basketball	0.4496	0.0022	0.2735	< 0.0001
Softball/ Baseball	0.5477	0.0015	0.2322	< 0.0001

Table 6. P-Values for Breslow-Day Test of Homogeneous Association and CMH Test of Conditional Association between Concussion with Gender and Game Setting for Each Type of Sport Across Different Academic Yeas

Results – Fitted Logistic Regression Model

Following MLE parameter estimates and the corresponding 95% Wald's confidence intervals were obtained:

Parameter	Estimate	ASE	P-value	95% Wald's Confidence Interval
Intercept (β_0)	-9.5451	0.1334	< 0.0001	$(-9.8066, -9.2827)$
Gender (β_1)	0.3355	0.0685	< 0.0001	$(0.2012, 0.4698)$
Game Setting (β_2)	1.2880	0.1643	< 0.0001	$(0.9659, 1.6101)$
Type of Sport				
Soccer (β_3)	0.1371	0.1868	0.4629	$(-0.2289, 0.5031)$
Lacrosse (β_4)	0.7130	0.1912	0.0002	$(0.3383, 1.0878)$
Basketball (β_5)	0.7835	0.1548	< 0.0001	$(0.4802, 1.0869)$
Game Setting*Type of Sport				
Game*Soccer (β_6)	1.5738	0.2207	< 0.0001	$(1.1412, 2.0063)$
Game*Lacrosse (β_7)	0.7427	0.2441	0.0023	$(0.2643, 1.2211)$
Game*Basketball (β_8)	-0.0972	0.2054	0.6359	$(-0.4998, 0.3053)$

Table 7. Maximum Likelihood Parameter Estimates, Asymptotic Standard Error and 95% Wald Confidence Interval for Our Logistic Regression Model

Interpretation of Parameter Estimates

Estimates Interpretation:

1. Gender (G): *Controlling for game setting and all four types of sports, the estimated odds of sustaining concussion for the female athletes are* $\exp\left\{\widehat{\beta}_1\right\} = \exp\{0.3355\} = 1.3986$ *times the estimated odds of sustaining concussion for the male athletes.*
2. Game Setting (S): *Controlling for gender (G), the estimated odds of sustaining concussion during actual game for those athletes who play*
   - (i) *softball/ baseball are* $\exp\left\{\widehat{\beta}_2\right\} = \exp\{1.2880\} = 3.6255$
   - (ii) *soccer are* $\exp\left\{\widehat{\beta}_2 + \widehat{\beta}_6\right\} = \exp\{1.2880 + 1.5738\} = 17.4929$
   - (iii) *lacrosse are* $\exp\left\{\widehat{\beta}_2 + \widehat{\beta}_7\right\} = \exp\{1.2880 + 0.7427\} = 7.6194$
   - (iv) *basketball are* $\exp\left\{\widehat{\beta}_2 + \widehat{\beta}_8\right\} = \exp\{1.2880 - 0.0972\} = 3.2897$

   times the estimated odds of sustaining concussion for such athletes during practice session.

Discussion

Further Discussion

1. By χ^2 tests, we conclude that the association between concussion incidence and gender is significant. Even without formal tests, this can be observed by looking at table 1 and 2, where the concussion rates per 1,000 athlete exposures for females are greater than those for males. (Potential reason: weaker neck strength for females.)
2. Breslow-Day tests was found to be insignificant for all sports except lacrosse, suggesting existence of potential interaction.

Discussion

Further Discussion

1. Goodness of fit evaluated using deviance test statistic and AIC.

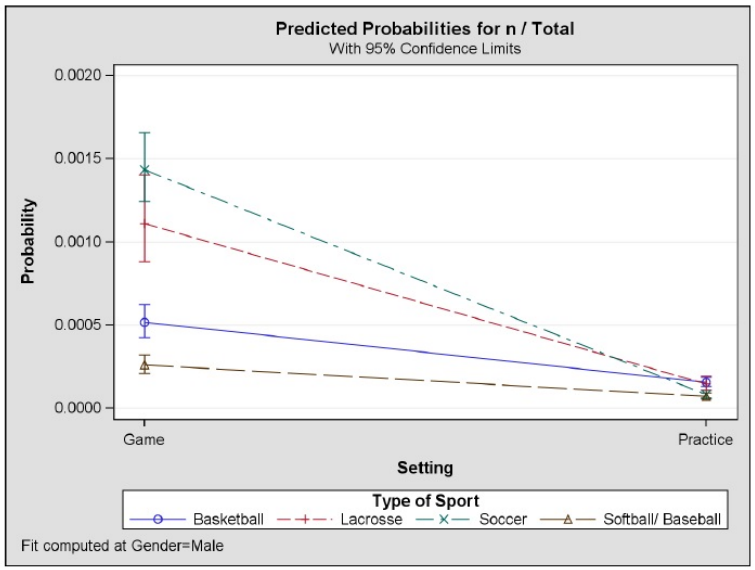
Model	Deviance		AIC
	Statistic	P-Value	
$G+S+T+Y$	161.3472	< 0.0001	403.4061
$G*S+T+Y$	160.1525	< 0.0001	404.2114
$G*T+S+Y$	153.7907	< 0.0001	403.8496
$G*Y+S+T$	159.8142	< 0.0001	405.8731
$G+S*T+Y$	59.8157	0.0993	309.8746
$G+S*Y+T$	159.4390	< 0.0001	405.4979
$G+S+T*Y$	144.6605	< 0.0001	402.7193
$G*S*T+Y$	43.9930	0.2327	312.0519
$G*S*Y+T$	153.0758	< 0.0001	409.1347
$G*T*Y+S$	129.8227	< 0.0001	415.8816
$G+S*T*Y$	30.2463	0.4018	316.3052
$G+S*T$	61.4080	0.1099	307.4669

