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SCOPING REVIEW ON STRESS-INJURY RELATIONS IN ATHLETIC AND OCCUPATIONAL CONTEXTS

HARNOOR SINGH
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Reviewed and approved* by the following:

David Conroy
Professor of Kinesiology
Thesis Supervisor

Jessica Schultz
Professor of Kinesiology
Honors Adviser

* Signatures are on file in the Schreyer Honors College.

Abstract

Injury is a pervasive, expensive and, to some extent, preventable problem. The National Hospital Ambulatory Medical Care Survey stated that in 2011, there were 40.2 million injury-related visits to the emergency department. Well-established factors that contribute to injury vulnerability include training volume and fitness. Psychological factors, such as stress responses, also contribute to injury risk but less is known about these risk factors. This paper presents a scoping review of the literature on stress-related injury in athletic and occupational environments. A multi-step screening process of four databases (Sport Discus, Psychinfo, Pubmed, and Web of Science) shortened a list of 1895 papers to a total of 56 quantitative studies – 34 from athletic contexts and 22 from occupational contexts – that examined relations between stress and injury. Studies were coded for demographic characteristics of the sample, strength of research design, stress and injury measures used, and conclusions about stress-injury relations. Studies used prospective (60.6%), cross-sectional (26.8%), and case control (12.5%) research designs. All studies were graded as being relatively low quality with scores of 0 (69.2%) or 1 (30.7%). Injury was most frequently defined as missing one subsequent day of training or work (35.7%). Approximately 75% of the studies indicated a positive association between negative affective reactivity and injury risk. Given the diversity of stress and injury measures and surveillance periods, caution is warranted when interpreting meta-analyses of this research.

TABLE OF CONTENTS

LIST OF FIGURES

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INTRODUCTION

Scoping Review on Stress-Injury Relations in Athletic and Occupational Contexts

Injury is a pervasive, expensive and, to some extent, preventable problem. Although some injuries may be largely unavoidable, other injuries may be preventable if risk factors can be identified. In athletic and occupational contexts, the physical causes of injuries are relatively well-established, but psychological factors, such as stress, also contribute to injury vulnerability and have been understudied. This paper systematically reviews and compares the scope of research on stress-injury relations in athletic and occupational contexts.

Injury as a Public Health Concern

Injury is the leading cause of death among American persons in the first half of their life (ages 1-44) (CDC, 2016)**.** The National Center for Injury Prevention and Control estimated that 26.9 million people were treated in emergency departments and 2.5 million people were hospitalized due to injuries in 2014 (CDC, 2016)**.** Not only does injury compromise physical and emotional well-being, but injuries also have an alarming economic toll. Within the United States, the total costs associated with fatal injuries were projected to be $214 billion (CDC, 2016)**.** Even more alarming, the total costs of nonfatal injuries accounted for over $457 billion creating a combined cost of $671 billion (CDC, 2016). When looking at the costs of injury both physically and financially, it is evident that prevention strategies that address injury risk factors are needed.

Etiology of Injury

To the casual observer, injury may seem to be the product of accidents or bad luck; however, a number of factors contribute to injury risk. These risk factors can be described as either extrinsic or intrinsic (Kumar, 2001). Extrinsic risk factors are those that can cause harm or damage and originate outside of the body. Examples of extrinsic factors include weather, field conditions, rules and equipment. Intrinsic risk factors are injuries internal to the individual. These examples include biomechanics, conditioning, maturational stage, somatotype, and psychological factors (Kumar, 2001). Within this framework, intrinsic risk factors may be the most suitable targets for prevention-focused interventions because they are more likely to fall under the control of the individual. Although psychological processes are relatively poorly understood risk factors, stress responses have emerged a robust psychological risk factor for injury in athletic and occupational contexts (Ivarsson et al., 2016; Johnston, 1995). This paper seeks to describe and compare the scope of research on stress-injury relations in athletic and occupational contexts so critical gaps can be identified to guide future research.

Defining Stress

Stress processes can be difficult to define and even more difficult to measure. Selye (1976) defined stress as "the nonspecific response of the body to any demand" (p. 2). The diversity of nonspecific responses has proven to be a challenge for research and research synthesis. Stressors refer to the sources of stress, and include both daily stressors and major life events. Daily stressors involve the more mundane problems encountered in daily life (e.g., unexpected deadlines, traffic jams, arguments with significant others; Almeida, 2005). These stressors can contribute to an immediate spike in affective responses associated with distress. Major life events include child abuse, death of a loved one, and job loss (Almeida, 2005). These stressors are less common and can elicit different and more prolonged stress responses than daily

stressors. Not all stressors, however, elicit the same psychological response. The nature and intensity of stress responses is influenced by how a person appraises a stressor and their coping potential. The extent to which stressors are perceived as more threatening or harmful will influence the magnitude of corresponding stress responses. Exposure to stressors and stress responses (i.e., reactivity) are separable constructs but inseparable elements of daily stress processes.

