Assessing Accident Risks in Campus Recreation: A Retrospective Study

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Abstract

A simulation study was conducted to compare accident risks for the University of Wyoming Campus Recreation. Using Campus Rec. accident reports, times and locations/activities were analyzed with a randomization-test-style procedure using logistic regression. Each location/activity combination was compared with MAC basketball as the reference, and it was found that 1) accident risk is estimated to increase throughout the day, 2) no locations/activities had a higher accident risk than MAC basketball, but some have the same odds of an accident, and 3) most activities/locations have a much lower odds of an accident than MAC basketball. Considering the locations/activities with no difference as the highest accident risks, changes in risk management procedures are recommended to ensure quick reaction times and reasonable accident prevention.

Introduction

The University of Wyoming Campus Recreation department handles most of the non-Athletics recreation within the University. Like any recreation-based university department, accidents—being injuries, episodes of sickness, physical confrontations, etc.—are bound to happen occasionally under the supervision of Campus Rec. Preventing and responding to those accidents is outlined by risk management: the outlines the policies and procedures done to both minimize and respond quickly to accidents. Since accidents cannot be completely prevented, every location and activity in the department carries an inherent accident risk. However, some have higher accident risks than others. The analysis conducted intends to assist risk management by quantifying accident risk given a certain time, location, and activity. Knowing the highest accident risks can adjust Campus Rec. policies and procedures to address those risks.

Expectations

Risk factors such as patron traffic, competitiveness, anaerobic requirements for play, etc. are more present in certain activities like basketball and volleyball rather than badminton and cycling. Therefore, it is expected that some specific locations and activities will have a higher accident risk than others. It is hypothesized that MAC Gym basketball has the highest accident risk in Campus Recreation. The high traffic in MAC combined with its often-competitive play means more risk factors. Similarly high-traffic and competitive activities, like rugby and volleyball, are also expected to have a high accident risk, but less so than MAC basketball due to less general play. All other activities in Campus Rec. are expected to have lower accident risks due to sparser play and less risky movement.

Analysis Setup

Campus Rec. accident reports from the 2018 fall semester to October 31, 2022 were collected for analysis[1]. Any reports with critically missing information, such as activity or location, were not included. 139 reports were used, with 11 reports were missing time values. Those time entries were imputed as the mean time to maximize sample size. No personal information was recorded from the accident reports, and only the time, location, and activity were used. After the accident information was entered, many locations/activities were found to have single entries; to simplify the study, locations and activities were categorized by their characteristics unless more than five accidents occurred by themselves. After processing, there were five locations and eight activities:

- Locations:
    - MAC Gym
    - Historic Gym
    - Facility: every location in Half Acre except MAC and Historic Gym: such as the climbing wall, pool, studios, etc.
    - Fields: the Laramie baseball field, the Recreational Fields, the Fraternity Mall field, and the Indoor Practice Facility
    - Other: the Laramie Ice Rink, locations outside Laramie, and other locations that did not fit the above categories
- Activities:
    - Basketball
    - Volleyball
    - Soccer
    - Climbing: bouldering and top rope
    - Rugby

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[1] See Appendix 1 on page 15 for the accident report.

- Open Recreation (OR): badminton, boxing room use, dodgeball, weightlifting, racquetball, running, swimming
- Recreational Sports (RS): cycling, baseball, softball, fencing, flag football, hockey
- Other: activity recorded but does not fit categories

Independence between activity and location was tested with a Pearson Chi-Square test, and there was not sufficient evidence ($\chi^2_{28} = 326.13, p < 0.001$) to conclude that activity and location are independent. Table 1 is the contingency table of accidents between each activity and location. Since location and activity are not independent, for ease of interpretability, the combinations between location and activity with non-zero values were combined into a single categorical variable with 20 levels.

