

RIB STRESS INJURIES IN THE NCAA COLLEGIATE ROWING ATHLETE:
A PROSPECTIVE OBSERVATIONAL PILOT STUDY

by

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LIST OF ABBREVIATIONS

Abbreviation	Description
RSI	Rib Stress Injury
RSF	Rib Stress Fracture
NCAA	National Collegiate Athletic Association
IRA	Intercollegiate Rowing Association
BMD	Bone Mineral Density
RED-S	Relative Energy Deficiency in Sport

ABSTRACT

Context: Rib stress injuries (RSIs) are one of the most debilitating injuries that the competitive rowing athlete may sustain during their career. Rib stress reactions can result in an average loss of 48 training days per year which increase to an average loss of 60 days per year if they develop into stress fractures. Minimal research exists on these injuries and associated risk factors in NCAA women's rowing athletes in the United States. Patient self-report injury surveys have been previously shown to be both sensitive and reliable. **Objective:** To document RSIs sustained and potential associated risk factors during a single NCAA rowing season in a series of female rowing student-athletes, and begin to assess the extent of the clinical problem. **Design:** Prospective observational pilot study. **Setting:** Field-based. **Participants:** 27 NCAA Division I and III female rowing athletes (age, 19.3 ± 1.8 yrs; height, 171.6 ± 6.3 cm; weight, 75.8 ± 9.3 kg). **Interventions:** A series of self-reported online surveys: a "baseline questionnaire" and 14 "weekly e-diaries." **Main Outcome Measurements:** Physical training program characteristics, nutritional supplementation use, menstrual activity, and medical details regarding reported potential RSIs. **Statistical Analysis:** Descriptive statistics, qualitative theme analysis, and a case series. **Results:** A total of 3,407 hours of physical training, on-water practices and competitions were reported by the 27 participants during the 14-week study. Seven of 27 participants (26%) reported a rib cage injury, of which 4 identified as RSIs. Aggressive RSI management at onset of symptoms, immediate removal from on-water/ergometer training for several days, and return to activity soon after were observed,

especially in Division I athletes. **Conclusions:** In our preliminary study, RSIs were prevalent in the sampled NCAA rowing population, suggesting that larger scale epidemiological studies should be conducted to determine the injury's true prevalence, severity, management and subsequent clinical course.

1. INTRODUCTION

Competitive rowing attributes most of its initial success and popularity to international competitions, specifically the Olympics. However, the sport has gained popularity internationally in various other settings and populations, including universities and colleges, high schools, and recreational teams. This is especially the case for rowing in the United States; since the implementation of Title IX in 1972, the number of NCAA rowing teams has substantially increased at universities and colleges across the country to help balance the largely-populated men's sports (primarily football).¹ While there is still a large population of both men's rowing programs and women's lightweight rowing programs in the United States, the NCAA is the only organization that recognizes women's open-weight rowing as a varsity sport and categorizes the various levels of the female rowing athletes into Division I, II, and III.

Collegiate rowing athletes experience a multitude of injuries throughout the course of their competitive career, most of which develop as chronic in nature. Of those injuries, the three body regions that sustain the highest number of injuries and result in the most time lost from practice and competition include low back pain, knee injuries, and rib injuries.²⁻⁴ While all three body regions are important for success in the collegiate rowing population, minimal research has been conducted on rib stress injuries (RSIs) in these athletes in comparison to low back pathology.

The operational definition of the term RSI is broad and includes both rib stress reactions, where the bone experiences microfracturing due to repetitive physiological stress and motion characterized by increased bone cell activity⁵, and rib stress fractures, where the bone actually breaks due to sufficient repetitive force.^{6,7} These RSIs present a

serious problem for not only the rowing athletes but also the coaches, athletic trainers, and physicians that manage and care for them. Rib stress injuries will often occur during high-volume training periods (for collegiate athletes, this is typically winter) as individuals prepare for their spring competition season; in the collegiate setting, this season is comprised of 2000-meter races in the spring and considered the ‘sprint’ season in comparison to the fall.^{8,9} Hooper et al.³ found that rib stress reactions can result in an average loss of 48 training days per year for rowing athletes, which increases to an average loss of 60 days per year if stress reactions develop into stress fractures. Typically, NCAA collegiate rowers only participate in a handful of competitive races each spring, and thus their winter training season is essential for optimal performance leading up to competition.

Research to date has explored possible theories for the mechanism of injury as well as potential intrinsic and extrinsic risk factors that may play a role in a rowing athlete’s risk for sustaining a RSI. There are however, few studies that have prospectively collected data on general musculoskeletal injuries in the competitive rowing athlete population, and none to our knowledge that have done so specifically with rib injuries.^{2,10,11} To date, most investigations conducted on rib injuries in collegiate rowing athletes have been retrospective studies focused specifically on RSFs, and their findings have been presented in the form of case studies or case series.^{8,12,13}

The primary theorized cause of rib injuries in competitive rowing athletes has to do with a combination of insufficient muscular endurance and over-activation of the serratus anterior and abdominal muscles, termed the Abdominal-Led Rib Cage Compression theory.¹⁴ In the absence of strong evidence identifying the mechanism(s) of

injury for RSIs, preventative programs are minimal, and the effectiveness of the programs that do exist have not been widely studied.

Some of the current available research has analyzed the involvement of potential risk factors related to the development of RSIs in these rowing athletes.^{15,16} These injury risk factors were divided into 2 categories: intrinsic and extrinsic. The intrinsic RSI risk factors include muscle imbalances, joint mechanics, sex, bone mineral density, concurrent or a past medical history of shoulder or low back injury.^{6,15} Suggested extrinsic risk factors include rowing style, training characteristics, equipment, and environmental concerns.^{6,15}

In order to construct a research design involving a topic with little available information and research, epidemiology recommendations and the effectiveness of data collection strategies are important to consider. Timpka et al.¹⁷ suggests that an ideal epidemiological study design in an athletic population should be prospective in nature and consist of a cohort design, while making note of weekly injury and illness incidence in the athletic teams. Incidence rates are essential in the initial stages of epidemiological research, as they provide quantitative values of the rate of new injuries and illnesses within a specific population during a given time frame.^{17,18} Through these measures, researchers can begin to develop a clinical picture of a disease or pathology, and eventually determine potentially effective therapeutic and preventative measures.¹⁹

By determining the extent of RSIs in the NCAA competitive rowing athlete during their intense and volume-loaded winter and spring training season, athletic trainers can determine how much emphasis should be placed on preventative measures for their student athletes. Furthering research on the incidence of RSIs in these athletes may assist

athletic trainers and other health care professionals in the assessment and identification of athletes at risk for sustaining RSIs and developing prevention training programs for this population. The purpose of this study was to document RSIs sustained and potential associated risk factors in a series of female rowing student-athletes during a single NCAA rowing season, and begin to assess potential associated risk factors for RSI development determining the extent of the clinical problem.

2. MANUSCRIPT

RIB STRESS INJURIES IN THE NCAA COLLEGIATE ROWING ATHLETE: A PROSPECTIVE OBSERVATIONAL PILOT STUDY

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Abstract

Context: Rib stress injuries (RSIs) are one of the most debilitating injuries that the competitive rowing athlete may sustain during the course of their career. Rib stress reactions can result in an average loss of 48 training days per year for rowing athletes, which increase to an average loss of 60 days per year if stress reactions develop into stress fractures. Minimal research exists on these injuries and associated risk factors in NCAA women's open-weight rowing athletes in the United States. Patient self-report injury surveys have been previously shown to be both sensitive and reliable. **Objective:** To document RSIs sustained and potential associated risk factors during a single NCAA rowing season in a series of female rowing student-athletes, and begin to assess the extent of the clinical problem. **Design:** Prospective observational study. **Setting:** Field-based study. **Participants:** 27 NCAA Division I and III female collegiate rowing athletes (age, 19.3 ± 1.8 yrs; height, 171.6 ± 6.3 cm; weight, 75.8 ± 9.3 kg). **Interventions:** Series of self-reported online surveys: a "baseline questionnaire" and 14 "weekly e-diary" surveys. **Main Outcome Measurements:** Physical training program characteristics, nutritional supplementation use, menstrual activity, and medical details regarding reported potential RSIs. **Statistical Analysis:** Descriptive statistics, qualitative theme analysis, and a case series. **Results:** A total of 3,407 hours of physical training, on-water practices and competitions were reported by the 27 participants during the 14-week study. Seven of 27 participants (26%) reported a rib cage injury during the single NCAA competitive season, with 4 of these injuries identified as RSIs. Aggressive RSI management at onset of symptoms, immediate removal from on-water/ergometer training for several days, and return to activity soon after were observed, especially in the Division I student athletes.

Conclusions: In our preliminary study, rib stress injuries were prevalent in the female NCAA rowing population we sampled, suggesting that larger scale epidemiological studies should be conducted to determine the true prevalence, severity, typical management and subsequent clinical course of these injuries.

Word Count: 324

Key Words: rib stress injury, rib cage, collegiate rowing, NCAA, women

Introduction

Competitive rowing attributes most of its initial success and popularity to international competitions, specifically the Olympics. However, the sport has gained popularity in the United States since the implementation of Title IX in 1972; the number of NCAA rowing teams has substantially increased at universities and colleges across the country to help balance the largely-populated men's sports.¹ While there is still a large population of both men's rowing programs and women's lightweight rowing programs in the United States, the NCAA is the only organization that recognizes women's open-weight rowing as a varsity sport and categorizes the various levels of the female rowing athletes into Division I, II, and III.

Competitive collegiate rowing athletes experience a multitude of chronic injuries throughout the course of their career, the three that result in the most time lost from practice and competition include low back pain, knee injuries, and rib injuries.²⁻⁴ While all three are important in preventing and managing in the collegiate rowing population, minimal research has been conducted on rib stress injuries (RSIs) in these athletes, especially in comparison to low back pathology.⁵ The operational definition of the term RSI is broad and includes rib stress fractures, rib stress reactions, and rib pain.^{6,7} These RSIs present a serious problem for not only the NCAA athletes but also the coaches, athletic trainers, and physicians that manage and care for them. Rib stress injuries will often occur during high-volume training periods (for collegiate athletes, this is typically winter) as individuals prepare for their spring competition season.^{8,9} Hooper et al.³ found that rib stress reactions can result in an average loss of 48 training days per year for rowing athletes, which can increase to an average loss of 60 days per year if these stress

reactions develop into stress fractures.

There are few studies that have prospectively collected data on general musculoskeletal injuries in the competitive rowing athlete population, and none to our knowledge that have done so specifically with rib injuries.^{2,10,11} To date, most investigations conducted on rib injuries in collegiate rowing athletes have been presented in the form of case studies or case series.^{8,12,13} Previous research has examined possible theories for the mechanism of injury as well as potential intrinsic and extrinsic risk factors that may play a role in a rowing athlete's risk for sustaining a RSI.^{6,15} In the absence of strong evidence identifying the mechanism(s) of injury for RSIs, preventative programs are minimal and their effectiveness has not been widely studied.

Epidemiology recommendations and the effectiveness of data collection strategies are important to consider when constructing a research design involving a topic with little available information and research. Timpka et al.¹⁷ suggest studies that are prospective in nature and consist of a cohort design, while making note of weekly injury and illness incidence in the athletic teams.¹⁸ Through these measures, researchers can begin to develop a clinical picture of a disease or pathology, and eventually determine potentially effective therapeutic and preventative measures.¹⁹

By determining the extent of RSIs in the NCAA competitive rowing athlete during their intense and volume-loaded spring training season, athletic trainers can determine how much emphasis should be placed on preventative measures for their student athletes. The purpose of this study was to document RSIs sustained during a single NCAA season, as well as potential associated risk factors in a series of NCAA female rowing student athletes, and begin determining the extent of this clinical problem.

Methods

Design

We utilized a prospective cohort experimental design that covered approximately 14 weeks of Division I and III NCAA women's rowing 2017 spring season, using female rowing athletes. We employed online survey questionnaires to document rib cage injuries (specifically RSIs) in the participants for this study. Extensive demographic data were collected prospectively for the descriptive aspects of this study. This information included: athlete age, number of years rowing in the collegiate setting, training characteristics (including primary side rowing, primary size of boat rowing in, types of training sessions each week, number of training sessions per week, duration of training sessions, intensity of training sessions), supplementation use, and the past medical history of RSIs and low back or shoulder pathology. This information was obtained remotely through the administration of a baseline questionnaire and subsequent weekly e-diaries. Our primary outcome measure was incidence of rib stress injury. Additionally, we asked the athletic trainers at the participating schools to complete a short survey in order to verify the diagnosis/assessment of any injuries that their student-athletes reported.

Participants

Initial subject recruitment comprised of a total of 31 participants (average age, 19.3 ± 1.8 yrs). This included one NCAA Division I rowing program (Team A) and one NCAA Division III (Team B) collegiate rowing program, with 17 student athletes and 14 student athletes, respectively. At the study outset one athletic trainer from each institution acted as the liaison between the study participants and the principal investigator (CAM). Both athletic trainers and student athletes were identified using the inclusion and

exclusion criteria listed in Table 2.1. All individuals, both rowing athletes and athletic trainers, were considered volunteers, as their participation in this study was not required.

Table 2.1. Participant Inclusion and Exclusion Criteria			
<i>Rowing Student Athlete Recruitment</i>		<i>Athletic Trainer Recruitment</i>	
<i>Inclusion Criteria</i>	<i>Exclusion Criteria</i>	<i>Inclusion Criteria</i>	<i>Exclusion Criteria</i>
≥18 years old	<18 years old	Currently employed as an athletic trainer with a NCAA Division I, II, or III rowing team	Currently working with high school, non-NCAA collegiate club teams, or national teams only
Female	Male		
Currently on a NCAA Division I, II, or III rowing roster	Currently on a non-NCAA university/college club rowing team		
Currently training/competing with their respective university/college team	Not currently training/competing when the injury surveillance begins		

Instrumentation

For each group, student athlete and athletic trainer, unique surveys adapted from a previously published Swedish epidemiological study were created and distributed via email.^{20,21} These surveys and the concept of athlete self-report have been recognized by the Oslo Sports Trauma Research Center (OSTRC) as a sensitive and reliable method in documenting injuries and associated characteristics.²² All athletic trainers involved in the study received a Student Athlete ID Key form; this key provided the opportunity for each participating athletic trainer to designate an identification number to each of the participating student athletes. This form also allowed athletic trainers to be able to reference the student athletes easily throughout the course of the study for the purposes of injury verification, while also allowing for anonymity.

For student athletes, there were two types of surveys that they were asked to complete – a baseline questionnaire and a recurring weekly check-in survey. The baseline questionnaire and weekly check-in survey form utilized in this study were adapted and condensed from a Swedish track and field epidemiology study conducted by Jacobsson et al.,²¹ and were altered to suit rowing and RSIs for our study. For the purposes of our study, we also created a two question Verification of Injury Form that athletic trainers were asked to complete upon a student athlete's reporting of an injury. This acted as a secondary method of checking, allowing for accurate reporting and documentation of injuries.

All questionnaires and surveys were uploaded and integrated into Qualtrics (Qualtrics, Provo, UT), an online survey platform made available by Texas State University to graduate students free of charge. The baseline questionnaire was comprised of demographic information, basic rowing characteristic information, past medical history of rib stress injuries, and supplementation use. The recurring Weekly Check-in survey provided the opportunity for individuals to document their training characteristics (types of training sessions, duration, intensity), supplementation use, details regarding any new injuries, and details regarding injuries that had resolved in the last week. For each survey, student athletes were able to skip any questions that they felt uncomfortable answering. Student athletes had access to the weekly survey for 48 hours, receiving a reminder email at the 24-hour mark. At the conclusion of the 48-hour period, the survey closed and data collection for that week ceased.

Experimental Procedures

Rowing teams were identified via the website www.Row2k.com, which provides an inclusive database of all universities and colleges that have NCAA, IRA, and club rowing teams for men and women, open-weight and lightweight. NCAA Division I, II, and III teams were then identified from this group, and contact information (email addresses) for the respective athletic trainer(s) working with each team was collected from their university's athletics website. These athletic trainers were contacted via email to ask for their participation in recruiting student-athletes from their teams to participate in the study.

Recruitment emails were sent to a total of 91 Division I, II, and III NCAA women's rowing teams. Of those 91 teams, 8 responded with interest and inquiry of the study and methodology; ultimately, 2 teams (a Division I and a Division III team) provided permission for us to contact and recruit their student-athletes for participation in this study (See Figure 2.1). Permission for data collection on the student-athletes was obtained from each university's athletic department and coaching staff via completion of a provided Permission Letter template (See Appendix).

Once written permission was obtained from the university's athletic department and coaching staff, athletic trainers were asked to provide a comprehensive list of email addresses for student athlete members of their rowing team. These student-athletes were then emailed a link to complete the online Informed Consent form in Qualtrics, informing them of the purpose of the study and the reason we were asking for their participation, as well as any risks associated with their participation.