Models of Stress as a Risk Factor for Injury

Stress has been proposed as a psychological risk factor for injury in athletic and occupational contexts (Andersen & Williams, 1988; Nakata et. al, 2006). The stress-injury model posits that potentially stressful situations generate stress responses based on the athlete's perception of the situation (Andersen & Williams, 1988). This stress response involves neuromuscular and attentional changes that increase injury risk. A related occupational model by Nakata et. al (2006) proposed that stress heightens risk for occupational injury. Similar to the Andersen and Williams (1988) model, stressors lead to acute reactions, such as physiological/attentional changes, that culminate in illness and injuries. Both models conceptualize stress as a risk factor for injury in athletic and occupational settings. Figure 1 integrates the common features of those models with research on daily stress processes. In this model, injury risk is expected to be positively associated with both stress exposures and stress responses. Stress responses are expected to at least partially mediate associations between stress exposures and injury risk. This mediational hypothesis has not received much attention to date so this review focuses on relations between the two components of the stress process and injury risk (paths (a) and (c) in the Figure).

Empirical Support for Stress as an Injury Risk Factor

A recent meta-analysis by Ivarsson et al. (2016) examined associations between stress or stress-management interventions and athletic injury rates. Johnston (1995) reported a similar review of research on stress and occupational injury. Both reviews concluded that stress was positively associated with injury. Neither review characterized the scope of prior research in sufficient detail to compare these literatures or identify future directions. For example, neither review provided details on how stress or injury were measured. Their search terms focused only on literature with the term, "stress." As discussed above, stress is a complex phenomenon that can encompass elevated emotional states such as depression, anxiety, anger, or worry. The lack of detail about the samples studied limits understanding of the potential generalizability of conclusions. Finally, the quality of the research designs in each study was not assessed. Without this information, it is difficult to gauge the appropriate strength of conclusions. These gaps in knowledge point to the need for a scoping review to define sample characteristics, quality of research designs, and approaches to measuring stress and injury. This paper will be the first to directly compare research on stress and injury vulnerability between athletic and occupational contexts.

Methods

A literature search from four databases was conducted to identify studies that measured a relationship between stress and injury. These databases included Sports Discus, Psychinfo, Pubmed, and Web of Science. The identified search terms used were: (*stress OR anxiety OR anxious OR worry OR thought OR anger OR angry OR sad OR depression OR reactivity OR cortisol OR pile-up OR recovery OR negative affect OR rumination)* AND *("sport injury" OR "athletic injury" OR "occupational injury" OR "military injury" OR "musculoskeletal injury" OR "overuse injury"*). Studies were included if they (1) were written in the English language, (2) involved human participants, (3) used observational (cross-sectional, retrospective, prospective) or experimental research designs, (4) included at least one measure of stress, anxiety, depression, anger, ruminative or intrusive thought, (4) included at least one measure of musculoskeletal injury incidence, (5) were published before in 2015 or earlier, and (6) reported a measure of association between stress and injury. This search identified 1895 records. Eight duplicates were removed, leaving 1258 unique records.

As shown in Figure 2, there were three stages in our screening process. A review of titles led to the exclusion of 833 records, leaving 425 unique records. Abstract review led to the exclusion of 300 records, leaving 125 records. These papers were read and 60 were excluded for not meeting one or more of the inclusion criteria. The remaining 65 records were coded for this review.

Studies were coded for their sample characteristics, including size, sex distribution, and age (mean and range). Further coding focused on study features, including research design, duration of injury surveillance, and quality of evidence. The quality of evidence was rated using a scale adapted from work by the Cochrane Applicability and Recommendations Methods Group

(Higgins & Green, 2008). Factors that increased the quality of evidence included (1) large magnitude of effect, (2) noting all plausible confounding variable that would reduce a demonstrated effect or suggest a spurious effect when results show no effect, and (3) dose-response gradient. Factors that decreased the quality of evidence included (1) limitations in the design and implementation of available studies suggesting high likelihood of bias, (2) indirectness of evidence (indirect population, intervention, control, outcomes), (3) unexplained heterogeneity or inconsistency of results (including problems with subgroup analyses), (4) imprecision of results (wide confidence intervals) and (5) high probability of publication bias. Each attribute that improved the quality of evidence was scored +1; each attribute that reduced the quality of evidence was scored -1. Scores were summed to create a single rating of the quality of evidence. The possible range of scores was -3 to +3.