	Basketball	Climbing	OR	Other	RS	Rugby	Soccer	Volleyball
Facilities	0	10	19	7	1	0	0	0
Fields	0	0	0	2	10	11	9	0
Historic	4	0	1	0	0	0	0	19
MAC	31	0	1	1	1	0	0	2
Other	0	0	0	1	6	2	1	0

Table 1: Location/Activity Contingency Table

Time was processed as the time in hours from 6 AM, as no times recorded were before 6 AM or after 10 PM. This time range is also the hours of the Half Acre facility. The mean time was 10.48 hours, about 4:30 PM, which was used in place of missing values. Figure 1 shows the distribution of time after processing.

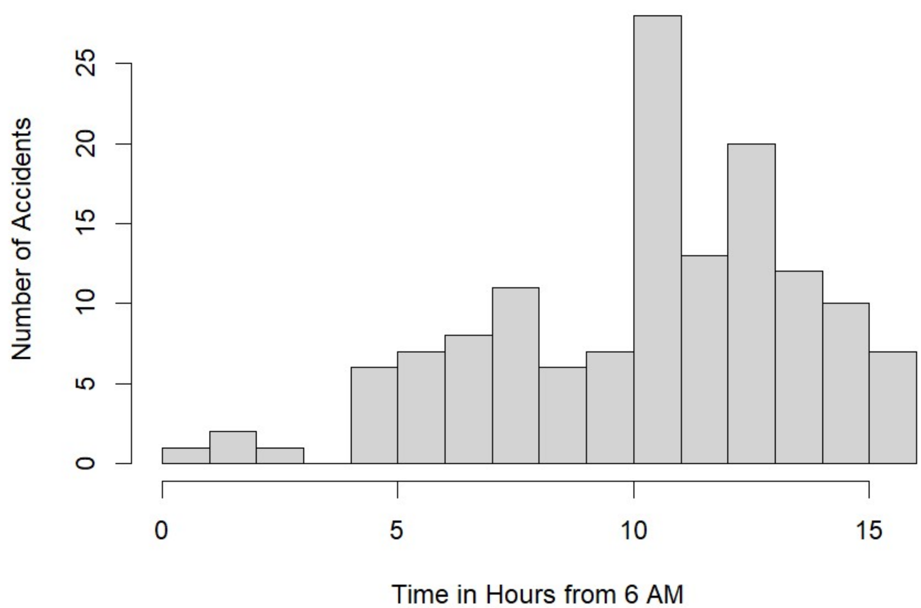

Figure 1: Histogram of Accident Times

Analysis Procedure

Accidents for the i^{th} individual are assumed Bernoulli distributed with accident probability p_i. Logistic regression was used to model accident risk, with coefficient estimates showing quantified risk. Time was assumed independent of activity/location, for both model simplicity and the fact that most activities in each location can happen at any time. This resulted in the following model:

$\mathrm{logit}(p_i) = \beta_0 + \beta_1(\mathrm{time})_i + \beta_2 I_{(\mathrm{facilities,climbing})i} + \beta_3 I_{(\mathrm{facilities,OR})i} + \beta_4 I_{(\mathrm{facilities,other})i} + \beta_5 I_{(\mathrm{facilities,RS})i} + \beta_6 I_{(\mathrm{fields,other})i} + \beta_7 I_{(\mathrm{fields,RS})i} + \beta_8 I_{(\mathrm{fields,rugby})i} + \beta_9 I_{(\mathrm{fields,soccer})i} + \beta_{10} I_{(\mathrm{historic,basketball})i} + \beta_{11} I_{(\mathrm{historic,OR})i} + \beta_{12} I_{(\mathrm{historic,volleyball})i} + \beta_{13} I_{(\mathrm{MAC,OR})i} + \beta_{14} I_{(\mathrm{MAC,other})i} + \beta_{15} I_{(\mathrm{MAC,volleyball})i} + \beta_{16} I_{(\mathrm{MAC,RS})i} + \beta_{17} I_{(\mathrm{other,other})i} + \beta_{18} I_{(\mathrm{other,RS})i} + \beta_{19} I_{(\mathrm{other,rugby})i} + \beta_{20} I_{(\mathrm{other,soccer})i}$ with β_0 being the log odds of an accident for MAC basketball at time = 0, and each I as indicators of the denoted activity and location.