Within the 2 teams, informed consent emails were sent to a total of 88 student

athletes: 33 from Team A, and 55 from Team B (where one email bounced). Of the 87 successful email deliveries, a total of 31 individuals signed the consent form. Seventeen of 55 (31%) student athletes from Team A consented to participate, while 14 of the 33 (42%) student athletes from Team B consented to participate. Twenty-six of the 31 rowers (84%) who consented to participate completed the initial demographic questionnaire.

A list of all student athletes from each university that completed the consent form in the designated time frame was then emailed to their respective athletic trainers along with the Student Athlete ID Key form (See Appendix). The athletic trainers at each university were asked to randomly assign an ID number to all participating student athletes. Student athletes were instructed to enter this ID number when completing all surveys. This allowed the researchers to link survey responses and data among participants on a weekly basis while allowing for anonymity. If a student athlete reported any new rib cage injury, low back injury, or shoulder injury throughout the duration of the study, the athletic trainer was prompted to confirm this injury by completing the "Verification of Injury" survey (See Appendix).

For all those that completed the consent form and agreed to participate, they were then emailed the baseline questionnaire (See Appendix). Participating student athletes were sent this baseline questionnaire on February 25, 2017; upon distribution of the baseline questionnaire to the 31 participants, a total of 27 (87%) completed the survey. Also starting on February 25, 2017, every Saturday afternoon student athletes were sent the Weekly Check-in survey (see Appendix) to complete. A comprehensive survey distribution timeline is presented in Table 2.2. Student athletes had 48 hours to complete

each e-diary before it closed, with a reminder email sent 24 hours after the initial survey response request. The last survey was sent out on Saturday, May 27, 2017. Participants were notified that this was the last survey, and thanked for their participation over the course of the last three months.

An original end date was planned for March 18, 2017. However, due to unforeseen timeline complications a secondary consent form was required to finish the data collection. Those who decided to re-consent were not required to complete an additional baseline questionnaire, but simply continued to complete weekly e-diaries as they had been for the previous few weeks. Of the 31 that originally consented to participate, 16 of the 31 (52%) student athletes re-consented for the remaining 10 weeks of the study. This included 7 student athletes from Team A ($7/17 = 41\%$), and 9 student athletes from Team B ($9/14 = 65\%$).

Figure 2.1. Study flow chart

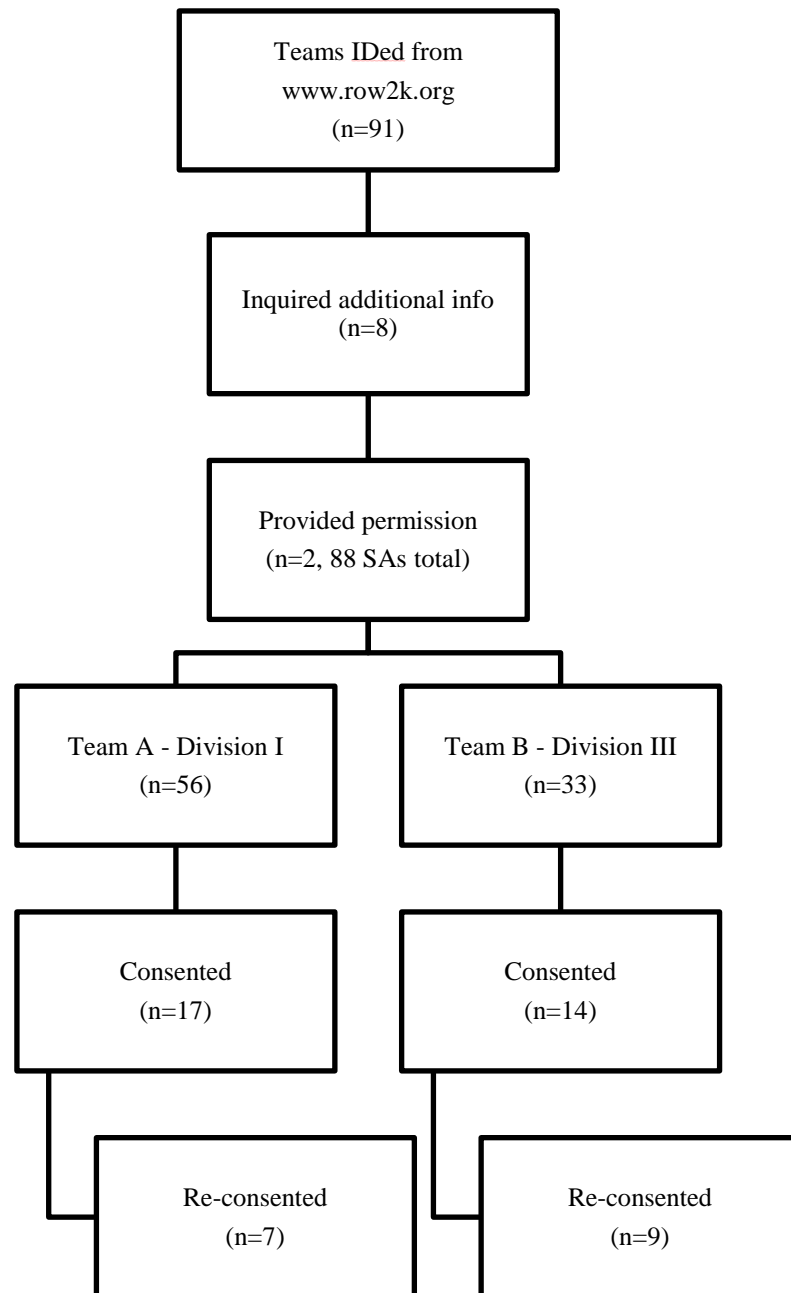


Table 2.2. Survey Distribution Schedule	
<i>Item</i>	<i>Date</i>
Baseline Questionnaire	February 25
Weekly Check-in #1	February 25
Weekly Check-in #2	March 4
Weekly Check-in #3	March 11
Weekly Check-in #4	March 18
Weekly Check-in #5	March 25
Weekly Check-in #6	April 1
Weekly Check-in #7	April 8
Weekly Check-in #8	April 15
Weekly Check-in #9	April 22
Weekly Check-in #10	April 29
Weekly Check-in #11	May 6
Weekly Check-in #12	May 13
Weekly Check-in #13	May 20
Weekly Check-in #14	May 27

Statistical Analysis

We used IBM SPSS software (version 23) to run descriptive statistics and frequencies to determine average weekly hours of training and average sessions trained, as well as mean values for demographic information. Paired t-tests were run to compare weekly average training hours between the two teams. Additionally, a qualitative theme analysis was conducted on the outcome measures to find themes amidst the participant weekly injury reports. We also collected information to comprise a case series of individuals who reported rib cage-related injuries.

Results

Baseline Questionnaire and Weekly E-Diary

Throughout the 14-week injury surveillance period, 4 individuals completed all distributed surveys (including the baseline questionnaire and the 14 weekly questionnaires): 2 participants from Team A, and 2 participants from Team B. There were 4 student athletes who did not submit any data after consenting to participate in the

study. The 27 rowers who completed the online baseline questionnaire took an average of 3.5 minutes to complete. Throughout the 14 weeks of the study, the weekly e-diary entries took on average 2.8 minutes to complete; 10 entries took more than 20 minutes to complete them. Survey completion frequency data are presented in Table 2.3.

Data from our baseline questionnaire provided detailed information relative to the individuals' nutritional rowing experience, supplementation, and menstrual activity. Eighteen of the 27 (67%) student-athletes reported that they did not row before college, and 14 of the 27 (52%) student athletes that provided information had been competing as a NCAA rower for less than 1 year. Twenty-three participants (85%) reported that they were not taking any nutritional supplementation at the time of their baseline questionnaire, while 8 participants (30%) indicated that they were using a hormonal contraceptive. In terms of menstrual activity, 4 individuals (15%) were classified as oligomenorrheic and the remaining 23 (85%) were classified as eumenorrheic.

Table 2.3. Student Athlete Survey Completion															
BL = Baseline															
<i>Week</i>	<i>BL</i>	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>	<i>7</i>	<i>8</i>	<i>9</i>	<i>10</i>	<i>11</i>	<i>12</i>	<i>13</i>	<i>14</i>
Team A (n)	13	13	12	12	11	7	7	5	5	4	4	4	4	3	3
Team B (n)	14	13	12	11	10	6	9	8	8	8	7	5	6	5	3
Total (n)	27	26	24	23	21	13	15	13	13	12	11	9	10	8	6

Training Characteristics

The 14 weeks of injury surveillance were divided into 4 seasonal categories to help organize and condense the data: (1) pre-competition, (2) early competition, (3) mid-competition, and (4) late competition. Data from each season category, relative to each team's respective competition schedule and their associated number of RSIs throughout the course of the study, is summarized in Table 2.4.

Table 2.4. Seasonal Divisions Relative to Team Schedules and Rib Cage Injuries					
<i>Season</i>	<i>Weeks</i>	<i>Reporting Dates</i>	<i>Team A Schedule</i>	<i>Team B Schedule</i>	<i># of Rib Cage Injuries</i>
Pre-competition	1	2/25/2017			2
	2	3/4/2017			
Early Competition	3	3/11/2017		Competition	3
	4	3/18/2017		Competition	
	5	3/25/2017	Competition		
	6	4/1/2017	Competition	Competition	
Mid-Competition	7	4/8/2017	Competition	Competition	1
	8	4/15/2017			
	9	4/22/2017	Competition	Competition	
	10	4/29/2017	Competition	Competition	
Late Competition	11	5/6/2017		Competition	1
	12	5/13/2017	Competition		
	13	5/20/2017			
	14	5/27/2017	NCAAs	NCAAs	

A total of 3,407 hours of training were recorded during the 14 weeks of injury surveillance. Team A trained an average of 18.4 hours per week, while Team B trained for an average of 13.8 hours per week. A weekly breakdown and comparison of average number of hours trained between Team A and Team B is presented in Table 2.5.

Data on total number of sessions trained per week was collected; between both teams, participants recorded a total of 1739 training sessions. Team A trained an overall average of 9.3 sessions per week, while Team B trained an overall average of 8.0 sessions per week. Additional descriptive information and comparison of average number of training sessions in regards to on-water, ergometer, weight training, and supplementary training/conditioning is also presented in Table 2.5.

A paired t-test was run to determine significance values ($\alpha = 0.05$) in regards to weekly average training hours compared between the two teams. Statistical significance ($p = 0.001$) was found for the differences in weekly average training hours for the first 12 weeks of the study. A second paired t-test was run on the entire 14 weeks of data; even

when training volumes were decreased at the end of seasons, we still found statistical significance ($p = 0.004$) and a large effect size (Cohen's $d = 0.97$) when looking at weekly training volume between teams. We only obtained data from one NCAA Division I and one NCAA Division III rowing teams, but in this context training, level of competition (NCAA division) appeared to have a significant effect on the mean number of weekly training hours.

Table 2.5. Weekly Mean Training Characteristics and Injury Count															
		<i>Week</i>													
		<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>	<i>7</i>	<i>8</i>	<i>9</i>	<i>10</i>	<i>11</i>	<i>12</i>	<i>13</i>	<i>14</i>
# Training Sessions	# Reporting SAs	26	24	23	21	13	15	13	13	12	11	9	10	8	6
	Mean Training Time (hours)	A: 19.85 B: 16.68	20.55 13.42	19.64 13.27	30.36 15.22	20.29 12.50	20.00 23.67	17.20 12.57	20.40 14.50	15.75 14.00	19.00 12.71	21.67 12.33	17.50 14.43	9.00 9.00	6.33 9.50
	On-water	A: 5.77 B: 6.69	5.83 4.17	5.25 4.64	8.30 5.40	6.86 5.00	6.33 8.56	5.20 5.00	5.80 5.14	5.75 6.13	5.75 4.43	6.75 3.33	4.75 5.29	5.00 3.80	7.00 5.33
	Ergometer	A: 1.23 B: 0.73	0.33 3.36	1.91 2.55	0.00 1.11	1.00 1.80	0.00 1.14	1.80 1.00	1.40 0.33	0.00 0.67	0.67 0.50	0.00 1.00	0.50 1.40	1.50 0.67	2.00 0.00
	Weight Training	A: 2.00 B: 2.23	2.00 2.18	1.67 1.20	0.29 2.00	1.80 1.50	2.00 1.00	1.60 0.86	2.00 1.17	1.75 1.13	1.75 0.50	1.50 1.40	1.00 1.50	0.00 0.00	- 0.00
	Supplementary Training/Conditioning	A: 1.50 B: 1.45	2.88 1.67	1.80 1.44	4.10 1.14	0.25 1.20	1.20 1.13	1.00 0.80	2.00 1.71	1.25 1.80	1.00 0.75	1.67 1.00	2.33 1.00	0.50 0.25	3.00 0.50
	Total	A: 9.82 B: 8.15	9.58 8.17	9.54 8.18	11.45 8.90	9.29 9.00	9.50 10.63	9.00 7.00	9.60 8.00	9.00 7.88	8.75 6.43	9.50 6.50	8.25 8.14	4.67 4.25	4.00 6.67
	# Injuries	A: 1 B: 0	0 1	1 0	2 1	1 0	1 0	0 1	0 0	1 0	0 0	0 1	0 0	0 0	0 0
	# RSIs	A: 0 B: 0	2 0	1 0	2 0	0 1	0 0	0 0	0 1	0 0	0 0	0 0	1 0	0 0	0 0

Reported RSIs and Additional Injuries

Throughout the 14-week injury surveillance period, 7 individuals reported some variation of a rib cage injury (4 of which could be classified as a potential RSI); these injuries were sustained by 5 student athletes from Team A ($5/15 = 33\%$) and 2 student athletes from Team B ($2/14 = 14\%$). A detailed description of each participants' baseline data compared to their respective RSI injury reports are noted below, while individual student-athlete's injury comments are presented in Table 2.6.

Student Athlete A1

A 19-year-old, left-hand dominant Division I student athlete (hgt, 170.2 cm; wgt, 68.2 kg) reported on her baseline questionnaire that she typically rows port in an eight boat. She had only been competing as an NCAA rower for less than one year, and did not

row before college. At the start of the study, she reported no hormonal contraceptive use, and reported having 12 menstrual periods in the last 12 months (eumenorrhea).

Additionally, she had received dietary recommendations from a dietician in the last season, and was taking several dietary supplements including Vitamin D, iron, calcium, and magnesium. She did not note any past medical history of injuries, and reported being free from injury at the start of the study.

The student athlete originally reported right posterior shoulder pain on March 20, which was first noticed during on-water practice. The pain was assessed by her athletic trainer, and she was able to participate fully with no changes in activity for the following 2 weeks. On April 17, she reported low back tightness that resolved in less than 1 week and did not result in any time loss or modification from activity. At Week 12 (May 10) this student athlete reported left posterior shoulder tightness and a possible RSI. She stated “the AT said that it was tight muscles around my shoulder blade starting at the acromion process and running in a backwards "C" shape down to the left side of my ribcage. Also, we’re watching it because there are signs of a possible rib stress [injury] due to some preliminary exercises she had me do.” The injury was first noted during on-water practice, and the athletic trainer was the individual who assessed the injury. The student-athlete’s activity level was modified to only include 4 on-water training sessions for the week. The week after the injury she did not have practice, and in turn did not provide any additional data regarding her status. Upon completion of the study, the athletic trainer verified the injury and noted that there was no diagnosed RSI, but rather serratus anterior hypertonicity.

Student Athlete A2

A 19-year-old, right hand dominant Division I rowing athlete (hgt, 175.3 cm; wgt, 75.0 kg) reported on her baseline questionnaire that she typically rows starboard in an eight boat. She had been competing as an NCAA rower for less than one year; however, she did row for 3 years prior to college. At the start of the study, she reported hormonal contraceptive use, and reported having 12 menstrual periods in the last 12 months (eumenorrhea). Additionally, she had received dietary recommendations from a dietician in the last season, but was not taking any dietary supplements at the time of her baseline questionnaire. She did not note any past medical history of RSIs; however, she reported that she was experiencing symptoms of patellar tendonitis at the start of the study. Additionally, she noted that due to some rib issues, “I sit out periodically from rowing for anywhere from 2 to 4 practices and bike instead, when my rib is bothering me more than usual.”

During Week 3 of the study, this student athlete reported rib pain, upon which she and her coach decided she would sit out for 2 on-water practices. In the same week of her reported rib pain, she was in the four boat and was rowing port. No further issues were reported after initial her “rib pain.”