Stress measures were coded as exposures or responses. Stress exposures involved measures of events and situations that were evaluated as a stressful occurrence (e.g., "How many times did you get into an argument today?"). Stress response measures focused on the individual's reaction to the situation (e.g., "Have you felt stress in the past few days/weeks/months?"). The operational definition of injury measurement in each study was also recorded. The direction of stress-injury relations was coded as null, negative, or positive based on the statistical significance and direction of the association.

RESULTS

A total of 56 studies were used in this review: 34 from athletic contexts and 22 from occupational contexts.

Athletic Context

Characteristics of the athletic samples are presented in Table 1. The total sample included 8,784 participants (27.3% female) with an age range of 11-41. For studies that reported a mean, the sample-size adjusted mean was 17.3 years. Participants in collision (50%), contact (50%), and non-contact (35.2%) sports were included (some studies included sports from multiple categories so values do not sum to 100%). Most participants were involved in either college (35.3%) or high school (25%) sports.

Table 2 summarizes the design and methodological rigor of studies in the athletic context. Most studies were prospective (94%) with injury surveillance periods ranges from 3 months to 2 years (M = 26.3 weeks, SD = 23.2 weeks). All of the articles were graded as 0 (70%) or 1 (30%) indicating a low-to-moderate quality of evidence.

Table 3 shows how stress and injury have been measured in research with athletes. Injury was most frequently operationalized (41.2%) as missing one day of practice or competition. Studies measured exposures only (60.9%), responses only (17.1%) or both exposures and responses (22.0%). Stress exposures included measures of major life events (54.3%), daily stressors (22.9%), or both (22.9%). Some studies included multiple measures of exposures or responses so the following analyses use the total number of measures as the denominator (i.e., a study with two measures of stress exposures could be counted twice if associations were reported for both exposure measures). In the research on major life events, 84.2% of the measures

exhibited a positive association between stress and injury and 15.8% of the measures exhibited a null association. In the research on daily stressors, 62.5% of the measures exhibited a positive association between stress and injury and 37.5% of the measures exhibited a null association. In the research that assessed both daily stressors and major life events, 75% of the measures exhibited a positive association between stress and injury and 25% of the measures exhibited a null association. Across all measures of stressor exposures, stress and injury exhibited a positive association (77.1%) more frequently than a null (22.9%) or negative association (0%).

Stress responses were frequently measured as perceived stress (37.5%). The majority of these studies (83.3%) reported a positive association between stress and injury and 16.7% reported a null association. Stress responses were also measured by questionnaires that assessed emotional states (62.5%; e.g., anxiety, anger, confusion, depression, worry). In the studies that measured anxiety, 66.6% reported a positive association between stress and injury and 33.3% reported a null association. In all studies that measured stress response as an emotional state, 75% reported a positive association between stress and injury and 25% reported a null association.

Across all studies of both stressor exposures and stress responses, 77.2% reported a positive association with injury and 22.8% reported a null association. No studies reported a negative association between stress exposures or responses and injury.

Occupational Context

Characteristics of the occupational samples are presented in Table 4. The total sample included 351,370 subject (32.9% female) with an age range of 11-92 years. For studies that reported a mean, the sample-size adjusted mean age was 39.3 years.

Table 5 summarizes the methodological quality of these studies. Studies used cross-sectional (59%), prospective (9%), and case control (31.8%). Surveillance periods ranged from two weeks to 24 years (median = 52 weeks, *M* = 120.89 weeks, *SD* = 283.11 weeks). All of the articles were graded as low-to-moderate quality, with ratings of either 0 (68.1%) or 1 (31.8%).

Table 6 summarizes how stress and injury have been measured in occupational contexts. Injury was frequently operationalized as suffering a work-related injury which occurred as a result of being at your job or performing your job duties in the past year (27.3%). Studies measured stressor exposures only (31.8%), stress responses only (31.8%) or both exposures and responses (36.4%). Some studies included multiple measures of exposures or responses so the following analyses use the total number of measures as the denominator (i.e., a study with two measures of stress exposures could be counted twice if associations are reported for both exposure measures). Stressor exposure measures were assessed as daily stressors (90%), major life events (0%), or both (10%). Daily stressor measures exhibited either positive (66.6%), null (22.2%), or negative associations (5.5%) with injury. All measures that assessed both daily stressors and major life events indicated positive stress-injury associations. Overall, measures that assessed stressor exposures reported either a positive association (70%), null association (20%), or negative association (5%; not all studies reported all possible associations between stress exposures and injury so these values do not sum to 100%)

Most stress response measurements used a measure of perceived stress (73.3%) and almost all of these (90.9%) reported a positive association between stress responses and injury. Other measurements looked at stress responses with questionnaires that assessed emotional states such as sorrow, anger, desperation, frustration, and depression. These measurements found that

negative affective reactivity was positively associated (86.7%) or not associated (6.7%) with injury.