The problem with using logistic regression in this case is that logistic regression requires a mix of successes (accidents) and failures (non-accidents) to estimate changes in probabilities, and no non-accidents were recorded. Non-accidents needed to be added to highlight accident probabilities, so a randomization-test-style resampling was used: holding the number of accidents constant, repeated samples with replacement from a pool of times and locations/activities were created. Those non-accidents were used for the logistic regression model. The analysis procedure was as follows:

1. Generate set of non-accidents with a time and location/activity. Location/activity is considered discrete uniformly distributed (with each location/activity having a 1/20 chance of being chosen) and time continuous uniformly distributed with minimum 0 (6

AM) and maximum 16 (10 PM). The mean number of accidents will be fixed at 0.5, so the non-accident set will also be size 139.

2. Run and save the logistic regression model.
3. Repeat the process 1010 times with a newly generated non-accident set each time. The model is the same for each iteration.
4. Use only the 6th to 1005th sorted entries to remove any perfect separation. When perfect separation occurs, a location/activity does not get chosen in the generated set which causes the estimated chance of an accident for that location/activity to be 100%.
5. Conduct a likelihood ratio test on the 1000 model estimates kept to assess significance[2]. The medians of the chi-square test statistic distributions will be used to conclude effects for both time and location/activity.

Since logistic regression calculates the maximum likelihood estimate for each coefficient, the empirical coefficient distributions will be the maximum likelihood estimators for each coefficient parameter. Therefore, each coefficient will be approximately normally distributed with the mean as the coefficient parameter. Since a normal distribution has an equal mean and median, the median was used as a point estimate. All tests and intervals were set at a 95% level

[2] See Appendix 3 on page 18 for the plots of chi-squares.

of significance, so the 2.5th and 97.5th quantiles of the distributions were used as confidence interval bounds. For this study, R software was used to make the calculations[3].

Results

Time was found to have sufficient evidence ($\tilde{\chi}^2_1 = 24.44, \mathrm{p} < 0.001$) that time is predictive of accident odds. Location/activity was found to have sufficient evidence ($\tilde{\chi}^2_{19} = 80.43, \mathrm{p} < 0.001$) that accident odds are different between different levels of location/activity. Therefore, no changes need to be made to the model. MAC basketball was not found to have accident odds different from 1, which makes sense because the estimated accident probability was fixed at 0.5. Every other coefficient, shown in Table 2, are log odds ratios[4] of an accident compared to MAC basketball at 6 AM, and the exponentiation of those estimates are the odds ratios[5]. The highlighted rows in Table 2 show insignificant intervals, with the log odds ratio intervals including 0 and the odds ratio intervals including 1.

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[3] See Appendix 2 on page 16 for code.

[4] See Appendix 4 on page 18 for plots of the log odds ratio distributions.

[5] See Appendix 5 on page 21 for plots of the odds ratio distributions.

Location/Activity	Log Odds Ratio Interval	Odds Ratio Interval	Odds Ratio Median
Time	(0.03, 0.17)	(1.028, 1.181)	1.1004
Facility, Climbing	(-2.38, 0.08)	(0.093, 1.080)	0.3374
Facility, OR	(-1.53, 1.13)	(0.217, 3.092)	0.8133
Facility, Other	(-2.66, -0.28)	(0.070, 0.756)	0.2358
Facility, RS	(-4.65, -2.30)	(0.010, 0.100)	0.0321
Fields, Other	(-3.86, -1.39)	(0.0210, 0.249)	0.0678
Fields, RS	(-2.35, 0.07)	(0.095, 1.077)	0.3052
Fields, Rugby	(-2.10, 0.55)	(0.123, 1.732)	0.4635
Fields, Soccer	(-2.44, -0.09)	(0.087, 0.917)	0.2915
Historic, Basketball	(-3.31, -0.96)	(0.037, 0.384)	0.1232
Historic, OR	(-4.62, -2.20)	(0.001, 0.111)	0.0322
Historic, Volleyball	(-1.75, 0.59)	(0.173, 1.809)	0.5678
MAC, OR	(-4.65, -2.31)	(0.010, 0.100)	0.0308
MAC, Other	(-4.68, -2.20)	(0.010, 0.111)	0.0334
MAC, RS	(-4.64, -2.27)	(0.010, 0.104)	0.0318
MAC, Volleyball	(-4.04, -1.62)	(0.018, 0.198)	0.0602
Other, Other	(-4.78, -2.21)	(0.008, 0.110)	0.0326
Other, RS	(-2.70, -0.15)	(0.0672, 0.862)	0.2372
Other, Rugby	(-3.79, -1.35)	(0.0226, 0.260)	0.0705
Other, Soccer	(-4.62, -2.13)	(0.010, 0.119)	0.0326