Student Athlete A6

A 21-year-old, right hand dominant Division I rowing athlete (hgt, 175.3 cm; wgt, 70.5 kg) reported on her baseline questionnaire that she typically rows starboard in an eight boat. She had been competing as an NCAA rower for 3 years; however, did not row prior to college. At the start of the study, she reported no hormonal contraceptive use, and reported having 12 menstrual periods in the last 12 months (eumenorrhea). Additionally,

she had received dietary recommendations from a dietician in the last season, but was not taking any dietary supplements at the time of her baseline questionnaire. She reported a past medical history of a diagnosed rib stress fracture within the last year, which resulted in a loss of two to three months of normal/full training. She noted that it is “not fractured as before, but still causes pain” and that she “must occasionally sit out.”

During Week 2 of the injury surveillance this student athlete reported no injury, but in her weekly survey reported “coach put me on the bike to save my rib for the next three weeks.” In the following 2 weeks, she first reported a lower trapezius muscle strain followed by residual symptoms of this injury along with associated rib pain. This particular student athlete did not re-consent between Weeks 4 and 5 of the study, and therefore we do not know if she suffered from any additional rib pain during the remaining weeks of the study.

Student Athlete A7

An 18-year-old, right hand dominant Division I rowing athlete (hgt, 172.7 cm; wgt, 75.2 kg) reported on her baseline questionnaire that she typically rowed port in a four boat. She had been competing as an NCAA rower for less than 1 year, and rowed for 2 years prior to college. At the start of the study, she reported no hormonal contraceptive use, and reported having 10 menstrual periods in the last 12 months. She did not receive any dietary recommendations in the last season, and was not taking any dietary supplements at the time of her baseline questionnaire. She reported a past medical history of an intercostal rib strain, which resulted in a loss of 1 to 2 weeks of normal/full training. Additionally, she noted that her right sacroiliac joint was out of rotation sometime within the year prior to the start of the study, which resulted in a loss of 1 to 2 weeks of

normal/full training.

On March 1 (Week 2), this student athlete reported a right-sided serratus anterior/latissimus dorsi injury. She participated fully during this week. On March 13 (Week 4), the participant also reported a rib cage/intercostal muscle injury. During Week 4, this individual participated in 8 supplementary training/conditioning sessions and only 4 on-water practice sessions. Upon Week 5, the individual was still experiencing symptoms of this left-sided rib injury, and reported that she was not training at normal/full capacity. We do not know how this individual progressed through the following weeks, as she did not provide data past Week 5.

Student Athlete A15

A 21-year-old, right hand dominant Division I rowing athlete (hgt, 152.4 cm; wgt, 81.8 kg) reported on her baseline questionnaire that she typically rowed port in an eight boat. She had been competing as an NCAA rower for 3 years, and rowed for 4 years prior to college. At the start of the study, she reported hormonal contraceptive use, and reported having 3 periods in the last 12 months (oligomenorrhea). Additionally, she had not received any dietary recommendations in the last season, and was not taking any dietary supplements at the time of her baseline questionnaire. She reported a past medical history of a rib stress reaction, which resulted in a loss of 2 to 4 weeks of normal/full training. Additionally, she noted that she had a hip flexor strain within the year prior to the start of the study, which resulted in a loss of 1 to 2 weeks of normal/full training. She reported being free of injury at the start of the study.

On March 1 (Week 2), the student athlete reported right-sided serratus anterior/rib pain. She reported that she “missed 2 days of on water training as a precaution against

further rib pain.” The athletic trainer made the assessment, and the student athlete reported that the coach ultimately decided she could return to normal/full training. She rowed port in an eight during the week of reported injury, taking part in four on-water training practices and five supplementary training/conditioning sessions. This student athlete did not re-consent to the extension of the study, and therefore we do not have additional follow-up on this reported rib injury; we only have data on this participant through Week 4.

Student Athlete B4

A 19-year-old, right hand dominant Division III student athlete (hgt, 170.2 cm; wgt, 72.7 kg) reported on her baseline questionnaire that throughout the season she typically rowed port in the eight boat. At the time of our study, she had only been competing as an NCAA rowing athlete for 1 year, and did not row before college. At the time of her baseline questionnaire, she was not taking any kind of hormonal contraceptive, and she reported that she had 9 menstrual periods in the last 12 months (oligomenorrhea). Additionally, she had not received any dietary recommendations in the last season, nor was she taking any sort of dietary supplement. Her past medical history within the last year included a herniated L5 disc, which resulted in a loss of 2 to 4 weeks of full/normal training. She reported that she still experienced sciatica as a result of this injury, but did not mention that she was suffering from any additional injuries.

The student athlete first reported left-sided latissimus dorsi pain on March 15 (Week 4), which was assessed by both herself and her athletic trainer. This injury was first noticed during the on-water practice session, and while she had to modify activity upon injury she was able to continue training. During all of her recorded weeks

throughout the course of the study, she rowed port in an eight boat and did not deviate from this assignment.

Student Athlete B5

A 19-year-old, 170.2 cm tall, 72.7 kg, right hand dominant Division III student athlete reported on her baseline questionnaire that she typically rows port in an eight boat. She had only been competing as an NCAA rower for less than 1 year, and did not row before college. At the start of the study, she reported that she did not use any kind of hormonal contraceptive, and had 6 menstrual periods in the last 12 months (oligomenorrhea). Additionally, she had not received any dietary recommendations in the last season, nor was she taking any sort of dietary supplement. Her past medical history within the year prior to the start of the study included a sacroiliac joint strain, which resulted in a loss of 1 to 2 weeks of full training. This individual reported issues related to sacroiliac joint inflammation at the start of the study.

The student athlete initially reported a pectoral muscle strain on April 11 (Week 7). She first noticed it during the warm-up portion of practice, noting that both she and her athletic trainer assessed the injury. She was able to continue participating in athletic activity, however during the initial week of the injury she reported four sessions of supplemental training/conditioning and no on-water training, no ergometer training, and no weight training. The next week (Week 8) she reported an anterior intercostal strain, eventually noting a lack of rib alignment, which was evaluated by both the athletic trainer and the physician upon persistence of pain. The student athlete continued to document training status and characteristics related to this intercostal strain, and reported issues and modifications to her training regimen during Weeks 9 through 13. Throughout the course

of this 14-week study, she remained in the eight boat and continued to row port.

Qualitative Themes

Several qualitative themes emerged from the survey information. First, there was a similar management style for several of the individuals who reported ‘rib pain’ or serratus anterior issues. Upon onset of symptoms, athletes were immediately removed from on-water practice (and sometimes ergometer training) and were instead instructed to do supplementary training and conditioning (biking and XTrain, for example). This occurred in a total of 4 individuals, 2 of which had a past medical history of rib pathology. It was not always clear who made the decision to pull the athlete from activity, whether it was strictly a decision made by the coach or in collaboration with the athletic trainer/healthcare provider.

In several of the reported rib cage injuries, there was a gradual development of tightness and pain in nearby and associated soft tissue prior to the onset of pain in the rib cage; this included areas of the shoulder and low back, specifically. Additionally, 5 individuals who reported rib cage injuries were younger student athletes, ages 18 and 19 years old. The majority of the rib cage injuries occurred in the first 5 weeks of the study, which consisted of training in the pre-competition and early competition seasons.

Table 2.6. Student Athlete Injuries and Associated Comments			
*PMH of RSI (or rib cage injury)			
[] = AT injury assessment upon verification			
<i>Participant</i>	<i>Week of Injury</i>	<i>Injury</i>	<i>Comments</i>
A1	<i>Week 1</i>	Forearm cramps/tightening to the point of no grip [Extensor Wad hypertonicity due to overgripping]	“Took off two days from training in regards to rowing or erging. Was able to do SkiErg and biking as supplemental.”

Table 2.6 (cont.)			
	<i>Week 4</i>	Very knotted muscle in back of thigh, causing tension in popliteal region of knee [Hamstring hypertonicity]	“Resolved with stretching, rolling, and cupping.”
	<i>Week 5</i>	Shoulder tightness [Hypertonic musculature of scapular stabilizers]	“Really bad knots right below my shoulder blade. Also, inflammation in "C" shape around shoulder blade, running from below armpit up to nape of neck.”
	<i>Week 9</i>	Low back muscle tightness [Hypertonic lumbar paraspinals]	“I was able to participate fully over the given time, and was given exercises to do to help stretch out my back, as well as having e-stim and heat done.”
	<i>Week 12</i>	Shoulder tightness, possible RSI [Serratus anterior hypertonicity]	“The AT said that it was tight muscles around my shoulder blade starting at the acromion process and running in a backwards "C" shape down to the left side of my ribcage, where there are knots. Also, we are watching it because there are signs of a possible rib stress [injury] related to some preliminary exercises she had me do.”
A2	<i>Week 3</i>	Rib pain	“Ribs were bothering me so I sat out for two water practices.”
	<i>Week 4</i>	Patellar Tendonitis returned	“Returned; had gone away for a while.”
A6*	<i>Week 2</i>	No injury reported (precautionary)	“Coach put me on the bike to save my rib for the next 3 weeks.”
	<i>Week 3</i>	Lower trapezius muscle strain	“Lower trap muscle strain, pulls on ribs to cause sharp pain in the front and back.”
	<i>Week 4</i>	Lower trapezius and rib pain	No comment
A7*	<i>Week 2</i>	Serratus anterior/latissimus dorsi injury [Serratus anterior hypertonicity with fascial adhesions]	No comment
	<i>Week 4</i>	Rib cage/Intercostal muscle injury [pleurodynia; rib pain]	No comment
	<i>Week 5</i>	Rib injury	No comment
A12*	<i>Week 6</i>	Lower trapezius spasms	No comment
A15*	<i>Week 2</i>	Right serratus anterior/rib pain	“I missed two days of on water training as a precaution against further rib pain.”
B1	<i>Week 4</i>	Back strain	No comment

Table 2.6 (cont.)			
B4	<i>Week 5</i>	Latissimus dorsi pain, possible RSF	“Started out as lat pain, AT is suggesting rib stress fracture but has not been confirmed by physician or through images.”
B5	<i>Week 7</i>	Pectoralis muscle strain	No comment
	<i>Week 8</i>	Intercostal strain	No comment
	<i>Week 10</i>	Intercostal strain (cont.)	Took “day off for recovery pre-race.”
	<i>Week 11</i>	Intercostal strain (cont.)	“Took days off the water to XTrain.”
	<i>Week 12</i>	Intercostal strain (cont.)	“One day off for injury prevention.”
	<i>Week 13</i>	Intercostal strain, lack of rib alignment (cont.)	“Been away from full training 4-6 weeks.”
B7	<i>Week 11</i>	Strained hip flexor	No comment
B10	<i>Week 2</i>	Achilles tendonitis	No comment

Discussion

An immense amount of training and technique work is required to be successful and competitive in this sport. While the average competitive rower trains year-round, a typical NCAA spring rowing season has only a handful of competitions, several of which determine seeding and national championship competition entrance eligibility.⁹ As a result, collegiate rowing athletes have a relatively small training window to reach their maximal rowing capacity.

With only a few published studies in the literature that prospectively document RSIs in the US collegiate rowing population, to the best of our knowledge, this study is the first that prospectively tracks RSIs and potential associated areas of injury (the shoulder complex and low back) in the NCAA rowing student athlete population.

While there were no confirmed diagnosed RSFs or rib stress reactions during the course of this study, several individuals in the study reported recurring or new rib cage

related injuries that resulted in some time lost from training (time lost varying across individuals). Expectations are that follow-up at the end of the season with participants who did not continue the study after extension would have produced a clearer perspective on the duration and ultimate outcome of these reported RSIs.

One of noted findings in our study was the management style of various rib cage-related issues. Several individuals from Team A reported instances of the onset of rib pain, after which their coach instructed them to modify activity and instead complete supplementary training rather than on-water training for a number of days; they would then return to normal/full activity upon (what we are assuming as) decreased or absence of pain. These findings are consistent with recent research conducted by D'Ailly et al. (2016) which mentions various RSI management strategies, and addresses this aggressive strategy specifically.¹⁶ Additionally, a 2016 editorial by Vinther and Thornton²³ reiterates that research has documented a more aggressive approach to managing these injuries, especially leading up to and during competitions, so that athletes are still able to compete. Traditionally, competitive rowing athletes have been found to employ various pain-reducing strategies to temporarily manage associated symptoms of RSIs, while also potentially taking part in a brief period of modified or no activity.^{23,24} These articles in conjunction with one another are supported by our findings of an aggressive approach to try and keep the student athletes training and performing optimally for competitions.

Our study results also highlight the physiological complexity of these injuries. One of the primary issues noted in previous studies is that often times, overuse rib injuries go undiagnosed due to lack of knowledge or comfort in diagnosing RSIs, especially considering the complex organization of soft tissue surrounding the rib cage.⁶

One participant in particular (Student Athlete A1) presented with a series of soft-tissue related issues throughout the course of the study including hamstring tightness, low back tightness, and eventually shoulder tightness with a possible RSF. The athletic trainer verified that the student athlete did not have a RSF at that time, but rather was suffering from serratus anterior hypertonicity. Another participant (Student Athlete B5) reported a pectoralis muscle strain a week prior to the onset of symptoms associated with a serratus anterior strain, ultimately resulting that she wasn't able to train fully/normally for 4 to 6 weeks. Both previous and concurrent shoulder and low back injuries have been noted in the literature to be potential risk factors in the development of RSIs. However, as previously mentioned we do not know the ultimate extent of the reported injuries from our study due to lack of diagnostic imaging to confirm or rule-out a diagnosis of a RSI.

These reports confirm and highlight one of the many issues regarding RSIs; there is a significant amount of critical soft tissue, both fascial and muscular in nature, surrounding the rib cage; with the function of that soft tissue being essential for not only rowing activity, but daily physiological and bodily functions. Team A's athletic trainer reported multiple issues of hypertonicity both isolated and in conjunction with rib cage-related issues. Because the most popular theory of injury mechanism involves the actions of various muscular structures (the serratus anterior and the external abdominis oblique),^{14,25} attention should be paid to the surrounding musculature and its biomechanical and physical characteristics throughout the season, as this may indeed impact the overall effectiveness and efficiency of these muscles during the rowing stroke. If these muscular structures are being placed under repetitive, intense stress, it may very well be sufficient force to bend the ribs in a manner in which induces bone stress injury.

Healthcare professionals who experience a lack of confidence in regards to assessing and diagnosis RSIs should refer to recent guidelines set forth by Evans and Redgrave in 2016.^{6,26}

In some cases past medical history had a significant effect on current and future training. We documented several individuals who had a past medical history of a diagnosed RSI within the last year, and these individuals experienced either residual or new symptoms of rib pain. Bone continues to calcify and heal months after the initial injury onset, and may be more susceptible to a secondary stress injury if continuously placed under sufficient stress through exercise and activity. We do not know if these symptoms are recurring from the precise area of the previous injury or are simply related yet in different locations; however, because of the complexity of the rib cage as a moving, bendable system, it is not unreasonable to suggest that if insufficient healing time is not provided to the bony area of injury, the risk for potential recurrence of injury would indeed increase.

Five out of the 7 individuals who reported rib cage injuries were of a younger age; they were 18 and 19 years old, and were either freshmen or sophomores in at their respective universities. Approximately half of the 7 who reported rib cage injuries did not row prior to their collegiate careers. This would lend one to conclude that younger collegiate athletes, especially those with little to no prior rowing experience, might be predisposed to injury due to the sudden increase of exercise volume and intensity required of a NCAA collegiate rowing program. However, considering the average age of all participants in the study was relatively young to begin with, it would not be fair to include this as a significant causal factor at this time.

The documented training characteristics also provide insight into the world and associated athletic injuries of an NCAA rower. D'Ailly stressed the importance of systematically describing training hours in time to improve future research on these injuries; this was the first study of our knowledge to prospectively document training hours and sessions in NCAA female rowing athletes while simultaneously looking to gather more detailed data on the development of RSIs.¹⁶ Wajswelner et al. observed that prevention of this injury includes attentive monitoring for injury and ultimately trying to avoid sudden increases in all aspects of training.²⁴ While the researchers managed to get some data on time lost from injuries or associated pain, more detailed information is necessary to draw any valid hypotheses or conclusions.

The results from our paired t-tests comparing weekly average training hours between the two teams indicate significance in that volume of training was significantly different between the two teams. Individuals from Team A reported a greater number of rib cage-related issues, and reported both a greater number of average training hours per week and a greater number of average training sessions per week as compared to Team B. These statistically significant differences in weekly training characteristics could certainly be a contributing factor to not only an increased rate of rib cage related injuries, but also other musculoskeletal injuries. Researchers have documented training characteristics as a risk factor for increased rates of RSIs; previous literature has noted that a gradual increase in training volume and intensity is ideal when looking to prevent bone stress injuries. Observationally, it was interesting to note that a majority of the RSI occurred early in the season and during weeks when there was the highest average training hours. With Team A being a Division I team, one would naturally expect a

higher level of competition and a program that is more physically demanding of their student athletes. Given that both Team A and Team B reported RSIs even with different training volumes demonstrates the need for more comprehensive research on the interaction of student-athlete characteristics and training characteristics relative to the impact they have toward the onset of RSI type conditions in this collegiate female population.