Across all studies of both stress exposures and stress responses, 80.7% reported a positive association with injury, 14.7% reported a null association, and 4.5% reported a negative association (some studies used multiple measures and did not report associations for each measure so values do not sum to 100%).

DISCUSSION

The purpose of this paper was to systematically review and compare the scope of research on stress-injury relations in athletic and occupational contexts. More research has been conducted in athletic than occupational settings; however, the average size of occupational samples is easily an order of magnitude greater than the average size of athletic samples. Occupational injury research has capitalized on large national surveys (e.g., National Longitudinal Survey of Youth). Researchers interested in psychosocial risk factors for athletic injuries may benefit from integrating measures of stress in national injury surveillance systems (for a review of methods, see Ekegren, Gabbe, & Finch, 2016).

The most common operational definition of injury in athletic and occupational contexts involved missing one subsequent day of practice, competition, or work (35.7%). Overall, injury measures varied considerably between studies, particularly in occupational studies. In viewing athletic injury measurements, greater overlap can be found in injury definition because the National Athletic Injury/Illness Reporting System provides a standard definition of injury (Alles, Powell, Buckley, & Hunt, 1979). Variability in occupational research may reflect the lack of a common system for defining injury. This variation complicates the challenge of meta-analyzing these results. Harmonizing measures for future research would be valuable.

Surveillance periods differed dramatically between athletic (M = 26.3 weeks) and occupational contexts (M = 117.3 weeks). Formal athletic seasons provide a natural boundary around data collection; however, training periods are increasingly year-round as a consequence of specialization and professionalization (Istvan, 2004). It would be useful to track injury risk during and out-of-season to understand whether stress-related risks for injury vary during these periods.

In occupational settings, the duration of injury surveillance has been impressive. Most forms of injury surveillance in occupational settings recorded only work-related injuries. More research is needed to determine whether work-related stressors cause injuries during leisure activities. Overall, it was clear that more rigorous research designs are needed to strengthen causal inferences about stress-injury relations (see also Ivarsson et al., 2016). Experimental designs evaluating stress management intervention effects on injury risk provide an ethical approach for future experimental research. A limited number of stress management interventions have been tested and shown promise for reducing injury risk but it can be difficult to time these interventions to align with naturally-occurring stress exposures and responses (Edvardsson, Ivarsson, & Johnson, 2012; Ivarsson, Johnson, Andersen, Fallby, & Altemyr, 2015; Urban Johnson, Ekengren, & Andersen, 2005; Kerr & Goss, 1996; Noh, Morris, & Andersen, 2007; Tranaeus et al., 2015). Valid real-time stress measures are needed to capture the dynamics of these processes without burdening users unduly. As these tools emerge, it may be possible to implement and evaluate context-sensitive, just-in-time stress management interventions when people are most vulnerable to an injury (Intille, 2004; Nahum-Shani et al., 2014; Nahum-Shani, Hekler, & Spruijt-Metz, 2015).

Stressor exposures have been assessed differently in athletic and occupational contexts. Studies in the athletic context have assessed a diverse array of daily stressors and major life events, and often both have been assessed in the same study. In contrast, studies in occupational contexts have prioritized daily stressors. Athletic stress exposure measures that focused on major life events have shown a strong positive association, suggesting the need to test this association in occupational contexts. Notwithstanding these differences, the pattern of stressor exposure and

injury associations is remarkably consistent across athletic and occupational contexts with most studies showing a positive association.

Stress responses were recorded in categories of emotional states in athletic and occupational contexts. In athletics, most stress response measures involved perceived stress as well as self-reported states of anxiety, whereas occupational measures involved perceived stress alone. Furthermore athletic studies tended to look at stress responses in a variety of emotional states (e.g. anger, anxiety, tension) while occupational studies focused on perceived stress and occasionally depression. Broadening the definition of stress to include a variety of unpleasant emotional states associated with stress may clarify links with injury risk. Stress responses in athletics and occupational studies shared a similar pattern of positive associations with injury. Stress responses and stress exposures in more than 70% of the studies reviewed across both contexts showed a positive association with injury.

Age is another important contrast between the research literatures in athletic and occupational contexts. Athletic samples tended to be over 20 years younger than occupational samples and had considerably less variation in the range of ages. This difference was expected given that competitive sport is more common in early adulthood whereas occupational activities can endure into older adulthood (Eime et al., 2016).