Table 2: Log Odds Ratio and Odds Ratio Intervals, all compared to MAC Basketball at Time 0 (6 AM)

Time was the only variable that had a significant positive effect, which means a 1-hour increment of time increases accident odds by an estimated 10%. In other words, the odds of an accident increase the later a location/activity is being played. The insignificant coefficients (climbing in facility, OR in facility, RS in fields, rugby in fields, volleyball in Historic) are the locations/activities with no difference in accident odds than MAC basketball. For Campus Rec. staff, rugby and rec sports in the fields having the same accident risk as MAC basketball is not too surprising because those tend to be contact sports with more accident-prone movement. Campus Rec. staff is already aware of this, shown by well-staffed Intramural and Club Sports games and a required disclosure of concussions. Historic volleyball is also not surprising because it and MAC basketball often match risk factors such as high-risk movement, competitiveness, and patron traffic. It was not expected that climbing and facility OR had the same accident risk as MAC basketball. Since OR has 7 activities binned into it, it is reasonable that the combined risk of many less-risky activities would have a similar risk to MAC basketball. All other locations/activities were found to have a lower odds of an accident than MAC basketball. The odds ratios were from RS in the facility, RS in MAC gym, and OR in MAC gym. The lowest relative accident risk, RS in MAC, has an estimated 96.82% lower odds of an accident than MAC basketball; in other words, MAC basketball has an estimated 31.42 times higher odds of an accident than RS in MAC. The highest significant odds ratio is soccer in fields, with MAC basketball being an estimated 3.43 times higher odds of an accident.

Discussion

Quantifying accident risks for Campus Rec. gives an interesting perspective on different locations and activities, particularly between lower accident risks. Because most of the locations/activities were found to have a much lower accident odds than MAC basketball and the five other locations/activities with the same odds, pairwise comparisons between lower accident risks do little to offer new, actionable information. Since the five insignificant results have no difference in accident odds from MAC basketball, pairwise comparisons between them and other locations/activities is the same result as the odds ratio estimates in Table 2. Therefore, the coefficient estimates and their relationship with MAC basketball gives the most actionable information. MAC basketball, with a better-understood accident risk, makes a good baseline for making decisions based off the results.

The simulation study used is one of the few ways to assess accident risk retrospectively. Assuming the proportion of recorded accidents are representative of the population accident proportions, the simulated results give a robust estimate of accident odds. However, a limitation of the analysis is the fact that some possible location/activity combinations were not recorded. If a certain activity/location has an accident risk and no accidents were recorded between late 2018 and end October 2022, then there was no way to assess that accident risk with this retrospective study.

Another limitation is that the results cannot be used for predictive purposes because the predicted probabilities are essentially meaningless. That said, predictability may not be useful in this case. Knowing the probability of an accident is of little use for Campus Recreation staff, because 1) knowing accident probability is only useful with a baseline for comparison, which was done with the simulation study, and 2) taking measures to lower accident probability would mean restricting patron activity more than at present, which may not be of interest. Campus Rec. staff are more interested in knowing where to be proactive with accident preparation than lowering accident chance.