There is conflict in the literature on whether or not the side on which a student athlete rows might affect the individual's risk of a rib cage injury.^{13,15} Due to the nature of the sweep rowing style primarily utilized by NCAA rowing athletes, one can visualize how the reaching and bending required of the athletes might lead to improper and unbalanced body mechanics, increasing the risk for injury. Unfortunately, not all individuals in our study noted the side on which they were experiencing rib pain or suffering an injury. Of those that did, there was no identifiable theme or pattern in regards to their typical rowing side and their reported side of injury. Another related contributor to rib cage injuries might be that individuals frequently asked to switch between port and starboard place additional stress on their body due to the constant readjustment of their biomechanics during the rowing stroke. Only one individual who reported a rib-related injury documented that they switched from starboard to port in the weeks prior to the onset of their injury. Almost all other individuals who reported a rib cage-related issue remained on their respective boat side throughout the duration of the study, and stayed in their respective boat size during the 14 weeks. However, due to the single case of this side-switching amidst this data of this scenario occurring along with a lack of data in regards to specific location of injury, we can only continue to hypothesize

this characteristic as a potential risk factor for RSIs. As a prospective change going forward, we would recommend documentation of specific side of injury, weekly reporting of the side on which they row, and the boat size in which they row.

Of the individuals who reported a rib cage injury, there were varying levels of menstrual activity. Two individuals from Team A had diagnosed RSIs within the last year (a rib stress fracture and a rib stress reaction, to be precise), however their menstrual activities over the course of the last year were completely different. There was no consistent pattern amidst individuals in terms of whether they were eumenorrheic, oligomenorrheic, or amenorrheic relative to their injury status. The consequences of an irregular or completely absent menstrual cycle in women has been documented extensively in research; it has taught healthcare providers to be mindful of the potential development of the Female Athlete Triad in their athletes, and the subsequent possibility of individuals developing a bone stress injury.²⁷ More recent literature has detailed the newly termed RED-S, which places an emphasis on energy availability (or lack thereof) in both male and female athletic individuals; where menstrual activity in females can be a contributing factor to bone stress injuries.^{6,28} The results of our study were inconclusive in this regard.

We collected information on each individual's supplementation use, looking specifically for correlation between usage and RSI frequency, but found no evident relationship between supplementation use (or access to nutritional resources) that clearly identified nutritional issues in relation to potential onset of a RSI or rib cage injuries. However, we did not collect any information in regards to each individual's specific BMD, and we did not ask if they had any sort of body composition testing done within

the last year. Vinther et al. documented a potential link between reduced BMD and exercise-induced rib stress fractures.²⁹ Nutritional aspect of competitive collegiate athletes should be monitored to ensure that their energy expenditure is equally met by their energy consumption.²⁸ McDonnell et al. suggested that athletes take supplements, particularly Vitamin D and calcium, during intense and high volumes of training so to help decrease the risk of injury.¹⁵ This will also help deter any potential development of RED-S in these competitive student athletes, along with the ensuing physical consequences of this issue.^{6,28}

Limitations

One of the biggest limitations of this study is the small sample size; this includes both the number of participating teams, as well as the number of student athletes from each team willing to consent and provide weekly data. While we aspired to have a greater number of participants in terms of teams and individuals, the fact that we were able to collect as much prospective data on this clinical predicament as we did and create a case series of individuals with variations of these rib cage injuries is beneficial to the add to the current literature. A contributing factor to this small sample size was also the fact that we were specifically looking at NCAA rowing athletes, meaning that we automatically eliminated male collegiate rowing athletes, all female lightweight teams, and female rowing teams both through universities and university club teams from inclusion in our study. However, this specified and targeted population allowed us to categorize individuals according to their respective division and ensure that they had an athletic trainer that we could rely on to verify reported injuries.

Along with the issue of our small sample size is that our retention rate and

consistency in weekly reporting amongst student athletes was not what we hoped it would be. We made efforts to minimize the time and effort required by the student athletes to complete the weekly e-diary entries, as evidenced by the average time recorded to complete these surveys, as well as the 24-hour reminders. Had we not needed to obtain renewed consent from participants after 4 weeks of data collection and survey distribution, we might have seen a higher reporting rate by the end of the season.

At present there is not a lot of information in the literature regarding RSIs, especially in this particular population of rowing athletes. This limitation made our attempts at targeting and documenting potential risk factors and analyzing the data more difficult than expected. Additionally, the delayed start in data collection for our study timeline deprived us of documenting important training weeks that we were eager to analyze. We would have hoped to record more of the winter training months (January to mid-March), as additional research in this particular segment of the season would allow for substantially more information regarding training characteristics that might be direct contributors to RSIs whose symptoms appear just prior to the start of the competition season. However, the fact that we were able to prospectively document 14 weeks' worth of training characteristics and injuries in NCAA female rowing athletes is an exciting contribution to the literature.

Conclusions

As noted in previous studies, RSIs are athletic issues of great complexity and are multifactorial in nature. We found that 27% of our sample of NCAA female collegiate rowing athletes is indeed suffering from a variety of rib cage issues, several of which have the potential to be classified under the umbrella of RSIs. Our results suggest that a

more in-depth analysis of these NCAA rowing athletes and their upper extremity injuries and ailments is necessary. This, along with continued prospective documentation of training characteristics, will hopefully provide a more comprehensive picture of the true extent of RSIs in the NCAA rowing population. This data might lead to insight on proper preventative and management strategies that would allow collegiate athletes to maintain performance levels without sacrificing the highly competitive nature of the sport.

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3. SUMMARY AND RECOMMENDATIONS FOR FUTURE RESEARCH

Considering our small sample size and the number of individuals who reported from each team, the fact that we had 7 student athletes out of 27 (26%) report some variation of a RSI or rib cage injury is troubling for the US collegiate rowing population. In particular, that 5 out of the 7 (71%) of these student athletes were members of Team A, the Division I school. While this logically makes sense considering the more rigorous and demanding nature of an NCAA Division I athletic program, it still warrants additional research to determine how widespread this issue amongst all levels of NCAA collegiate rowing programs.

Future research should look to survey a larger sample size (including more teams and more student athletes) that can hopefully be retained throughout the duration of the study so to draw better conclusions from the weekly data. A greater variety of ages and years of experience both in the collegiate setting and prior to their NCAA careers would also be valuable information. However, the key to any prospective study is finding a way to ensure that retention rates remain high throughout the duration of the research. The increased consistency in reporting will allow researchers to study trends and themes amongst different individuals, and hopefully provide some clarification on specific risk factors.

While student athlete self-report is beneficial in some situations, it does have its drawbacks. Some of our participants reported information that was anatomically impossible, and we were unable to discern what their intended information meant and in turn had to exclude it from this study. However, the self-reporting of data by our participants gave us relatively detailed information regarding each individual's ailments

and respective training characteristics while dealing with those injuries. Additionally, it did not place a significant burden on athletic trainers by not requiring them to keep track of each individual's specific training regimens relative to their injury status, and in turn placed some accountability on the student athletes. More detailed questions should be included in the survey material to obtain a more descriptive and comprehensive picture of RSIs from the student athlete's point of view. Nonetheless, future research would benefit from a greater detail of verification by athletic trainers in terms of training characteristics and injury onset details as long as it does not place an undue burden on team healthcare providers.

APPENDIX SECTION

IRB APPLICATION

For IRB Use Only	
File Number:	
Approval	
Type of Review	

IRB Review Application Texas State University Institutional Review Board

Section I: Filling Out and Saving the Form

Save this form on your desktop and when ready submit this application along with all supplemental documents to the IRB Office as an attachment. All documents should be saved as First Name or Initial, Last Name, and one-word description, with no extra spaces or special characters other than underscores. Acceptable examples: JohnSmithapplication, J_Smith_application.doc, JohnSmith_consentformEnglish.pdf, JSmithconsentformSpanish.doc

Type only in the [blue fields](#), and closely follow all stated length limits. **Handwritten forms will not be accepted.**

Section II: Risk Review

Please click the box indicating your answer to **each** of the following questions.

1. Will your research study involve any vulnerable populations such as children, prisoners, pregnant women, mentally disabled persons, elderly, or minority groups?
☐ Yes
☒ No
2. Could public disclosure of any identifiable data you collect place the participants at risk of criminal or civil liability or be damaging to the participants' financial standing, employability or reputation?
☐ Yes
☒ No
3. Will your study involve data collection procedures other than surveys, educational tests, interviews, or observation of public behavior?
☐ Yes
☒ No
4. Will your study involve any sensitive subject matters such as: abortion, criminal activity, sexual activity, sexually transmitted diseases, prior diagnosis for mental health disorders, victims of violence, alcohol use, alcohol abuse, illegal drug use or drug abuse?
☐ Yes
☒ No
5. Will your study involve audio-recording or video-recording the participants?
☐ Yes
☒ No
6. Will your study involve obtaining individually identifiable information from health care plans, health care clearinghouses, or health care providers?
☐ Yes
☒ No
7. Is the data you are collecting anonymous data? Anonymous meaning you as an investigator cannot be linked in any way back to the source of the data.
☐ Yes
☒ No

Form designed and maintained by Texas State University ORIC, JCK 489, 512-245-2334. Last updated on March 2016
OHRP Federal wide Assurance: FWA00000191

8. Will you be using public available data banks?

☐ Yes
☒ No

9. Will you be using data that was previously collected by another researcher, institution, second vendor, third party authorized by Texas State IRB, or intellectual property of another institution/researcher?

☐ Yes
☒ No

Reminder: Upload Data Usage Agreement if Yes to question # 9

Section III: General Information

Type only in the **blue fields**, and closely follow all stated length limits. **Handwritten forms will not be accepted.**

1. Title of Study

Must be identical to the title of any related internal or external grant proposal.

Incidence and Risk Factor Analysis of Rib Stress Injury in the Collegiate Rowing Athlete

2. Investigator (Primary Researcher)

First Name	Last Name	Title (i.e. grad student, faculty, ect.)
Caitlin	Madison	Graduate Student
Degree program/Department	Texas State Email Address	Phone Number
Athletic Training/Health and Hi	kate.madison@txstate.edu	214-729-0027

3. Co-Investigator/ Texas State University Supervising Faculty (if applicable)

Must be a full-time Texas State University faculty member or a full-time staff employee whose job responsibilities include conducting human subject's research. A faculty Supervising Investigator is required for all student studies which require IRB review, including all theses and dissertations that use humans as research participants. Student Investigator information is entered in Section III question 2.

First Name	Last Name	Texas State E-mail Address
Gabriel	Fife	gabefife@txstate.edu
Department or University	Title (Associate Professor, Professor, Dean, ect)	
Health and Human Performance	Assistant Professor	
Phone number		
512-245-3480		

4. Key Personnel

List the name of all other Key Personnel (including students) who are responsible for the design, conduct, or reporting of the study (including recruitment or data collection).

Rod Harter, Jeff Housman

5. CITI IRB Training

Have you, any Co-Investigator, any Student Investigator, and all Key Personnel completed the CITI training course ("Social and Behavioral Research")?

- ☒ Yes
☐ No

If you answered "No," this training is **required for all Key Personnel before your study can be approved**. The CITI course may be accessed by visiting: <https://www.citiprogram.org/>. **Training is only valid for 3 years** and will require a refresher course if expired. Your **application will not be approved till all required training is completed and current**.

Reminder: Upload CITI Certificates

6. Funding Information (if applicable)

Has **external or internal funding** been proposed or awarded for this project?

- ☐ Yes
☒ No

If **yes**, please submit the statement of work or a project summary that was included with the proposal. Also please provide the OSP or Texas State Project Number for any external funding or the account number for any internal funding for this project.

Proposal Number or Project ID Number _____
Statement of work or project summary attached?

- ☐ Yes
☐ No

Reminder: Upload Grant docs

7. Financial Conflict of Interest Disclosure (if applicable)

Has **external funding** been proposed or awarded for this project?

- ☐ Yes
☒ No

If yes, Texas State University requires the Principal Investigator, any Co-Investigator, any project director, and any other person with responsibility for designing, conducting, or reporting of externally funded research to complete an online Financial Conflict of Interest disclosure each fiscal year.

Have all Investigators and other key personnel for this proposed project completed an online Financial Conflict of Interest disclosure for the current fiscal year? (The online process for submitting a Financial Conflict of Interest Disclosure is available at <http://www.txstate.edu/research/orc/researcher-conflict-of-interest.html>).

☐

Yes

☒

No

Section IV: Research Protocol Information

1. Purpose of Study

In no more than a page, briefly state the purpose of your study in **lay language**, including the research question(s) you intend to answer. A brief summary of what you write here should be included in the informed consent form.

Throughout their athletic careers, competitive rowing athletes experience a multitude of acute and chronic injuries that prevent them from participating in important training seasons or parts of their competition seasons. One such injury that can have significant consequences is the rib stress injury. This is an umbrella term that includes rib stress reactions (where the bone has not truly broken), rib stress fractures (where the bone breaks due to sufficient force), and generalized rib "pain." These injuries present a major problem for not only the athletes, but also the athletic trainers, coaches, and doctors that are responsible for their care and training. Because NCAA collegiate rowers only participate in a handful of competitive races each spring, their winter training season is essential for optimal performance and competition. Research to date has examined possible theories for the mechanism of injury as well as potential intrinsic and extrinsic risk factors that may play a role in a rowing athlete's risk for sustaining a rib stress injury, however evidence is still lacking, especially in the United States collegiate rowing athlete.

The primary purpose of this study will be to answer the following questions: 1) What is the estimated incidence rate of rib stress injuries in the NCAA rowing athlete during the winter training months, and 2) Is there a relationship between any of the hypothesized risk factors for rib stress injuries among NCAA rowing athletes (specifically past medical history of injury, preceding low back or shoulder injury, training characteristics, menstrual activity, and supplementation use) and the rate of rib stress injury.

2. Previous Research

In no more than half a page, summarize previous research leading to the formulation of this study, including any past or current research conducted by the Investigator that leads directly to the formulation of this study (including citations and references.)

Most studies that have been conducted on rib stress injuries have looked at national teams and populations outside of the United States. As a result, estimated rib stress injury incidence rates are based on individuals who compete at the most elite level of rowing. A systematic review conducted by McDonnell et al. (1) stated that through their review of 20 studies involving 144 rowers with a rib stress fracture, the average incidence of injury was 9.2%. Of the 20 studies, 19 were retrospective in nature and only one was prospective. In 2011 Hooper et al. found that rib stress reactions can result in an average loss of 48 training days per year for rowing athletes, which can increase to an average loss of 60 days per year if these stress reactions develop into stress fractures. (2) The theorized cause of rib injuries in competitive rowing athletes has to do with insufficient endurance and over-activation of specific chest wall muscles (the serratus anterior and abdominal muscles, respectively), termed the Abdominal-Led Rib Cage Compression theory. (3) Because of this lack of evidence regarding the true mechanism of injury, preventative interventions and recommendations are minimal and their effectiveness has not been studied. Recent research has analyzed the involvement of potential risk factors related to the development of rib stress injuries in these rowing athletes. They can be divided into two main categories, intrinsic and extrinsic risk factors. Of the intrinsic risk factors, they include muscle imbalances, joint mechanics, sex, bone mineral density, concurrent or a past medical history of shoulder or low back injury. (1,4) Suggested extrinsic risk factors include rowing style, training characteristics, equipment, and environmental concerns. (1,4) However, minimal research exists on these potential risk factors and their relationship with rib stress injuries in the rowing athlete, much less in a collegiate setting.

1. McDonnell LK, Hume PA, Nolte V. Rib stress fractures among rowers: definition, epidemiology, mechanisms, risk factors and effectiveness of injury prevention strategies. Sports Med. 2011;41(11):883-901.

2. Hooper I, Blanch P, Sternfeldt J. The development of a clinical management pathway for chest wall pain in elite rowers. J Sci Med Sport. 2011;14:104.

3. Warden SJ, Gutschlag EB, Weiswanger H, Crossley KM. Aetiology of rib stress fractures in rowers. Sports

3. Recruitment of Participants

Describe the projected number of subjects.

For our study we hope to have 3 teams participating, with approximately 20 athletes from each team submitting weekly e-diary reports. This would amount to approximately 60 student athletes. Additionally, from each team we hope to have at least one athletic trainer per school available to confirm injury diagnoses provided by the student athletes.

Describe the population from which subjects will be recruited (including gender, racial/ethnic composition, age range, occupation, institution, ect).

Participants will be recruited from NCAA Division I, II, and III university rowing teams in the United States. Because the NCAA only sanctions women's open weight rowing programs in the United States, all participants will be female. Participants will be required to be 18 years of age or older.