Athletic injury research has emphasized contact and collision sports; research with noncontact sport participants were less common. In a study done by Hootman et al. (2007), the majority of injuries in college sports were incurred during contact sports. The level of physical contact in sports is an important contextual risk factor that may influence study outcomes. Occupational studies were conducted on populations in a variety of working conditions, some of which did not involve intense physical demands. The overall positive association was robust in

occupational studies observing less physically demanding jobs so it is possible that it may also exist in non-contact sports. This hypothesis requires testing in future research.

From a research design perspective, most athletic injury research has been prospective (94%), whereas occupational injury research has been cross-sectional (50%). This difference likely reflects a limitation of relying on large surveillance datasets in occupational contexts. Given the dynamic nature of stressor exposures and stress responses, it is noteworthy that no studies have used ecological momentary assessments. These designs are well-suited to link dynamic processes in everyday life (Shiffman, Stone, & Hufford, 2008). Understanding of stress-related injury vulnerability would be enriched by data on the dynamics of stress processes.

Key limitations of this review warrant attention. First, although this review broadened the scope of stress measures by including studies focused on negative affective reactivity, other search terms should be included for future quantitative reviews (e.g., accident, work, intervention). The present review was also limited to information reported in primary reports. To the extent that the original authors did not report relevant information, that information was not included in this review. All studies examined were non-experimental in nature which limited the strength of conclusions that can be drawn. All of the studies in this review relied upon self-report measures of stress. It is not clear whether findings will generalize to studies using biomarkers or wearable sensors to measure stress (Valent et al., 2016; Hovsepian et al., 2015).

In conclusion, this scoping review characterized and compared the participants, measures, and research designs used in research on stress-injury relations in athletic and occupational contexts. Given the diversity of stress and injury measures and surveillance periods, caution is warranted when interpreting meta-analyses of this research. As this literature develops, harmonizing measures of stress exposures, responses, and injury would accelerate progress.

Decisions about which measures to pursue should be made on theoretical rather than pragmatic grounds. A number of gaps in the literature were identified in this review to define priorities for future research on stress-related injury vulnerability.