Simplicity and interpretability were the most important considerations for the study, so many possible confounding variables were not accounted for: subpopulations of people that engage in more risky behavior, intramural and club sports seasons, fall/spring/summer semesters, winter and summer breaks, counts of patrons engaging in a certain activity, among others may have affected the results. Knowing those confounding effects may give more insight on accident risk, so further research is suggested within this campus recreation department. Though experimenting with injuries may not be possible, keeping patron counts, factoring in time frames, grouping patrons by risky behavior, etc. may add more information about accident risk in conjunction with the analysis results.

The results of this study suggest that risk management procedures should be adjusted to be better aligned with accident risk. Fortunately, most of the highest risks are the most thoroughly staffed. All Campus Rec. field activities are exclusively intramural and club sports games: supervisors, referees, and other officials are present at every game. If an accident happens with those activities, little can be done to speed up response time; however, MAC basketball and Historic volleyball have inconsistent supervision. For intramural and club games, staffing is the same in the gyms as in the fields; otherwise, patrons are free to play unsupervised. When unsupervised, the Open Recreation department is responsible for preventing and responding to accidents. The results of the analysis should be used to inform staff about accident-prone facility conditions. With that information, staff are better equipped to catch risky behavior or accident events. This is only a slight change from the current risk management of Open Rec. staff, but a serious adjustment should be made regarding the climbing wall. Generally, the climbing wall is not supervised except for top rope in the evening, competitions, and occasional staffing. Since the climbing wall is almost always open while the Half Acre facility is open, staff should be checking the wall more often for risky behavior, or unreported accidents. When managers and facility assistants are doing their by-shift risk management walkthrough, they ought to be checking the climbing wall, and a policy ought to be added that ensures the climbing wall gets regularly checked.

Given these suggestions are implemented, the day-to-day operations of Campus Rec. would change very little. Accidents rarely occur under the responsibility of Campus Rec., with staff intentionally overprepared for accident scenarios. However, accidents are random events with patterns of risk. Because they are unpredictable, having a safety net of preparation is important for accidents when they inevitably happen. Understanding those risk patterns, which this analysis was designed for, allows Campus Rec. staff to bolster that safety net. Continuing to research accident risk is suggested to optimize risk management procedures. Allowing staff to have more efficient risk management is a better use of resources and contributes to the safe environment that Campus Rec. continues to develop.

Appendix 1: Accident Report

University of Wyoming — Accident Report

Individual Involved Information

Name (First & Last): | UW W Number (if applicable): | Phone Number: | Date: ____/_____/________ Time: ____________ AM/PM

Address: | City: | State & Zip Code:

□ Male □ Female □ Other

□ Student □ Participant □ Volunteer □ Spectator □ Employee □ Youth □ Dependent □ Faculty □ Staff □ Guest

General Accident Information

Location of Accident (EX: HA Business Office):________________________Visiting University (if applicable):___________________________

Type of Activity that Caused Injury (EX: Club Soccer):

Program Area: □ Aquatics □ Climbing Wall □ Fitness & Instruction □ Intramural Sports □ Open Rec □ OP Trip □ Wellness Center □ Personal Training □ Club Sports □ Other: __________________________

Suspected Injury (check all that apply):

□ Allergic Reaction	□Electrocution
□ Amputation	□ Fainting
□ Bleeding	□ Head/Spine Injury
□ Blurred Vision	□ Laceration
□ Breathing Difficuty	□ Muscluloskeltal Injury
□ Burn	□ Nausea/Vomiting
□ Cardiac Emergency	□ Puncture
□ Choking	□ Shock
□ Dizziness	□ Seizure
□ Drowning	□ Stroke
□ Other: ___________________	

Parts of Body Injured (check all that apply):

□ Abdomen	□Jaw
□ Ankle (L/R)	□ Knee (L/R)
□ Arm (L/R)	□ Leg (L/R)
□ Back	□ Mouth
□ Chest	□ Neck
□ Ear (L/R)	□ Nose
□ Elbow (L/R)	□ Pelvis/Hips
□ Eye (L/R)	□ Ribs (L/R)
□ Face	□ Shoulder (L/R)
□ Finger	□ Spine
□ Foot (L/R)	□ Tooth
□ Groin	□ Toe
□ Hand (L/R)	□ Torso
□ Head	□ Wrist (L/R)
□ Other: __________________________	