Describe how you will recruit subjects (face-to-face, e-mail, flyer, classroom announcement, etc.).

Participants (NCAA rowing student athletes) will be recruited via their athletic trainer at their respective university. NCAA Division I, II, III rowing teams will be identified on the web page www.row2k.com (as they have a list of all collegiate rowing teams in the country). From there, athletic trainers who work with these NCAA rowing teams will be identified via their respective university's athletics website, and emailed information about the study; they will be invited to participate and recruit student athletes from their rowing teams on which we can

Please upload all of the recruitment materials such as flyers, e-mails, scripts for classroom announcements, ect.

Reminder: Upload recruitment all documents

4.. Vulnerable Populations

Please Identify any vulnerable populations who will be participating in this study:

- | | |
|--|--|
| <input type="checkbox"/> Children (under 18 years of age) | <input type="checkbox"/> Pregnant Women |
| <input type="checkbox"/> Prisoners | <input type="checkbox"/> Mentally Impaired or Mentally Retarded |
| <input type="checkbox"/> Elderly who are not emancipated, in a nursing home, or receive hospice care | <input type="checkbox"/> minority populations that do not speak English (i.e. migrant workers) |

If any boxes are checked, describe any special precautions to be taken in your study due to the inclusion of these populations.

5. Location of Study

Identify all locations where the study will be conducted.

The study will be conducted at a variety of locations, including all universities that agree to participate and provide data on their rowing student athletes.

For data collection sites other than Texas State, have you attached a signed and dated letter on the cooperating institution's letterhead giving approval for data collection at that site?

- ☒ Yes
☐ No

Reminder: Upload supporting documents

6. Anticipated Project End Date

March 20, 2017

7. Informed Consent Process

Describe the steps for obtaining the subjects' informed consent (by whom, where, when, etc.).

Student athletes will be informed of the study by their respective athletic trainer/coaching staff. The athletic trainer/coaching staff will then provide email addresses for all members of their rowing team. All participants will be emailed an electronic version of the consent form through Qualtrics, and asked to read the consent form and complete it if they agree to participate.

8. Informed Consent Forms

Written informed consent forms to be signed by the subject after IRB approval are required for most research projects with human participants. A waiver of informed consent can be requested in certain situations such as:

- 1) Telephone surveys
- 2) Internet surveys
- 3) Subject not present
- 4) Collecting consent signature places identity of participant at risk or prevents anonymity
- 5) If signing informed consent is not standard practice for your type of research and project is of minimal risk

When Informed consent is waived the principal investigator needs to provide a written statement to participant informing them of the research project and that participation will imply consent.

Templates for creating informed consent forms are located on the IRB website at <http://www.txstate.edu/research/orc/IRB-Resources.html>. **Final drafts of all informed consent documents you plan to use must be submitted before IRB review can begin.**

Will you be requesting a waiver of informed Consent?

- ☐ Yes
☒ No

If requesting waiver of Consent explain rationale and how consent will be obtained.(i.e. Verbal, participation implied consent, clicking on link provides consent, ect.)

What is the estimated time for a subject's participation in each study activity (including time per session and total number of sessions)?

The baseline questionnaire survey should take each athlete approximately 15 minutes to complete (which they will only have to complete once at the beginning of the study). Each weekly e-diary entry should take no more than 15 minutes to complete, with a total of approximately 10 entries over the course of the study. Athletic trainers will also be sent a Verification of Injury survey when any of their athletes report an injury.

9. Compensation

Describe any compensation subjects will receive for participating in the study. Include the timing for payment and any conditions for receipt of such compensation. If extra credit for a course is offered, an alternative non-research activity with equivalent time and effort must also be offered.

Student athletes and athletic trainers will not be compensated for their participation in this study.

10. Foreign Languages

Will your study involve the use of any language other than English for informed consent forms, data collection instruments, or recruitment materials?

☐

Yes

☒

No

If "Yes," submit copies of all translated consent forms, recruitment documents, surveys, questionnaires, ect. to the IRB.

Specify all foreign languages below:

Reminder: Upload all translated documents

11. Data Collection

Which methods will you use to collect data?

☐

Interviews

☐

Surveys

☐

Focus Groups

☐

Assessment Instruments

☒

Internet Surveys

☐

Review of Existing Records

☐

Observation

☐

Other - Please list below

If "Review of Existing Records" and/or "Observation" are checked above, please describe below the records you plan to review and/or the observations you plan to make for your study.

Will your study involve audio-recording or video-recording the participants?

☐

Yes

☒

No

Have you attached a copy of all data collection instruments, interview scripts, focus group topics, questionnaires, and intervention protocols to be used?

Reminder: Upload data collection documents

☐

Yes

☐

No

12. Risks and Benefits

Describe any foreseeable risks outside normal activities subjects may be presented by the proposed study and explain precautions you will take to minimize such risks.

There are no foreseeable risks that participants may be subjected to during the study.

Describe the anticipated benefits to subjects or others (including your field of study).

The benefits of this study will primarily affect the athletic trainers who care for NCAA Division I, II, and III women's open weight rowing athletes, as well as the athletes themselves. From this study, we will hopefully be able to begin identifying risk factors that are associated with rib-stress injuries, eventually allowing athletic trainers to implement preventative measures for high-risk individuals. This will in turn hopefully decrease a rowing athlete's chance for sustaining a rib-stress injury during their collegiate rowing career.

13. Confidentiality

Describe the procedures you will use to maintain the confidentiality of any personally identifiable data.

All communication with the rowing athletes will be done through the secure website Qualtrics. All survey responses will be recorded and stored in Qualtrics, and at the end of the surveillance period the data will be exported to a Microsoft Excel document to be analyzed. All documents will be stored on the personal computer of the researcher, which is password protected. No questionnaire/survey results from the student athletes will be shared with anyone other than the researcher and associated committee members.

While names and personal emails will be stored in Qualtrics for weekly communication, this data will remain secure within the Qualtrics database until its eventual export. Additionally, the only identifying feature of each survey will be the student athlete's ID, as all surveys will remove the responder's email address so to maintain anonymity.

Please note if student investigator the sponsoring faculty/staff member **must store the data for 3 years per federal regulations**. After three years the **IRB will contact the principal investigator or sponsoring faculty/staff member to confirm data destruction**.

Please specify how and where your research records will be maintained

Research records will be maintained on the personal laptop of the researcher, as well as in the secure profile on Qualtrics (both require unique usernames and passwords to access).

Please specify any coding or other steps you will take to separate participants' names/identities from research data

All survey responses through Qualtrics will have the associated email addresses removed to ensure anonymity. We will provide each athletic trainer with a Student Athlete ID form that will allow them to assign specific identification codes to each of their student athletes. The student athletes will then use this ID when completing the surveys. This will allow researchers to link baseline survey responses with weekly e-diary entries without knowing the specific identity of the reporting student athlete. Additionally, when student athletes report an injury and it prompts the athletic trainer to fill out a "Verification of Injury" form, the ID will be used to accurately notify the athletic trainer which student athlete has reported an injury. At the conclusion of the study, the athletic trainer will be allowed to destroy the Student Athlete ID form if they so choose.

14. Publication of Results

Please identify all methods in which you may publicly disseminate the results of your study.

- | | |
|--|---|
| <input checked="" type="checkbox"/> Academic Journal | <input type="checkbox"/> A Thesis or Dissertation for One of Your Students |
| <input checked="" type="checkbox"/> Academic Conference Paper or Public Poster Session | <input checked="" type="checkbox"/> Texas State University Scholarly Works Repository |
| <input type="checkbox"/> Book or Chapter | <input type="checkbox"/> Other – Please list below. (Website, blog, etc.) |

Investigator or Supervising Investigator Certification

IRB Application for Review

Page 11 of 12

☒ By checking this box, I am certifying that the information in this application is complete and accurate. I agree that this study will be conducted in accordance with Texas State IRB Guidelines and the study procedures and forms approved by Texas State IRB.

The application and all supplementary documents must be submitted together to be processed for review. All applications will be reviewed and if revisions or additional information is needed you will be contacted by the IRB. **If revisions or additional information is needed you have 30 days to submit requests** from the date the IRB first contacted you. **If all revisions or additional information is not submitted within the 30 day window of initial contact your application will be discontinued.** If your application is discontinued you will need to resubmit another application.

Contact The Office of Research Integrity and Compliance at (512) 245-2334 for any questions about completion of your application.

Save

IRB MODIFICATION REQUEST

Modification Request Texas State University Institutional Review Board

Purpose: Complete this form when you would like to change the key personnel, data collection sites, protocol (e.g., compensation, study procedures, etc.), and/or Informed Consent/Assent Form in a research study that has already received IRB approval. Submit this form along with copies of any new or modified materials or documents you describe below. If modifications are more extensive than can be easily described on this form, please submit a new IRB application. NOTE: You may not implement any changes to an IRB-approved study until your Modification Request has been approved.

Filling Out and Saving the Form

Please type in the blue fields. Check "No" or "Yes" on items #5-9 and elaborate on "yes" answers as indicated. Save this form on your desktop and when ready submit this application along with all supplemental documents to the IRB Office as an attachment. All documents should be saved as First Name or Initial, Last Name, and one-word description, with no extra spaces or special characters other than underscores. Acceptable examples: JohnSmithapplication, J_Smith_application.doc, JohnSmith_consentformEnglish.pdf, JSmithconsentformSpanish.doc

1. IRB Application Number:

2017375

2. Title of Study

Must be identical to the title of any related internal or external grant proposal.

Incidence and Risk Factor Analysis of Rib Stress Injury in the Collegiate Rowing Athlete

3. Investigator (Primary Researcher)

First Name

Caitlin

Last Name

Madison

Title (i.e. grad student, faculty, ect.)

Graduate Student

Degree program/Department

Health and Human Performance

Texas State Email Address

cam411@txstate.edu

Phone Number

2147290027

4. Co-Investigator/ Texas State University Supervising Faculty (if applicable)

First Name

Gabriel

Last Name

Fife

Texas State E-mail Address

gabefife@txstate.edu

Form designed and maintained by Texas State University ORIC, JCK 489, 512-245-2334. Last updated on March 2016
OHRP Federal wide Assurance: FWA00000191

Department or University

Health and Human Performance

Title (Associate Professor, Professor, Dean, ect)

Assistant Professor

Phone number

512-245-2561

5. Are there changes in key personnel assisting in the research project?

☐

No

☒

Yes - List changes below and have all new key personnel complete CITI training The CITI course may be accessed by visiting: <https://www.citiprogram.org/>.

Names and Texas State Affiliation of new Key Personnel:

Rod Harter - Co-Investigator

Marie Pickerill - Added Key Personnel

Names of Key Personnel to be Deleted:

Gabriel Fife

6. Are there any additions or changes to sites where the data will be collected?

☒

No

☐

Yes - Identify specific data collection sites or agencies below. In addition, submit a signed letter on official letterhead approving data collection at each site (other than Texas State University).

7. Are there any proposed changes to the informed consent/assent form(s)?

☒ No

☐ Yes – Provide a *brief* description of and rationale for proposed changes below. In addition, submit a tracked/highlighted *revised* informed consent/assent form(s) showing the changes and a clean copy of the informed consent/assent form(s).

8. Are there any proposed changes in the protocol requested (e.g., recruitment procedures, data collection instruments or procedures, compensation)?

☒ No

☐ Yes – Provide a description of and rationale for proposed changes below. In addition, submit copies of any recruitment materials, data collection instruments, etc. that have been modified or added since your last IRB approval of this study.

9. Are there any proposed changes not described above?

☒ No

☐ Yes – Provide a brief description of and rationale for the proposed changes.

Investigator or Supervising Investigator Certification

☒ By checking this box I am certifying that the revised information provided for this project is correct and that no other procedures or forms will be used. I confirm that no changes will be implemented until I receive written approval for the changes from the Texas State IRB.

The application and all supplementary documents must be submitted together to be processed for review. **Applications submitted will only be valid for 30 days.** If your application expires after 30 days you will need to resubmit another application.

If you have questions, please contact The Office of Research Integrity and Compliance at (512) 245-2334.

Save

IRB CERTIFICATE OF APPROVAL



In future correspondence please refer to 2017375

February 1, 2017

Caitlin Madison
Texas State University
601 University Drive.
San Marcos, TX 78666

Dear Ms. Madison:

Your IRB application 2017375 titled "Incidence and Risk Factor Analysis of Rib Stress Injury in the Collegiate Rowing Athlete," was reviewed and approved by the Texas State University IRB. It has been determined that risks to subjects are: (1) minimized and reasonable; and that (2) research procedures are consistent with a sound research design and do not expose the subjects to unnecessary risk. Reviewers determined that: (1) benefits to subjects are considered along with the importance of the topic and that outcomes are reasonable; (2) selection of subjects is equitable; and (3) the purposes of the research and the research setting is amenable to subjects' welfare and producing desired outcomes; that indications of coercion or prejudice are absent, and that participation is clearly voluntary.

1. In addition, the IRB found that you need to orient participants as follows: (1) signed informed consent is required; (2) Provision is made for collecting, using and storing data in a manner that protects the safety and privacy of the subjects and the confidentiality of the data; (3) Appropriate safeguards are included to protect the rights and welfare of the subjects.

This project is therefore approved at the Exempt Review Level

2. Please note that the institution is not responsible for any actions regarding this protocol before approval. If you expand the project at a later date to use other instruments please re-apply. Copies of your request for human subjects review, your application, and this approval, are maintained in the Office of Research Integrity and Compliance. Please report any changes to this approved protocol to this office.

Sincerely,

Monica Gonzales
IRB Regulatory Manager
Office of Research Integrity and Compliance

CC: Dr. Gabriel Fife

OFFICE OF THE ASSOCIATE VICE PRESIDENT FOR RESEARCH

601 University Drive | JCK #489 | San Marcos, Texas 78666-4616

Phone: 512.245.2314 | fax: 512.245.3847 | WWW.TXSTATE.EDU

This letter is an electronic communication from Texas State University-San Marcos, a member of The Texas State University System.

RECRUITMENT EMAIL MESSAGE TEMPLATE

To Whom It May Concern:

My name is Kate Madison and I am writing to you today to ask for your help in gathering data for my Master's thesis at Texas State University. You have been identified as an athletic trainer who is currently working with an NCAA Division I, II, or III collegiate rowing team. The purpose of this study is to establish an estimated incidence rate of rib stress injuries in collegiate rowing athletes and determine associated risk factors for these injuries.

The study is comprised of an injury surveillance period that will run from approximately January 5th to March 20th. Student athletes will complete a baseline questionnaire prior to the start of the study, and will subsequently receive weekly check-in surveys via email regarding their training, supplement use, and injury status. They will be asked to report any new injuries or injuries that have resolved during the surveillance period, specifically related to rib stress injuries. The weekly questionnaire should take them no longer than 15 minutes to complete.

While this study is in the process of obtaining IRB approval, I am hoping to gauge interest prior to the holidays. There are no risks or consequences for your student athletes' participation in this study. Their participation is voluntary and their survey responses will remain anonymous in the publishing of this research. If at any time they wish to stop the study, they may do so by simply not responding to further surveys.

If you are interested in submitting members of your team for participation in this study, I will need permission from your coaching staff and athletic department to contact your student athletes by email. Please feel free to contact me at the phone number or email address below with any questions you may have. I greatly appreciate your time and efforts in making this a successful research study.

Sincerely,

Kate Madison, ATC, LAT
Graduate Assistant Athletic Trainer
Texas State University
kate.madison@txstate.edu
(214) 729-0027

PARTICIPATING UNIVERSITY PERMISSION LETTER

[DATE]

Dr. Jon Lasser, Ph.D.
Chair, Institutional Review Board
Texas State University
San Marcos, TX 78666
lasser@txstate.edu

Dear Dr. Lasser:

The purpose of this letter is to grant Caitlin Madison, a graduate student at Texas State University permission to conduct research at [name of university]. The project, “Incidence and Risk Factor Analysis of Rib Stress Injury in the Collegiate Rowing Athlete” entails a series of surveys that will be distributed to our rowing student athletes on a weekly basis from approximately January 1, 2017 to March 20, 2017. The purpose of this study is to establish an incidence rate of rib stress injuries in the collegiate rowing athlete. This will be completed through a series of online surveys that document past medical history of injury, new injuries, training characteristics, and supplementation use. [name of university] was selected because we have an NCAA rowing team. I, [insert director’s name] do hereby grant Caitlin Madison permission to conduct “Incidence and Risk Factor Analysis of Rib Stress Injury in the Collegiate Rowing Athlete” at [insert university’s name].

Sincerely,

STUDENT ATHLETE ID KEY

Please assign each student athlete an ‘Athlete ID’ and share this identification number with her. They will need this number when completing any surveys, as this will allow for the anonymity of responses. You will also need to reference this key when completing any “Verification of Injury” email requests. This is for your records, and may be destroyed upon the conclusion of the research study.