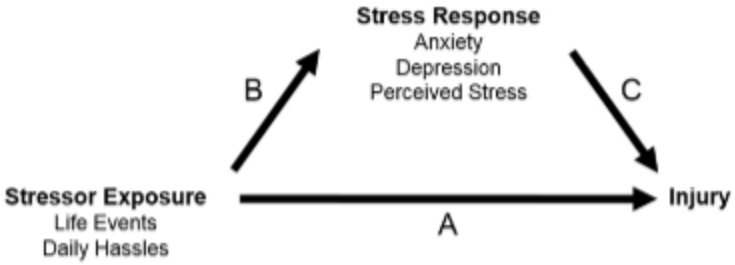

Figure 1 Integrated Stress-Injury Model Athletic and Occupational Contexts

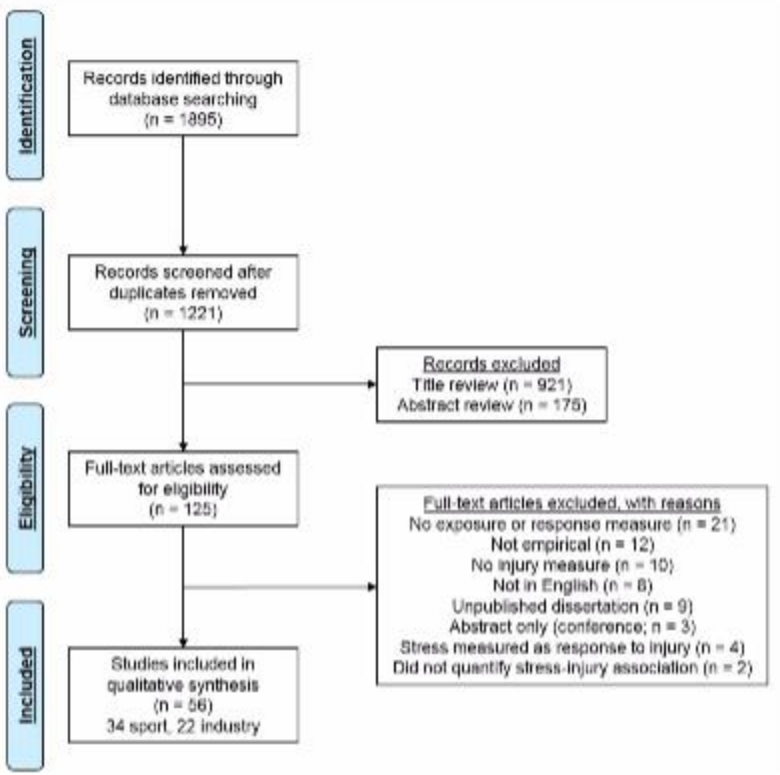

Figure 2 Screening Process Shown in PRISMA Chart

TABLES 1-6

Table 1. Sample characteristics: Athletic context

Citation	Population	Type	Level	N	Female (%)	*M* Age (yrs)
Andersen & Williams (1999)	Gymnastics, Swimming, Cross country, Track and Field, Wrestling , American football, Baseball , Softball, Volleyball and Basketball	College	Contact (27%), Collision (5%), Noncontact (68%)	196	59.70%	Not reported
Blackwell & McCullagh (1990)	Football	College	Collision	105	0	Not reported
Coddington & Troxell (1980)	Football	High school	Collision	114	0	15.9
Dunn, Smith, & Smoll (2001)	Basketball, Wrestling, and Gymnastics	High school	Noncontact, Contact, Collision	425	44.50%	16.21
Fawkner, McMurrary, & Summers (1999)	Field hockey, Volleyball, and Triathlon.	Not reported	Noncontact (57%), Contact (43%)	98	72.40%	26.09
Ford, Eklund, & Gordon (2000)	Australian football, basketball, cricket, field hockey, netball, volleyball	State, National, or International Standard	Contact (66%), Collision (34%)	121	46.30%	22.5
Galambos, Terry, Moyle, & Locke (2005)	Basketball, Beach volleyball, Canoeing, Cricket, Cycling, Golf, Gymnastics, Hockey, Netball, Rugby league, Rugby union, Soccer, Softball, Swimming, Tennis, Triathlon, and Water polo.	Not reported	Noncontact, Contact, Collision	845	51.20%	18.8
Hanson, McCullagh, & Tonymon (1992)	Track and Field	College	Noncontact	181	32%	19.9
Hardy & Riehl (1988)	Baseball, Softball, Tennis, and Track	College	Noncontact, Contact	86	43%	Not reported
Ivarsson & Johnson (2010)	Soccer	Competitive level	Contact	48	0	22
Ivarsson, Johnson, & Podlog (2013)	Soccer	Professional	Contact	56	32.10%	25.05

Ivarsson, Johnson, Lindwall, Gustafsson, & Altemyr (2014)	Soccer	High school	Contact	101	33.70%	16.7
Johnson & Ivarsson (2011)	Soccer	High school	Contact	108	21.30%	Not reported
Laux, Krumm, Diers, & Flor (2015)	Soccer	Professional	Contact	22	0	25.8
Lavallee & Flint (1996)	Football and Rugby players	College	Collision	55	0	22
Maddison & Prapavessis (2005)	Rugby	College	Collision	470	0	20.69
Mann et al., (2016)	Football players	College	Collision	101	0	19
McKay et al., (2013)	Ice hockey	Bantam, Midget, Elite	Contact	316	0	Not reported
Noh , Morris. and Andersen (2005)	Ballet	Professional, University, Institute	Noncontact	105	96.20%	20.46
Passer & Seese (1983)	Football	College	Collision	104	0	Not reported
Petrie (1993)	Football	College	Collision	158	0	19.6
Rogers & Landers (2005)	Soccer	High school varsity	Contact	171	42.70%	16.1
Schafer & McKenna (1985)	Running club	Adult	Noncontact	572	Not reported	Not reported
Shrier & Halle (2011)	Circus artists	Trainers	Noncontact	47	36.20%	Not reported
Sibold & Zizzi (2012)	Football, Soccer, Women's volleyball, Cross-country	College	Noncontact (18.6%), Contact (39.4%), Collision (42%)	177	34.50%	19.45
Smith, Ptacek, & Patterson (2000)	Ballet	Major company	Noncontact	46	67.40%	26.23
Smith, Smoll, & Ptacek (2008)	Basketball, Wrestling, Gymnastics	High school Varsity	Noncontact, Contact, Collision	451	44.60%	16.23
Steffen, Pensgaard, & Bahr (2009)	Football	High school	Collision	1430	0	15.4
Thompson & Morris (1994)	Adolescent Football	High school	Collision	120	0	not reported
Trent A Petrie (1993)	Football	College	Collision	98	0	19.7

VanMechelen et al. (1996)	Not reported	Not reported	n/a	139	54%	Not reported
Wadey, Evans, Hanton, & Neil (2012)	Not reported	Recreational-International	n/a	694	47%	19.17
Wadey, Evans, Hanton, & Neil (2013)	Not reported	Recreational-International	n/a	694	47%	19.17
Yang et al. (2014)	Football	College	Collision	330	0	Not reported