Local Clinics and Hospitals

UW Student Health: Student Health Building 307-766-6602

Ivinson Memorial Hospital: 225N. 30th St. 307-755-4410

Albany Community Health Clinic: 1174 N. 22nd St. 307-766-3313

Grand Ave. Urgent Care: 3236 E. Grand Ave. 307-760-8602

Stiches Acute Care: 3810 Grand Ave. 307-721-1794

Was Your Supervisor Alerted? □ Yes □ No

Was the Patient Coherent?: □ Yes □ No

Were Crutches Needed?: □ Yes □ No #___________

If no first aid was given explain on the back.

Other Equipment Used:

SAMPLE (For Suspected Injury or Illness)

Signs and Symptoms:

Allergies:

Medications:

Pertinent Past Medical History:

Last Oral Intake:

Events Leading Up:

FAST (In case of Suspected Stroke)

Face:

Arms:

Speech:

Time:

Were Emergency Services Called?: □ Yes □ No

Did Patient Request Ambulance?:□ Yes □ No

If ambulance was called:

□ Patient was only assessed by EMT (no transport)

□ Patient was treated and transported by EMT

□ Patient declined treatment from EMT

Appendix 2: R Code for Analysis Procedure

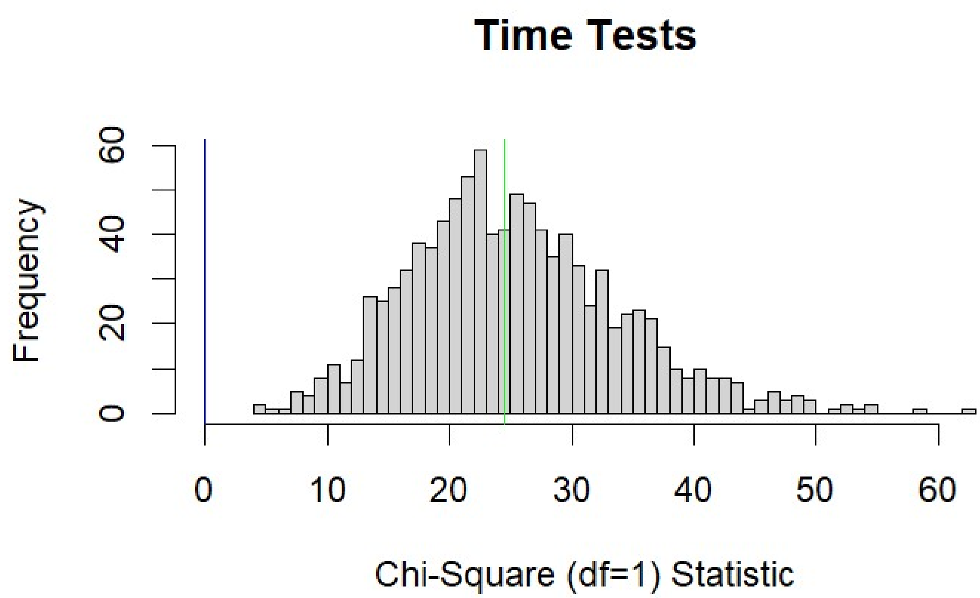
```
randomized.glmlist <- function(df,randomizedlist,f) {
	glmlist <- list()
	for(i in 1:length(randomizedlist)) {
		tempdf <- rbind(df,randomizedlist[[i]])
		tempdf$time <- as.numeric(tempdf$time)
		tempdf$locact <- as.factor(tempdf$locact); tempdf$locact <-
		relevel(tempdf$locact,ref='MAC.basketball')
		glmlist[[i]] <- glm(f,data=tempdf,family=binomial)
	}
	return(glmlist)
} # end function randomized.glmlist
coefslist <- function(matrix) {
	to.return <- list()
	for(i in 1:ncol(matrix)) to.return[[i]] <- matrix[,i]
	names(to.return) <- colnames(matrix)
	return(to.return)
} #end function coefslist
#creating list of non-accident sets
randlist <- list()
for(i in 1:1010) {
	acc.temp <- data.frame(
	time=runif(139,min=0,max=16),
```