[illegible]

TEXAS STATE INFORMED CONSENT

Study Title: Incidence and Risk Factor Analysis of Rib Stress Injury in the Collegiate Rowing Athlete

Principal Investigator: Caitlin Madison Co-Investigator/Faculty Advisor: Dr. Rod Harter

Sponsor: Dr. Marie Pickerill, Dr. Jeff Housman

This consent form will give you the information you will need to understand why this research study is being done and why you are being invited to participate. It will also describe what you will need to do to participate as well as any known risks, inconveniences or discomforts that you may have while participating. We encourage you to ask questions at any time. If you decide to participate, you will be asked to sign this form and it will be a record of your agreement to participate. You will be given a copy of this form to keep.

You are invited to participate in a research study to learn more about the incidence of rib stress injury and associated risk factors in NCAA rowing athletes. The information gathered will be used to analyze injury risk factors and help determine the importance of preventative measures. You are being asked to participate because you have been identified as an NCAA Division I, II, or III rowing athlete that will be training during the 2016-2017 season.

The injury surveillance period will take place from approximately January 1, 2017 to March 18, 2017. If you agree to be in this study, you will participate in the following:

- One baseline questionnaire at the beginning of the study, which should take no more than 10 minutes to complete.
- Approximately 11 weekly check-in surveys that should take no more than 15 minutes per week to complete. These surveys will be distributed on Saturday afternoons.

All surveys will be distributed by email using the survey platform Qualtrics (Qualtrics, Provo, UT). The survey will include a section requesting demographic information. There are no risks or consequences for your participation in this study, and we will make every effort to protect participants' confidentiality. However, if you are uncomfortable answering any of the questions in either the baseline questionnaire or weekly check-in survey, you may leave them blank.

In the unlikely event that some of the survey or interview questions make you uncomfortable or upset, you are always free to decline to answer or to stop your participation at any time. Should you feel discomfort after participating, you may contact your respective university's health services department for counseling services.

There will be no direct benefit to you from participating in this study. However, the information that you provide will help determine the extent of rib stress injuries in NCAA rowing athletes and aide in the creation and implementation of preventative measures that may help in reducing rib injuries in this population.

Reasonable efforts will be made to keep the personal information in your research record private and confidential. Any identifiable information obtained in connection with this study will remain confidential and will be disclosed only with your permission or as required by law. The members of the research team and the Texas State University Office of Research Compliance (ORC) may access the data. The ORC monitors research studies to protect the rights and welfare of research participants.

Your name will not be used in any written reports or publications which result from this research. Data will be kept for three years (per federal regulations) after the study is completed and then destroyed. You will not be paid for your participation in this study.

You do not have to be in this study if you do not want to. You may also refuse to answer any questions you do not want to answer. If you volunteer to be in this study, you may withdraw from it at any time without consequences of any kind or loss of benefits to which you are otherwise entitled.

If you have any questions or concerns about your participation in this study, you may contact the Principal Investigator, Caitlin Madison: kate.madison@txstate.edu.

This project 2017375 was approved by the Texas State IRB on February 1, 2017. Pertinent questions or concerns about the research, research participants' rights, and/or research-related injuries to participants should be directed to the IRB Chair, Dr. Jon Lasser 512-245-3413 - (lasser@txstate.edu) or to Monica Gonzales, IRB Regulatory Manager 512-245-2314 - (meg201@txstate.edu).

I have read this form and decided that I will participate in the project described above. Its general purposes, the particulars of involvement and possible risks have been explained to my satisfaction. I understand I can withdraw at any time.

DOCUMENTATION OF CONSENT: I have read this form and decided that I will participate in the project described above. Its general purposes, the particulars of involvement and possible risks have been explained to my satisfaction. I understand I can withdraw at any time.

Printed Name _____

Signature of Study Participant _____

BASELINE QUESTIONNAIRE

Rib Stress Injuries in NCAA Rowing Research Study: Baseline Questionnaire

1. Thank you for your participation in this survey. This questionnaire will take no more than 10 minutes of your time. Please answer each question as completely and truthfully as possible.

2. Athlete ID#

3. In what division of NCAA athletics do you participate?

☐ Division I

☐ Division III

4. What is your current age?

5. Height (inches)

6. Weight (lbs)

7. In what size boat do you typically row (>50% of the time)?

☐ Eight

☐ Four

☐ Other _____

8. On what side of the boat does you typically row (>50% of the time)?

☐ Port

☐ Starboard

☐ Not applicable (scull)

9. How long have you been competing as a NCAA rower?

☐ <1 year

☐ 1 year

☐ 2 years

☐ 3 years

☐ 4 years

☐ 5 years

10. Did you row before college?

- ☐ Yes
- ☐ No

11. If so, for how long?

- ☐ <1 year
- ☐ 1 year
- ☐ 2 years
- ☐ 3 years
- ☐ 4 years
- ☐ 5 years
- ☐ >5 years

12. Are you using some form of hormonal contraceptive that controls the number of menstrual periods you have? (hormonal contraceptive – method of birth control that includes the pill, skin patches, vaginal rings, or shots)

- ☐ Yes
- ☐ No

13. How many periods have you had in the last 12 months?

14. Have you ever received help with dietary recommendations during the previous season? (Select all that apply)

- ☐ No
- ☐ Yes, by a physician
- ☐ Yes, by a nurse
- ☐ Yes, by a dietitian
- ☐ Yes, by an athletic trainer
- ☐ Other _____

15. Do you consume dietary supplements?

- ☐ Yes
- ☐ No

16. If so, what kind? (Select all that apply)

- ☐ Vitamin D
- ☐ Iron
- ☐ Other _____

17. Which is your dominant hand?

- ☐ Right
- ☐ Left

18. What is the duration of a usual (on average) training session, including warm-up and cooling down?

- ☐ 1 hour
- ☐ 1.5 hours
- ☐ 2 hours
- ☐ 2.5 hours
- ☐ 3 hours
- ☐ 3.5 hours
- ☐ 4 hours

19. What is the usual duration of the warm-up part?

- ☐ 15 minutes
- ☐ 30 minutes
- ☐ 45 minutes
- ☐ 1 hour
- ☐ 1.5 hours

20. Have you during the last year had a rib injury, low back injury, or shoulder injury that caused you to abstain from athletics training completely or partially?

- ☐ No
- ☐ Yes

21. What was the injury diagnosis?

22. For approximately how long were you away from training due to the injury/injuries reported?

- ☐ 1 week
- ☐ 2-4 weeks
- ☐ 2-3 months
- ☐ >3 months
- ☐ Not back

23. For how long have you been back in full training after the last of the injuries you have reported?

- ☐ 1 week
- ☐ 2-4 weeks
- ☐ 2-3 months
- ☐ >3 months
- ☐ Not back

24. Are you completely free from injury today?

☐ Yes

☐ No - What is the injury diagnosis? _____

WEEKLY E-DIARY QUESTIONNAIRE

Rib Stress Injuries in NCAA Rowing Research Study: Weekly E-Diary

1. Please answer the following questions regarding your training and injury status within the last week.

2. Athlete ID#

3. Did you train at normal (full capacity) last week?

- ☐ Yes, completely normal
- ☐ Yes, I returned to normal training after an injury period
- ☐ No - Please indicate the reason _____

4. How many sessions did you train last week?

- ☐ 0
- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ 6
- ☐ 7
- ☐ 8
- ☐ 9
- ☐ 10
- ☐ 11
- ☐ 12
- ☐ 13
- ☐ 14
- ☐ 15

5. Number of hours of training (including warm up and cool down last week)?

- ☐ 0
- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5
- ☐ 6
- ☐ 7
- ☐ 8
- ☐ 9
- ☐ 10
- ☐ 11
- ☐ 12
- ☐ 13
- ☐ 14
- ☐ 15
- ☐ 16
- ☐ 17
- ☐ 18
- ☐ 19
- ☐ 20
- ☐ 21
- ☐ 22
- ☐ 23
- ☐ 24
- ☐ 25
- ☐ 26
- ☐ 27
- ☐ 28
- ☐ 29
- ☐ 30
- ☐ Other _____

6. Please indicate the number of training sessions in each practice setting for the last week.

- On-water practice (select number)
- Ergometer session (select number)
- Weight training (select number)
- Supplementary training/conditioning (select number)

7. Training intensity was

- ☐ Easy
- ☐ Moderate/Mixed
- ☐ Hard

8. In what size boat did you row this past week (>50% of the time)?

- ☐ Eight
- ☐ Four
- ☐ Other _____

9. On what side of the boat did you row this past week (>50% of the time)?

- ☐ Port
- ☐ Starboard
- ☐ Not applicable (scull)

10. Did you consume any dietary supplements in the past week?

- ☐ Yes
- ☐ No

11. If so, what kind? (Check all that apply)

- ☐ Vitamin D
- ☐ Iron
- ☐ Other _____

12. Do you have a NEW INJURY to report?

- ☐ No
- ☐ Yes

13. When did the injury occur?

- Year (select)
- Month (select)
- Day (select)
- AM/PM (select)

14. In what athletics setting did you first notice the injury?

- ☐ Warm-up
- ☐ On-water practice
- ☐ Ergometer session
- ☐ Weight training
- ☐ Supplementary training/conditioning
- ☐ My injury did not occur in an athletics setting

15. Which body part has been injured?

- ☐ Rib cage
- ☐ Low Back
- ☐ Shoulder
- ☐ Other

16. Have you injured the front or the back side? (Check all that apply)

- ☐ Front
- ☐ Back
- ☐ Not relevant

17. Have you injured the left or the right side? (Check all that apply)

- ☐ Left
- ☐ Right
- ☐ Not relevant

18. Who made the diagnosis? (Check all that apply)

- ☐ I myself
- ☐ Coach
- ☐ Athletic Trainer
- ☐ Physician
- ☐ Other _____

19. What is the provisional (initial) diagnosis of your injury?

- ☐ Rib Cage Injury: _____
- ☐ Low Back Injury: _____
- ☐ Shoulder Injury: _____

20. If a rib injury, how was diagnosis confirmed?

- ☐ Bone scan
- ☐ X-ray
- ☐ Athletic trainer's assessment
- ☐ Other

21. Have you stopped training as a result of this injury?

- ☐ Yes
- ☐ No, but we've modified my activity/participation level
- ☐ No, I am participating fully

22. Who decided that you should stop training? (Check all that apply)

- ☐ I myself
- ☐ Coach
- ☐ Physician
- ☐ Athletic Trainer
- ☐ Other _____

23. Do you have an injury that has resolved within the last week?

- ☐ Yes
- ☐ No

24. When were you back in full training?

Select year:

Select month:

Select day:

25. Which body part was injured?

- ☐ Rib Cage
- ☐ Low Back
- ☐ Shoulder
- ☐ Other

26. Who made the diagnosis? (Check all that apply)

- ☐ I myself
- ☐ Coach
- ☐ Physician
- ☐ Athletic Trainer
- ☐ Other _____

27. What is the final diagnosis of your injury?

If a rib cage injury: _____

If a low back injury: _____

If a shoulder injury: _____

28. Who decided that you could return to normal (full) training? (Check all that apply)

☐ I myself

☐ Coach

☐ Physician

☐ Athletic Trainer

☐ Other _____

29. How long have you been away from normal (full) training?

☐ <1 week

☐ 1-2 weeks

☐ 2-4 weeks

☐ 4-6 weeks

☐ >6 weeks

30. Do you have anything further you want to report?

VERIFICATION OF INJURY SURVEY

Rib Stress Injuries in NCAA Rowing Research Study: Verification of Injury Survey

1. One of your student athletes has reported a new injury in the last week. Please complete the following short survey to verify the nature of their injury.

2. Athlete ID# (provided)

3. Diagnosis/assessment provided by the student athlete: (provided)

4. Is the above diagnosis/assessment correct?

☐ Yes

☐ No

5. If no, please provide the correct diagnosis/assessment:

Thank you for verifying this student athlete's injury!

REVIEW OF LITERATURE

Rib stress injuries (RSIs) are some of the most debilitating injuries for competitive rowers at both the collegiate and international levels, and are reportedly one of the primary sources of time lost in regard to competition and training.^{1,2} Several authors have researched various characteristics of RSIs in various levels of rowing athletes; these characteristics include theorized mechanisms of injury, presentation of injury, diagnosis and management of injury, and possible intrinsic and extrinsic risk factors.^{3,4} As a result of the National Collegiate Athletic Association's (NCAA) Title IX implementation, rowing presence and popularity for women in the collegiate setting has dramatically increased in the United States throughout the last few decades.⁵⁻⁷ However, little to no research has been conducted on RSIs specifically in the NCAA collegiate rowing population, which is only comprised of the women's open weight category as defined by USRowing; this entails no limitations as to individual weight allowed per person in a boat, as well as the total weight of all individuals in a boat.⁷

Due to the lack of research and evidence regarding RSIs across all rowing populations in the United States, additional research and injury surveillance is necessary to determine the cause and contributing risk factors of this injury in the NCAA collegiate population. To aid in the generalizability of data collected for target populations, several authors have documented standards and recommendations for injury surveillance and epidemiological research.⁸⁻¹¹ This review of literature will summarize the pertinent history of rowing, the biomechanics of the rowing stroke, the intrinsic and extrinsic risk factors associated with rib stress injuries, and the key principles of sports injury epidemiology research.

The Sport of Rowing: History and Characteristics

The terms ‘rowing’ and ‘crew’ are often interchanged; in the United States ‘rowing’ is an all-encompassing term used to describe collegiate teams (both male and female), whereas ‘crew’ is traditionally used to describe a team of rowers affiliated with an academic setting.¹² For the purpose of this review, the term ‘rowing’ will acknowledge all individuals participating in this particular athletics activity.

The sport of rowing has attained most of its present-day popularity through competitions at the international level, as it officially became a member of the Olympic Games in 1908.¹³ Rowing athletes compete in a variety of settings and levels; the most elite athletes compete on national teams, taking part in the Olympic Games, world championships, and various other international competitions. Rowing is the oldest competitive collegiate sport in the United States, which originated through a race between Harvard and Yale in 1852.¹⁴ In the United States, the national governing body for rowing is the United States Rowing Association, more commonly known as USRowing.¹³ College-aged rowers can participate in the NCAA’s Division I, II, or III programs, the Intercollegiate Rowing Association (IRA), or they may opt to row for a non-sanctioned university or college club team.⁷

The sport’s popularity for women has substantially increased in the United States since the NCAA’s implementation of Title IX. This law, enacted in 1972, prompted universities to begin establishing women’s rowing teams as a way to balance out the large population of men’s football programs and create equal opportunity amongst sexes in the collegiate athletic setting in regards to scholarship money and NCAA participation opportunities.⁷ Within the various levels of United States collegiate rowing (including the

NCAA, IRA, and other non-sanctioned university club teams), there are two classes in both the men's and women's competition: an open weight (heavyweight) or a lightweight class. Class assignment is determined for both men and women according to body weight values.¹²

The NCAA only recognizes women's open weight (also known as "heavyweight") as a varsity sport, which amounted to 145 rowing programs in the United States in 2014.⁷ All other classifications of collegiate rowing (including men's heavyweight rowing, men's lightweight rowing, and women's lightweight rowing) fall outside of the NCAA governing body, and while they still follow the rules and regulations set forth by USRowing their National Championships fall under the responsibility of the IRA.⁷ Outside of the collegiate setting, younger athletes can compete on their high school or local club crew teams.¹⁵ Individuals of all ages may also choose to row recreationally through their community boathouse or recreation center.

There are two styles of rowing – sweep rowing and sculling.¹⁶ Sweep rowers hold one oar with both hands, and individuals row on either the right or left side of the boat (starboard or port, respectively).^{16,17} Boats specifically used for sweep rowing can seat two, four, or eight individuals, and typically have a coxswain who sits in the stern of the boat and steers.¹² Individuals whose oars are on the left side of the boat are port, while those on the right side are starboard. In sculling, each athlete rows with two oars, one in each hand, and individuals do not have a designated side on which they row.¹⁶ Boats designated for sculling can seat one, two, four, or eight individuals.¹⁷

Biomechanics of the Rowing Stroke

The rowing stroke is comprised of 4 phases – the catch, the drive, the finish, and the recovery (Figure 1).^{12,18} The rowing stroke is a series of sequential movements that involve the extension and flexion of the body. During the transition from the drive to the finish, the rhomboids, trapezius, and serratus anterior are pulling the scapula posteriorly until it is fully retracted, and the shoulder is moving into extension¹⁹; additionally, the hips and knees extend and the trunk moves posteriorly. The upper extremity characteristics of the transition from the recovery to the catch involve shoulder flexion, elbow extension, and scapular protraction, as the scapula is being pulled anteriorly by the serratus anterior and pectoralis minor¹⁹; simultaneously, the trunk moves anteriorly while the hips and knees flex until the athlete reaches the starting position again. The rower places the oar above the water during the recovery phase, and subsequently places the blade back in the water and propels the boat forward during the power-oriented drive phase.¹⁶ Due to the nature and predicted risk factors of RSIs, this review of literature will focus primarily on the trunk and upper extremities as they relate to rib cage injuries.