Table 2. Research design characteristics: Athletic context

Citation	Design	Duration of Injury Surveillance	Quality Rating
Andersen & Williams (1999)	Prospective	1 season	0
Blackwell & McCullagh (1990)	Prospective	1 season	1
Coddington & Troxell (1980)	Prospective	1 season	1
Dunn, Smith, & Smoll (2001)	Prospective	1 season	1
Fawkner, McMurrary, & Summers (1999)	Prospective	1 season	0
Ford, Eklund, & Gordon (2000)	Prospective	~ 6 months	0
Galambos, Terry, Moyle, & Locke (2005)	Prospective	Did not report	1
Hanson, McCullagh, & Tonymon (1992)	Prospective	18 weeks	0
Hardy & Riehl (1988)	Prospective	1 season	0
Ivarsson & Johnson (2010)	Prospective	3 months	0
Ivarsson, Johnson, & Podlog (2013)	Prospective	13 weeks	0
Ivarsson, Johnson, Lindwall, Gustafsson, & Altemyr (2014)	Prospective	10 weeks	0
Johnson & Ivarsson (2011)	Prospective	8 months	0
Laux, Krumm, Diers, & Flor (2015)	Prospective	16 months	1
Lavallee & Flint (1996)	Cross-sectional	1 season	1
Maddison & Prapavessis (2005)	Prospective	1 season	0
Mann et al., (2016)	Prospective	20 weeks	1
McKay et al., (2013)	Prospective	1 season	0
Noh , Morris. and Andersen (2005)	Prospective	10 months	0
Passer & Seese (1983)	Prospective	1 season	0
Petrie (1993)	Prospective	1 season	0
Rogers & Landers (2005)	Prospective	1 season	0
Schafer & McKenna (1985)	Cross-sectional	3 months	1
Shrier & Halle (2011)	Prospective	16 weeks	0
Sibold & Zizzi (2012)	Prospective	1 season	0
Smith, Ptacek, & Patterson (2000)	Prospective	8 months	1
Smith, Smoll, & Ptacek (2008)	Prospective	1 season	0
Steffen, Pensgaard, & Bahr (2009)	Prospective	8 months	0
Thompson & Morris (1994)	Prospective	1 season	0
Trent A Petrie (1993)	Prospective	1 season	0
VanMechelen et al. (1996)	Prospective	1 year	1
Wadey, Evans, Hanton, & Neil (2012)	Prospective	2 years	0
Wadey, Evans, Hanton, & Neil (2013)	Prospective	2 years	0
Yang et al. (2014)	Prospective	Up to 2 years	0

Table 3. Stress-injury measures and conclusions: Athletic context

Citation	Injury	Stressor Exposure Measure	Exposure-Injury Association	Stress Response Measure	Response-Injury Association
Andersen & Williams (1999)	Missing or modifying at least one day of practice or competition beyond the injury occurrence.	Life Events Survey for Collegiate Athletes	Positive	State - Trait Anxiety Inventory	Null
Blackwell & McCullagh (1990)	National Athletic Injury Reporting System	Athletic Life Events Scale	Positive	None	n/a
		Daily Hassles Scale	Positive	None	n/a
Coddington & Troxell (1980)	National Athletic Injury Reporting System	Life Event Scale for Adolescents	Positive	None	n/a
Dunn, Smith, & Smoll (2001)	Missing or modifying at least one day of practice or competition beyond the injury occurrence.	Adolescent Perceived Events Scale	Null	None	n/a
		The Sport Experiences Survey	Positive	None	n/a
Fawkner, McMurrary, & Summers (1999)	Missing or modifying at least one day of practice or competition beyond the injury occurrence.	Daily Hassles Scale	Positive	None	n/a
Ford, Eklund, & Gordon (2000)	Missing or modifying at least one day of practice or competition beyond the injury occurrence.	Athletic Life Experiences Survey	Positive	None	n/a
Galambos, Terry, Moyle, & Locke (2005)	Operationalized as all medically attended, sport related somatic damage.	None	n/a	Brunel Mood Scale	Positive
		None	n/a	Perceived Stress Scale	Positive
Hanson, McCullagh, & Tonymon (1992)	Classified as mild, moderate, Severe 1, Severe 2 (nonparticipant, or Severe 3 (nonparticipation for more than 4 weeks	Athletic Life Experiences Survey	Positive	None	n/a
		Everyday Problems Scale	Null	None	n/a
Hardy & Riehl (1988)	Missing or modifying at least one day of practice or competition beyond the injury occurrence.	Athletic Life Experiences Survey	Positive	None	n/a