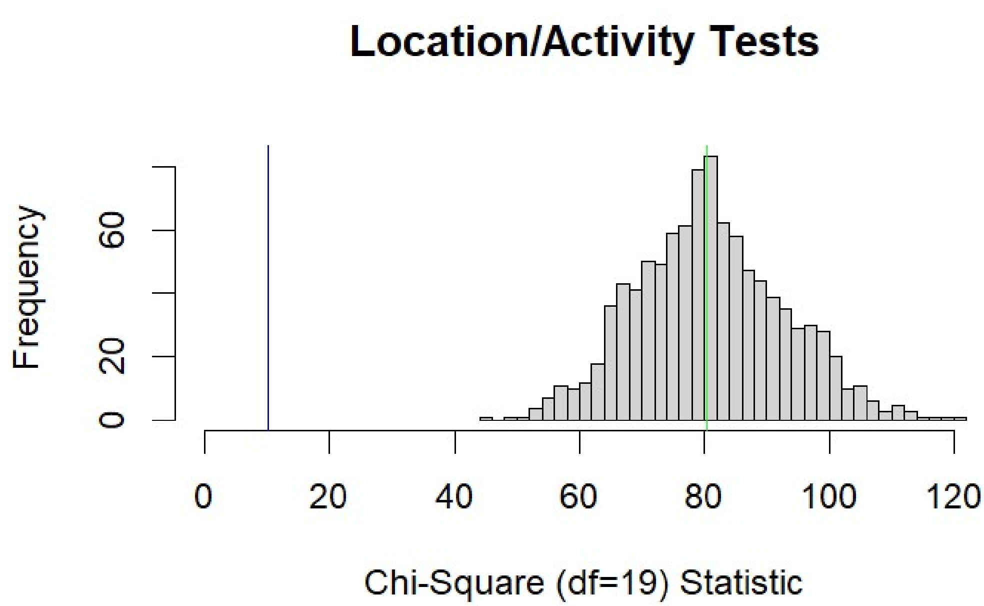
```
    locact=sample(unique(acc.short$locact),size=RES_NUM,replace=TRUE,accide
    nt=0)
    names(acc.temp) <- c('time','locact','accident')
    randlist[[i]] <- acc.temp
}
acc.shortoneway <-
data.frame(time=acc.short$time,locact=acc.short$locact,accident=1)
#running model on each set
glmlist <- list();
for(i in length(randlist)) glmlist <-
randomized.glmlist(acc.shortoneway,randlist,accident~time+locact)


model.coefs <-
matrix(NA,nrow=length(glmlist),ncol=length(coef(glmlist[[1]])))
for(i in 1:length(glmlist)) model.coefs[i,] <- coef(glmlist[[i]])
colnames(model.coefs) <-
c("(Intercept)",'time',substr(names(coef(glmlist[[1]])[3:21]),start=7,stop=99
))
model.coeflist <- coefslist(model.coefs)
for(i in 1:21) model.coeflist[[i]] <- sort(model.coeflist[[i]])[6:1005]
```