Figure 1. Phases of the rowing stroke as described by Warden et al. (2002).



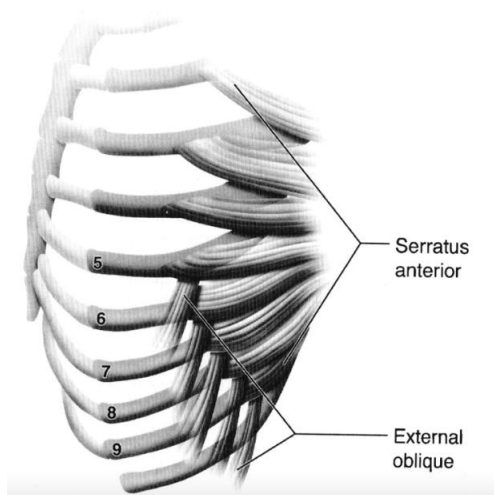
Rib Stress Injuries: Anatomy and Mechanisms of Injury

There are a total of 12 pairs of ribs that comprise the rib cage; from the posterior aspect, all sets of ribs attach to the thoracic vertebral column via the costotransverse articulation between the head of the rib and the respective transverse process of the

vertebrae. Anteriorly, the ribs have 1 of 3 potential relationships with the sternum: ribs 1 through 6 are connected directly to the sternum via costal cartilage, while ribs 7 through 10 are connected indirectly to the sternum via costal cartilage extending from the sixth rib above; the remaining pairs of ribs, 11 and 12, are not connected anteriorly to the sternum in any capacity, but are instead considered “floating” ribs.²⁰

There are a series of muscles that assist with either inspiration or expiration in respiratory mechanics.²⁰ There are 2 layers of intercostal muscles that surround the ribs (internal and external). Primary inspiratory muscles include the diaphragm and the

Figure 2. Attachment sites of the serratus anterior muscle and the external abdominal oblique muscle to the rib cage (left is anterior aspect of rib cage, right is posterior aspect). (Karlson et al., 1988)



external intercostal muscles and anterior internal intercostal muscles, while primary expiratory muscles include the diaphragm, posterior intercostal muscles, and the abdominal muscles (internal oblique, external oblique, rectus abdominis, and transverse abdominis).²⁰

Surrounding musculature can also be described by their relationship and attachment sites to the rib cage. As previously mentioned, the abdominal muscles play a key role in thoracic

musculature and attach to various aspects of the rib cage; specifically, the external abdominal oblique attaches from the anterior iliac spine and the linea alba to ribs five through twelve. The serratus anterior attaches from the medial border of the scapula to the anterolateral aspect of the rib cage (specifically the first through eighth or ninth ribs). The relationship and overlap between these two primary thoracic cage muscles can be

seen in Figure 2.

Rib Stress Injuries: The Basics

A rib stress injury (RSI) is defined as “the development of pain due to bone edema caused by (stress) overload along the bone shaft,”²¹ and can occur on any bone that comprises the rib cage.²² This term includes conditions of rib pain, rib stress reactions, and rib stress fractures.²¹ A rib stress fracture (RSF) is defined as “an incomplete fracture occurring from an imbalance between the rate of bone resorption and the rate of bone formation.”²³ Compared to stress fractures in other parts of the body, RSFs are substantially less common and don’t occur as frequently, primarily due to the non-weight-bearing nature of the bones involved.²² Because of the rare incidence rate of RSFs in athletic populations, they are often misdiagnosed or go undiagnosed altogether.²¹ The typical differential diagnoses that clinicians must consider include a serratus anterior strain, an intercostal strain, and Ewing’s sarcoma.^{23,24} While RSIs have been found in both athletic and non-athletic populations, the majority of data collection and incident recording of this injury primarily occurs in athletic populations. Sports with the highest number of reported RSIs in athletes are swimming, baseball, softball, golf, dance, and rowing.^{22,25}

In non-athletic populations, RSIs are most common in patients who suffer from a chronic, persistent cough. A case series done by De Masseneer et al.²⁶ documented 3 patients varying in age that were diagnosed with RSFs following different bouts of illnesses; patients included a 21-year-old female who had been coughing for 1 month due to a viral respiratory infection, a 79-year-old male who suffered from severe coughing, and a 47-year-old female who was diagnosed with an upper respiratory tract infection and

presented with severe chest pain during recovery from her illness.

Katrancioglu et al.²⁷ reported on 12 individuals who suffered from severe coughing as a result of chronic obstructive pulmonary disorder or asthma were diagnosed with spontaneous, non-traumatic rib fractures. They found that most fractures were located on the fourth to ninth ribs, and that bone density measurements amongst all individuals were low enough to put them at risk of potential bone stress injury.²⁷ Researchers have proposed 2 mechanisms for these cough-induced RSFs: the shearing forces of the serratus anterior and external oblique muscles as they contract and pull in opposite directions during persistent coughing, and repeated bending force along the middle one-third of the rib, which might be sufficient to cause a small fracture, eventually developing into a larger fracture.²⁸

RSIs in Rowing Athletes

While specific mechanism(s) of RSIs in rowing athletes are not yet known, current evidence suggests that the primary cause involves the upper extremity and thoracic musculature that attaches to the rib cage.⁴ Specifically applied to the upper extremity and thorax, muscle contraction creates tensile, compressive, and rotational stress on the bones of the rib cage.²² The rowing biomechanics from both the drive to the finish phases and the recovery to the catch phases are the 2 segments of the stroke that would most likely subject an individual to the proposed muscular stresses of a RSF.¹⁹ What researchers have determined is that the serratus anterior is most active just prior to the catch in the late recovery stage¹⁴, and abdominal muscles (in particular the external abdominal oblique) are most active in the late drive phase just prior to the finish; these abdominal muscles are contracting eccentrically as they work against gravity to extend

the trunk. From a physiological standpoint, this coincides with the timing of the most stress applied to the ribs.^{29,30}

Some researchers have postulated that because the serratus anterior and the external abdominal oblique muscles are primarily active during 2 different parts of the rowing stroke cycle, these 2 muscles do not work together to cause stress on the rib.^{3,29} In 2006, Vinther et al.³¹ analyzed electromyographic (EMG) measurements and movement patterns amongst 7 Danish national team rowers (each with a past medical history of a RSF), and compared them to matched team members according to sex, age, height, weight, and number of years of elite training. These research efforts found differences in thoracic muscle co-contraction (RSF: 47.5 ± 3.4 , 48.5 (35.8–60.2)% EMG signal overlap vs Control: 30.8 ± 6.5 , 27.0 (11.2–61.6)% $P = 0.043$) during the mid-drive phase between individuals with and without a previous history of RSF, as well as a lower knee-extensions to elbow-flexion strength ratio (RSF: 4.2 ± 0.22 , 4.3 (3.5–5.1) vs Control: 4.8 ± 0.16 , 5.0 (4.2–5.3) $P = 0.043$).³¹ This indicated that individuals with a previous history of RSF had stronger arms relative to their legs as compared with control participants.

In this same study, Vinther et al. found altered movement patterns in individuals who had previously suffered from a RSF. These athletes displayed a higher velocity of the seat in the initial drive phase of the rowing stroke (RSF: 0.25 ± 0.03 , 0.25 (0.15–0.33) m/s vs Control: 0.15 ± 0.06 , 0.18 (-0.11–0.29) m/s $P = 0.028$), indicating that their biomechanics of the rowing stroke were slightly altered compared to their control counterparts.³² These individuals were shooting their hips backward more quickly than their non-RSF injured teammates, which resulted in a biomechanics pattern that requires additional core and thoracic musculature activation in a shorter period of time.

Ultimately, their findings support Warden's⁴ theory on rib cage compression during the drive phase of the rowing stroke as the most likely mechanism of RSI.³¹

The current concept that many researchers have turned to as an explanation for RSFs in the rowing athlete is Warden's Abdominal-Led Rib Cage Compression Theory.⁴ This theory argues that contrary to previous theories, the serratus anterior actually has a protective contractile characteristic from its angle of pull during the drive phase which results in expansion rather than compression of the rib cage (as rib cage compression has been shown to cause negative effects on the ribs).⁴ When the serratus anterior fatigues during prolonged exercise, its ability to expand the rib cage is significantly diminished, resulting in the body's inability to resist rib cage compression just after the finish phase of the rowing stroke.³⁰

Because of this, the contraction of abdominal muscles during the initial stage of the recovery phase is most likely to be the true culprit of the injury mechanism.^{4,31} Both the external abdominal oblique and rectus abdominis muscles have attachments on the external surfaces of the 5th through 8th ribs²⁰, and additional analysis of RSI data by Warden et al. found that 84% of reported RSFs occurred in ribs 5 through 8.⁴ While this information further reinforces the Warden's Abdominal-led Rib Cage Compression theory, additional research is necessary to confirm these findings and establish a evidence-based mechanism of injury.

Early studies on the mechanism of RSFs have implicated the forces associated with serratus anterior contraction as the primary cause of injury.^{16,33} However, a counterintuitive line of thinking exists in that rehabilitation for RSIs typically involves serratus anterior strengthening exercises; Warden et al.⁴ suggested that if the serratus

anterior was truly the culprit, additional strength training development specifically for this muscle would only increase its ability to apply repetitive, extreme force to the rib cage during the rowing stroke, ultimately increasing the likelihood of injury. This concept contradicts most research that states that the controlled, gradual increase in tension on the bone would increase bone mineral density, ultimately making the bone stronger and more resistant to stress fracture.²³ Even with the research and associated theories that exist, there is still an ongoing debate regarding the true contributions and role of the serratus anterior muscle in relation to RSIs in the rowing athlete.³²

Several comprehensive research articles have surfaced in the last decade that both share and analyze available literature. A 2011 systematic review of 20 studies involving 144 rowers with RSFs conducted by McDonnell et al.³ concluded that the average incidence of injury was 9.2%. Of the 20 studies they reviewed, 19 were retrospective in nature. A more recent systematic review published by D'Ailly et al.³⁴ in 2016 found that taking into account the McDonnell study, through the duration of a competitive rowing athlete's career they experience injury rates ranging from of 8% to 16% in relation to these RSFs.^{3,34}

Additional studies not included in the McDonnell review have documented generalized injuries in rowing athletes across varying settings and countries.^{35,36} Wilson et al.³⁶ conducted a 12-month prospective cohort study with the Irish national rowing team in 2010, and found that more injuries occurred in sculling rowers compared to sweep rowers. These injuries included low back pain, knee injuries, and cervical spine issues. Bernardes et al.³⁵ conducted a study on musculoskeletal injuries in competitive Portuguese rowers, finding that the most common location and type of injury were in the

lumbar region and muscular pathologies, respectively.

The general lack of research on RSIs in the rowing population at all levels fails to address a significant injury risk to these athletes. In particular, the lack of a determined incidence rate for RSIs in the competitive rowing athlete at the collegiate level specifically in the United States is concerning for this population of women's athletics, especially considering the potential consequences and limitations of this injury. The recent and gradual rise in popularity of rowing as an NCAA sport after the implementation of Title IX⁷, plus the fact that rowing is not included in any published NCAA's Injury Surveillance System (ISS) documents³⁷, are likely reasons for limited research in this population.

Typical Presentation of RSIs

Rib stress injuries can have a variety of symptoms with some common characteristics; initially the injury may present as vague thoracic discomfort for several weeks, which progresses to increased and more localized pain.¹⁶ This pain may be present at rest, upon compression of the chest, during a coughing episode or deep breathing.^{16,19,29} RSIs may present pain along the scapular spinal border and radiate out towards the mid-axillary line, or generally radiate along an intercostal nerve distribution.^{19,22} Pain typically increases with activity and becomes more specific as movement continues, further increasing with deep breathing and positional changes. Range of motion may be painful in any one or more of the following: shoulder flexion, shoulder abduction, shoulder extension, trunk flexion, end-range trunk extension, scapular protraction/retraction.²³ The standard recovery time for these RSF injuries is approximately 3 to 8 weeks, dependent upon the severity of the injury upon

diagnosis.^{29,38} Hooper et al.² found that rib stress reactions can result in an average loss of 48 training days per year for rowing athletes, which increases to an average loss of 60 days per year if these stress reactions develop into stress fractures.

Research suggests that the most susceptible area of the rib to stress injury is the middle third (lateral chest wall), as it experiences the greatest bending force.^{16,19}

McDonnell et al.³ reported that the most common sites of RSFs are as follows – the first rib anterolaterally, the upper ribs posteromedially, and the fourth through ninth ribs posterolaterally. In rowing athletes specifically, the fourth through ninth ribs are most commonly affected in terms of stress injuries.¹⁹ As mentioned previously, variation in presentation and location of injury is influenced by the individual and their respective training characteristics and rowing technique during activity.¹⁶

Risk Factors for RSI

Several risk factors are associated with RSIs, and can be classified as either intrinsic or extrinsic. Of the intrinsic category, muscle imbalances, arthrokinematics, sex, bone mineral density, Relative Energy Deficiency in Sport (RED-S), and concurrent injury may impact an individual's susceptibility to a RSI.^{3,16,21} Of the extrinsic risks, the primary factors are rowing style, pre-participation conditioning and training characteristics (including frequency, duration, intensity), equipment, and environmental concerns.^{21,22}

Intrinsic Risk Factors

Muscle and Soft Tissue Deficits. Generally speaking, the individual response of each rib under mechanical load will vary according to characteristics of the body and the surrounding tissue.⁴ Lack of muscular endurance, flexibility, and strength may all play a

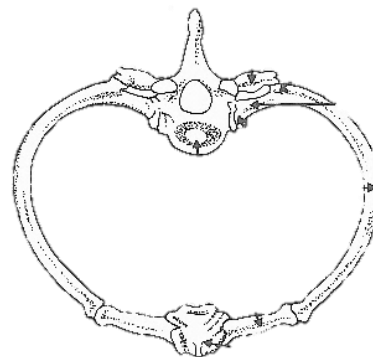
role in potential RSI in rowing athletes.³ In particular, muscles of greater concern in terms of RSI development in rowing athletes are the serratus anterior and external abdominal oblique, followed by additional trunk and hip musculature. This is where the Abdominal-Led Rib Cage Compression Theory is most relevant in regards to possible risk factors.⁴ If an individual lacks the proper mobility, flexibility, and strength to complete the biomechanical demands of the repetitive rowing stroke, this may subject the body to undue stresses, particularly in the thorax and rib cage area.²¹ Muscular fatigue may also be a significant contributor to risk of rib injury, as individuals might alter postural and technical characteristics of their rowing stroke upon extensive, intense bouts of exercise.²³ However, as previously mentioned more research is necessary to determine the extent of muscle and soft tissue characteristics in relation to risk of RSI in the rowing athlete.

Arthrokinematics. The degree to which RSFs in rowing are affected by joint characteristics is still to be determined.

When examining the rib cage as an entire system, it is important to consider the structure of each rib and the many connections with the vertebrae and the sternum – the “bony ring”⁴ (see Figure 3).⁴

The 3 associated joints are the costochondral, costovertebral, and costotransverse joints.^{4,20} Ribs attached to the sternum via costochondral cartilage may possess substantially more movement than the other 2 joints, creating the opportunity for a greater ability to dissipate forces imposed on the rib

Figure 3. The “bony ring” as described by Warden et al., 2002.



cage.³ When considering the stiffness of the thoracic spine as a contributing factor to RSFs, research suggests that risk would also be reduced with sufficient joint mobility.^{3,21} Most researchers agree that varying characteristics of associated rib joints are primary contributing factors to the true mechanism of injury. More research is required to determine the implications of stiffness on the mechanical deformation of ribs.³⁰

Bone Mineral Density (BMD) and RED-S. As in most conversations regarding stress fractures, bone mineral density (BMD) is a popular topic of discussion relating to the mechanism and risk of both an initial stress fracture and subsequent re-fracture.^{32,39} Researchers have found that lower BMD values are frequently observed in individuals with a past medical history of RSFs; this is most likely attributed to nutritional and hormonal factors.^{3,23,32,34} Specifically, low levels of calcium, Vitamin D and iron in the body may also impact an individual's risk for bone-stress injuries.^{40,41} More high quality evidence-based research is necessary to examine the specific involvement of BMD as related to the sport of rowing and associated RSFs being reported.