Table 8. Goodness-of-Fit Tests for Various Logistic Models

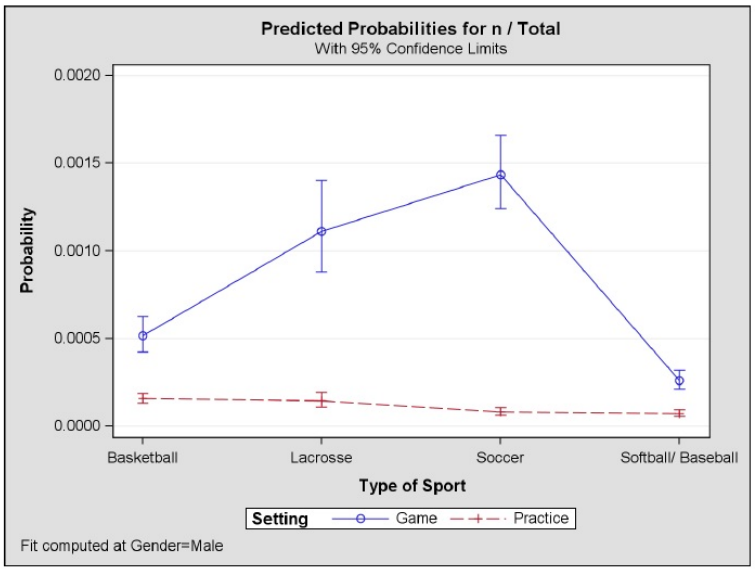
Discussion

Further Discussion

1. Plotted the predicted probability of concussion for each combination of game setting and sports, as well as Wald's confidence interval.



(a) Game setting on x-axis and type of sport as grouping variable



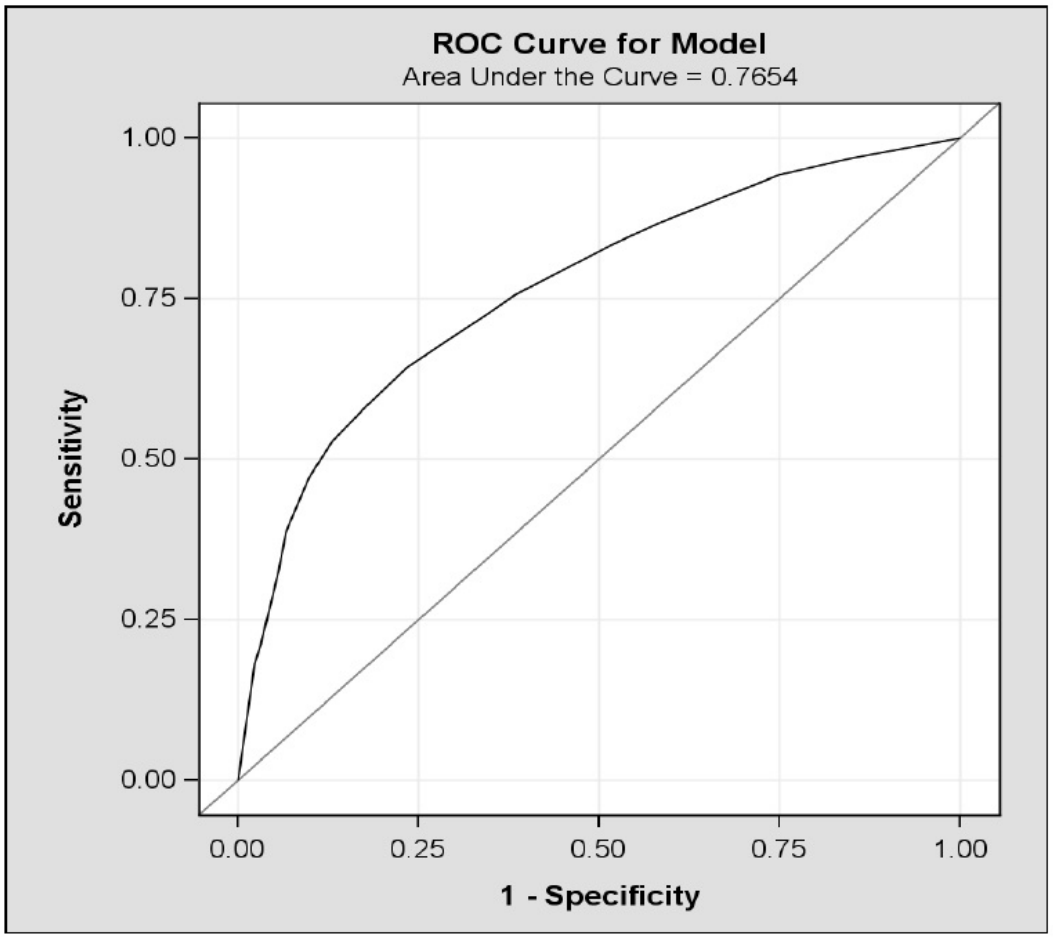
(b) Type of Sport on x-axis and game setting as grouping variable

Figure 1. Interaction plot depicting estimated effects of type of sport and game setting on the estimated probabilities of concussion, along with 95% confidence limits.

Discussion

Area Under the ROC Curve

1. Fitted Model: 0.7654; Simpler Model: 0.5790



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Thank You!