Appendix 3: Plots of Likelihood Ratio Chi-Square Statistics

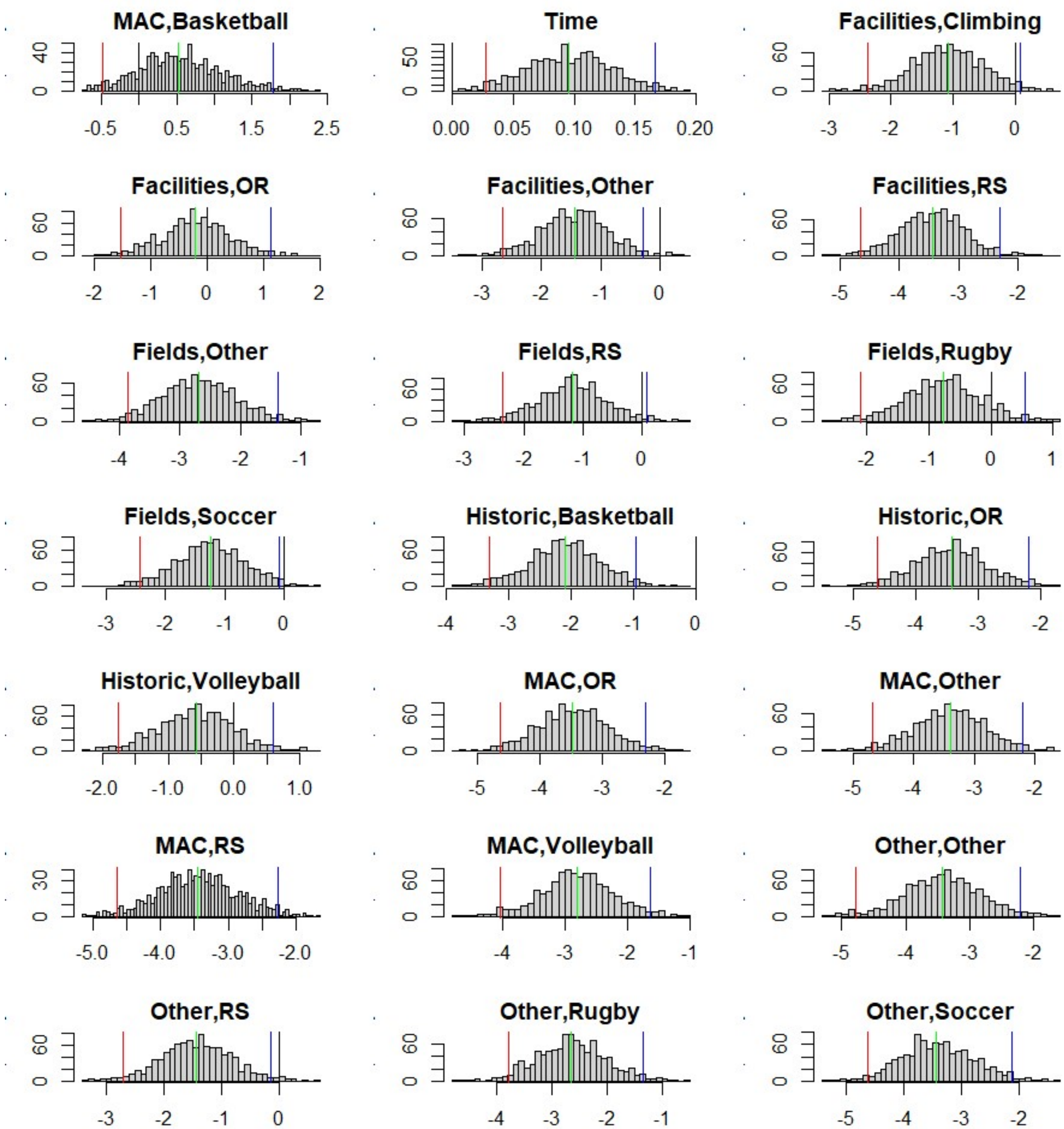
Both plots are the results of the 1000 likelihood ratio tests with their respective chi-square test statistics. The green line represents the median statistic value, and the blue line is the critical value for a 95% level of significance for their respective degrees of freedom.





Appendix 4: Plots of Coefficient Distribution Estimates

The plots are histograms of each distribution of the log odds ratio (or log odds for MAC basketball) estimates. The x-axis is the estimate, the red line is the 2.5th quantile, the green line the median, the blue line the 97.5th quantile, and the black line is set to 0.



Appendix 5: Plots of Odds Ratios to MAC Basketball

The plots are histograms of the odds ratio between the coefficient labeled and MAC basketball at 6 AM. The x-axis is the odds ratio estimate, the red line is the 2.5th quantile, the green line is the median, and the blue line is the 97.5th quantile, and the black line is set to 1.