Researchers have documented several specific micronutrients necessary for proper physiological function, especially in relation to bone health and ability to resist injury^{42,43}; in particular, Vitamin D and calcium have both been shown to promote bone growth and health, in turn potentially decreasing the risk of the development of bone stress injuries.^{39,44} Iron, on the other hand, plays a significant role in muscle function and capacity to complete athletic tasks; lack of iron can ultimately lead to anemia and menstrual irregularities.⁴² Deficiency or insufficiency in this area of nutrition can have detrimental effects on an individual's BMD and muscle function, simultaneously contributing to things like the Female Athlete Triad or Relative Energy Deficiency in

Sport (RED-S).^{45,46}

The 2005 International Olympic Committee (IOC) Consensus Statement defined the Female Athlete Triad as a combination of disordered eating and irregular menstrual activity which can eventually lead to physiological and hormonal consequences, ultimately leading to decreased BMD values and osteoporosis.^{47,48} In 2007, the American College of Sports Medicine redefined the term as an interworking relationship between three components: energy availability, menstrual function and bone health.⁴⁹ Recently, the IOC reconvened and determined that a more inclusive and comprehensive term needed to be created to replace the Female Athlete Triad; they concluded that RED-S was most suitable, and is defined as an individual's physiological status and functions described by impaired metabolic rate, menstrual activity, bone health, the body's immunity, protein synthesis, and cardiovascular health problems as a result of relative energy deficiency.⁴⁶ Their goal was to highlight the idea that male athletes also suffer from similar lack of energy availability, as well as this syndrome's overall impact on homeostasis and bodily functions, especially in repair following an intense bout of exercise.⁴⁶ Physiological consequences including dietary insufficiencies, low body mass index, past medical history of stress fracture, and menstrual dysfunction may lead to unfavorable modifications to bone structure, ultimately increasing risk for stress fractures.^{42,47,50}

Sex Differences. Existing research on bone stress-related injuries has placed more emphasis on data regarding stress injuries in other areas of the body compared to the rib cage.^{22,50,51} Research specific to RSIs has claimed that female rowers are potentially more at risk for RSIs as compared to their male counterparts.¹⁹ Some evidence has been

gathered on general injury incidence differences between male and female rowers; Bernardes et al.³⁵ found that female Portuguese rowers had a greater risk of injury compared to their male counterparts, primarily during their off-water training sessions. In contrast these authors found that male rowers were more likely to sustain an injury during on-water activity.

At this juncture, it is inconclusive as to whether this is more of an issue in male versus female rowers. While the available case studies on RSIs document them in both male and female rowers^{19,23,38,52}, two studies make note that female rowing athletes seem to be at greater risk (although this isn't properly demonstrated due to the lack of female participants in studies).^{19,52} While more research is necessary to determine the true contribution of sex, current research theorizes that females are predisposed to stress fractures due to hormonal influence on bone mineral density (BMD) and associations with menstrual activity.³

One of the important facets of both the Female Athlete Triad and RED-S is the status of a female's menstrual cycle.^{43,45,46} There are 3 categories of menstrual activity and abnormal uterine bleeding: eumenorrhea, oligomenorrhea, and amenorrhea.⁵³ Emenorrhea is defined as normal menstrual activity, with a menstrual cycle every 26-32 days. Oligomenorrhea refers to irregular menstrual activity, and includes menstrual cycles longer than 35 days. Amenorrhea is the more extreme and worrisome of the three categories, and is a complete absence of menstrual activity altogether. The irregular menstrual activity classifications in female athletes often lead to physical and physiological consequences, typically related to bone and muscle health.^{53,54} While there are additional classifications of menstrual activity status, this review of literature will

focus on these 3 due to their relationship with bone stress injuries and because our participant population consisted of all females.

Concurrent Injury. At this juncture, no significant data exists regarding the relationship between RSIs in rowing athletes and concurrent shoulder or low back pathology. Evans and Redgrave's²¹ recent guidelines for the diagnosis and management of RSIs noted that both concurrent shoulder pathology/injury and low back injury were intrinsic risk factors related to the development of such injuries. Prior to that, case studies published on individuals with RSFs sometimes noted various accompanying injuries of this nature¹⁹; because rowing is a sport that involves the body's entire kinetic chain, injuries in areas surrounding the rib cage may indeed contribute to additional stress or improper biomechanics in the torso and upper extremity.

Extrinsic Risk Factors

Rowing style. Difference in rowing style and technique may play a role in the incidence of rib injuries in the rowing athlete. Aside from the number of oars used, another primary difference that exists between sculling and sweeping is that scullers biomechanically move in a more linear motion with almost no lateral trunk flexion or rotation during the stroke; sweep rowers must laterally flex their trunk and slightly rotate their body to fully extend the oar during the stroke, the direction depending upon what side of the boat they are rowing (port vs. starboard).¹⁹ As a result, the rib cage of a sweep rower may be subjected to additional repetitive forces that are unbalanced between the two sides of the body. At this time no relationship has been established between side of injury and specific side of rowing in sweep athletes.³⁸

Two common motor strategies that rowers utilize are: the sequential method or the synchronous method³; both have the potential to influence muscle force on the rib cage and its many soft tissue and bony structures. In the sequential strategy, each individual phase of the rowing stroke is very distinct during activity, and rowers make a conscious effort to separate the stages. On the contrary, the synchronous strategy emphasizes a greater blend of the rowing stroke phases so the entire movement is substantially more fluid. Most teams typically employ the synchronous strategy, as it ends up being a more natural movement for individuals while still emphasizing technique and efficiency.³ Karlson et al.¹⁶ noted that the potential for development of a RSI and the location of said injury may vary according to slight technique differences between individuals and teams, as these differences would rely on varying involvement of chest wall muscles (including the serratus anterior and external abdominal obliques). While no studies to date have directly examined the relationship between these two strategies and incidence of RSIs, D'Ailly et al.³⁴ recommended teaching new rowing athletes to employ smooth and less violent characteristics of the rowing stroke to reduce risk of injury.

Training Characteristics. There are 3 primary characteristics of training that are considered risk factors for RSIs: intensity, volume, and duration.^{3,34} As these variables are manipulated, risk of injury may increase or decrease. The athlete completes each stroke using repetitive, identical motions, in turn resulting in repetitive loading cycles on the body's entire kinetic chain throughout the duration of the stroke cycle. Many researchers claim that one of the greatest contributors to RSF injury (as with most stress fractures of the body) is a sudden increase in training volume.¹⁹ During the winter training months as the rowing athlete transitions from the fall to spring sprint competition

season, they undergo substantially higher workout volumes. This high volume of activity is normally completed at a low intensity and heart rate, indicating lower stroke rates.⁵⁵ These slower speeds result in a greater load per stroke on the body, that when combined with the high volume of activity makes the individual substantially more susceptible for stress-related injuries.¹⁶

The risk of RSI in rowing athletes increases dramatically with higher level of competition, which may be attributed to the training requirements of higher-level athletes.³ Specifically, when an individual is not conditioned properly for the volume of training being imposed on their bodies, it can lead to muscle fatigue and decrease the body's ability to dissipate outside forces, potentially resulting in bone trauma.²²

Rowing athletes obtain supplementary sources of training through both ergometer training and weight lifting programs.³ The rowing ergometer is a land-based training alternative to workouts in the boat, and is often utilized to improve speed and endurance on an individual athlete.³ Rowing ergometers allow athletes to closely mimic the mechanics of on-water rowing, with the added ability of changing the “drag factor” so to increase or decrease resistance during a workout. Ergometers are often used for conditioning and ‘testing’ of the rowing athletes to determine individual physiological work output, as it provides quantitative data regarding work expenditure and characteristics throughout an individual's training session.^{18,56} Research postulates that the use of ergometers as a “supplementary” training and conditioning tool may contribute to the development of a RSI, as the individualized load is simply added on top of the on water training that athletes already do, further putting the rib cage under stress.^{3,34}

Rowing programs also typically utilize a strength-training program in the weight room to improve athlete performance. Two specific exercises, the bench pull and the bench press, are similar to the drive and recovery phases of the rowing stroke in that there are substantial amounts of scapular retraction and protraction occurring to accurately complete each exercise.^{3,4} While these exercises are intended to strengthen and improve endurance capabilities in chest wall muscles, these supplementary training methods increase the athlete's exposure to possible fracture-inducing stress on the bones.³ Additional research is necessary to explore the true impact of training and associated variables on RSIs in rowing athletes.

Equipment. In 1991, rowing teams began to switch their blade shape from tulip to hatchet-shaped (see Figure 3); this allowed for greater efficiency on the water due to increased blade surface area, but increased the load per stroke that the body is required to absorb.^{4,12,38} In the years following the switch, coaches and rowers became more aware of RSF occurrences in their own programs and student athletes.¹⁶ A modification was also made to the oar's shaft material, as companies began manufacturing oars with a carbon fiber shaft rather than wood.⁴ This resulted in a stiffer oar that increased the rower's ability to transmit force through the oar to the blade and in turn the water (allowing for greater displacement of the boat from its previous position), however it also increased the magnitude of loading on the torso and entire kinetic chain of the athlete.⁴ While there is a case regarding the negative implications of these changes to rowing equipment in relation to RSF incidence, there is no substantiated research at this time that demonstrates these relationships.

Environmental Concerns. Because rowing is an outdoor sport, additional risk factors for injury include environmental characteristics.²¹ If there is sufficient wind during a training session and athletes are attempting to move the boat against it, this can significantly increase the pressure and force that individuals must exert to continuously move the boat quickly and efficiently. This additional force being applied through the body's kinetic chain can combine with other risk factors to further increase the stress applied, leading an individual to possibly sustain a rib injury.

Diagnosis and Management of RSIs

Several different methods can be utilized for diagnosis of RSIs, including clinical diagnosis, x-ray, bone scan, magnetic resonance imaging (MRI), and ultrasound.^{3,19,52} Because x-rays may be negative early on, technetium-99 bone scan is the most commonly used diagnostic tool due to its 100% sensitivity for bone stress injuries and ability to diagnose them early (as compared to x-rays).²² However, x-rays may be able to show a fracture line or callus formation if the injury history is long enough.¹⁶ MRIs are the preferred diagnostic tool in terms of distinguishing between a soft tissue injury and bone injury, as they are the most sensitive and specific diagnostic imaging tool.⁵⁷

Management styles vary according to the coach, healthcare provider, and ultimately the setting in which the athlete presents with an injury. Previously, McDonnell et al.³ reported that while a variety of management tactics exist, research showed that rowers responded best to modified training along with several weeks of rest (depending on the extent of the injury and severity of symptoms).^{1,19,38} A recent systematic review by D'Ailly et al.³⁴ reported various management styles, but specifically noted the aggressive maneuvers to keep individuals participating in activity and competition for as long as

possible.³³ Vinther et al.⁵⁸ also highlighted this strategy in a 2016 editorial on management of rib pain in rowers. Part of these aggressive injury management styles may be due to a lack of clinical skill and confidence in diagnosing these injuries (and instead treating them as a soft tissue injury), in addition to the athlete's decision to continue training and competing until the end of their competition season regardless of pain level.^{21,23} Evans and Redgrave^{21,59} published an evidence-based guideline in 2016 for the diagnosis and management of RSIs to assist healthcare providers who lack familiarity and confidence in diagnosing these injuries.

Prevention of RSI

At this juncture, little information exists on the prevention of RSIs in the competitive rowing athlete. Only 2 studies identified information regarding prevention of RSIs in rowing athletes.^{16,33} Another more study focused on general injuries found that rowing athletes were lacking in the number of general injury prevention education sessions that they received, as over half of the athletes that responded to researchers reported that no educational sessions occurred during their previous season.³⁵ Additional studies suggested that a decreased risk of RSIs, specifically stress fractures, may be possible through modification of the rowers' techniques and the utilization of a smaller blade.^{16,29} However, no information is available confirming that the change in equipment wouldn't negatively impact the overall performance and current race standards of a NCAA competitive team.

SPORTS EPIDEMIOLOGY: CURRENT RESEARCH RECOMMENDATIONS

In order to evaluate the incidence rate and contributing factors of RSI development in the NCAA collegiate rowing population, sports epidemiological research

must be conducted. Epidemiology is defined as the study of the extent and contributing factors to the rates of injury, illness, and health issues in human populations.¹¹ Duncan⁶⁰ listed 7 potential uses for epidemiological data following collection of information: (1) identifying causes of disease, (2) completing clinical picture of disease, (3) allowing for the identification of syndromes, (4) determining effectiveness of therapeutic and preventative measures, (5) providing means to monitor health of a community or region, (6) quantifying risks, and (7) providing an overview of long-term disease trends.

Specific Study Design Recommendations

According to Timpka et al.⁸, an ideal epidemiological study design should be prospective in nature and consist of a cohort design. They also strongly recommend weekly recordings of injury and illness incidence in athletic teams and populations, as this allows for greater data collection and determination of risk factors associated with injury. A cross-sectional study design has been deemed appropriate for tracking long-term, overuse-related injuries in athletes.⁸

Meeuwisse and Love¹⁰ have also provided recommendations of design characteristics that studies should attempt to incorporate into their design. The designed system should possess flexibility so to address evolving injury patterns throughout the duration of the surveillance period, and be simple and easy to use for the participants. The system should easily collect athletic exposure data and have a standardized method of documentation for injury diagnosis, severity, treatment, and associated risk factors. Use of team athletic trainers who have daily contact and interaction with the athletes to collect data has also been suggested. However, one of the major barriers that researchers are presented with when trying to collect high quality epidemiological data is that

physicians, athletes, athletic trainers, and other study participants may not always report information on a consistent basis.⁸ This presents challenges with establishing accurate injury timelines and severity of specific injuries.

Meeuwisse and Love¹⁰ have also suggested several key concepts that researchers should keep in mind when collecting injury data during epidemiological studies. First, researchers must/should maximize the comparability of their data to other studies; methods for accomplishing this include providing a detailed description of the system design and reporting methods so future researchers can easily and clearly follow your study. Next, researchers should clearly define what a “reportable event/injury” is for the purposes of their study, and in turn collect outcome information on each reportable event.^{9,60} In the NCAA’s ISS, a reportable injury is defined as an injury that can be documented as occurring due to an individual’s participation in an organized intercollegiate training session or competition; these ‘reportable injuries’ typically require some variation of medical assistance via a team healthcare provider.³⁷ Finally, Meeuwisse and Love¹⁰ suggest that researchers acknowledge any potential source of error that may have occurred during their study and data collection period.

Important Epidemiological Study Components

Baseline Information. When collecting baseline information on an athlete, there are numerous pieces of information that are necessary to obtain in order to create a comprehensive image of the participant: age, sex, height, weight, dominant arm and leg, main events, training volume (including hours and sessions per week) and intensity, level of competition, number of years in athletics, and previous and ongoing injuries should all be documented prior to the beginning of the injury surveillance period.^{8,9}

Surveillance Information. To successfully accumulate and analyze sports epidemiology information, several features should be included: mode of injury onset, exposure data, and training characteristics.⁸ When mode of injury onset is recorded, the it should be classified as either sudden or gradual⁸; sudden injury onset can be split further to distinguish traumatic versus the sporadic symptoms associated with gradually developed overuse injuries.

Athlete exposure can be separated into two primary categories: competition exposure and training exposure.⁸ Competition exposure includes exposures in the following settings: competition including warm-up, interval between starts during a competition day, competition and cool-down.⁸ Training exposure is defined as any physical activity or bodily movements that are part of a designated regimen used to maintain or improve an individual's performance in an athletic setting.⁸ Documentation of these exposures help researchers establish incidence rates. Incidence can be defined as a quantitative value of the rate of new injuries and illnesses within a specific population during a given time frame.^{8,11}

Training duration, volume, and intensity are also essential components to consider with epidemiology studies. Jacobsson et al.⁶¹ suggest a method for quantifying training load in what they term the 'training load rank index.' This value can be determined by multiplying the reported training intensity by minutes of training performed during the week (where low, moderate, high are assigned values of 1, 3, and 5, respectively). The training load rank index discussed by Jacobsson et al. derived its ranking values from the category ratio rating of perceived exertion (RPE) scale.⁶² In epidemiological studies, training volume is simply defined as the number of trained hours per week.⁸

CONCLUSION

At this juncture, research lacks sufficient evidence and reporting statistics to confidently make a claim regarding the true mechanism of RSFs in the rowing athlete, as well as the incidence of injury. The empirical and anecdotal evidence to date would strongly suggest a multifactorial cause with primary contributions from various upper extremity and trunk muscles³¹, yet further research is necessary to determine a more accurate degree of contribution regarding each potential injury-inducing factor; this includes joint involvement, BMD, associated supplement intake, training characteristics, and equipment.

Throughout the years, changes in rowing training plans and equipment have had the ability to improve the speed and power production of athletes and their respective boats during competitions.¹² However, there remains a need for investigation of changes that can be made to decrease the injury rate of RSIs without compromising the integrity and competitive nature of the sport. This may be accomplished through epidemiology studies that further identify and detail potential risk factors, along with the degree to which they may contribute to the development of RSIs in the NCAA collegiate rowing athlete.

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