Ivarsson & Johnson (2010)	Missing or modifying at least one day of practice or competition beyond the injury occurrence.	Life Events Survey for Collegiate Athletes	Positive	None	n/a
		Daily Hassles Scale	Null	None	n/a
Ivarsson, Johnson, & Podlog (2013)	Missing or modifying at least one day of practice or competition beyond the injury occurrence.	Life Events Survey for Collegiate Athletes	Positive	None	n/a
		Hassles and Uplift Scale	Positive	None	n/a
Ivarsson, Johnson, Lindwall, Gustafsson, & Altemyr (2014)	Restriction of the athlete's participation for three days or more beyond the day of injury	Hassles and Uplifts Scale	Null	None	n/a
Johnson & Ivarsson (2011)	Defined as all types of injuries that occur in connection with sport participation; the severity of injuries was categorized according to the length of time the athlete was incapacitated.	The Life Events Survey for Collegiate Athletes	Positive	State-Trait Anxiety Inventory	Positive
Laux, Krumm, Diers, & Flor (2015)	Missing or modifying at least one day of practice or competition beyond the injury occurrence.	None	n/a	Recovery-Stress Questionnaire for Athletes	Positive
Lavallee & Flint (1996)	Recording of injuries for both sports was performed by the head student therapist of each sport according to Reid's12 classification of injuries, specifically, Grade I, Grade II, and Grade III injuries	Social Athletic Readjustment Rating Scale	Positive	Profile of Mood States (POMS)	Null
Maddison & Prapavessis (2005)	Calculated injury time with a formula [total time missed due to injury/(number of players x total time played and trained)]	Life Events Survey for Collegiate Athletes	Null	None	n/a
Mann et al., (2016)	Cause any restriction to any drill or other component in practice were recorded	High academic stress due to midterms or final	Positive	None	n/a

McKay et al., (2013)	Missing or modifying at least one day of practice or competition beyond the injury occurrence.	None	n/a	Competitive State Anxiety Inventory-2R	Positive
Noh, Morris. and Andersen (2005)	Missing or modifying at least one day of practice or competition beyond the injury occurrence.	Adolescent Perceived Event Scale	Positive	None	n/a
		The Sport Experiences Survey	Positive	None	n/a
Passer & Seese (1983)	Time-loss from practice and games constituted the measure of athletic injury. The primary time-loss measure was the number of days each athlete was placed on a nonparticipation status due to injury; also assessed were the number of days of limited participation status. due to injury. The injury assessment period included all regular season games and practices, as well as preseason practices and scrimmages held after the administration of the life change	Athletic Life Experiences Survey	Positive	State-Trait Anxiety Inventory	Positive
Petrie (1993)	Missing or modifying at least one day of practice or competition beyond the injury occurrence.	Life Event Scale for Collegiate Athletes	Positive	The Sport Competition Anxiety Test-Adult	Positive
Rogers & Landers (2005)	Missing or modifying at least one day of practice or competition beyond the injury occurrence.	Life Events Survey for Athletes	Positive	Perceived Stress Scale	Null
Schafer & McKenna (1985)	"How many times during the past three months have you been injured in each of the following places? (eg knee, ankle, foot). By injured we mean hurt enough to reduce your running or to miss a day of running."	Holmes and Rahe Social Readjustment Rating Scale	Positive	Whether stress level had been from 'much higher than normal for me' to 'much lower	Positive

				than normal for me' during the past three months.	
		NONE	N/A	Distress Symptom Scale	Null
Shrier & Halle (2011)	Considered an injury to be any visit to the therapist for a new work-related complaint (eg, sprained ankle skiing would be excluded).	None	n/a	Recovery-Stress Questionnaire for Athletes	Positive
Sibold & Zizzi (2012)	Missing or modifying at least one day of practice or competition beyond the injury occurrence.	Life Event Scale for Collegiate Athletes	Null	None	n/a
Smith, Ptacek, & Patterson (2000)	Missing or modifying at least one day of practice or competition beyond the injury occurrence.	None	n/a	Perceived Events Scale	Null
Smith, Smoll, & Ptacek (2008)	Missing or modifying at least one day of practice or competition beyond the injury occurrence.	Adolescent Perceived Events Scale	Positive	None	n/a
Steffen, Pensgaard, & Bahr (2009)	Missing or modifying at least one day of practice or competition beyond the injury occurrence.	Life Event Scale for Collegiate Athletes	Positive	None	n/a
Thompson & Morris (1994)	Missing or modifying at least one day of practice or competition beyond the injury occurrence.	Social Readjustment Rating Scale	Positive	Framingham Anger Scale	Positive
Trent A Petrie (1993)	National Athletic Injury Reporting System	Life Event Scale for Collegiate Athletes	Positive	None	n/a
VanMechelen et al. (1996)	Missing or modifying at least one day of practice or competition beyond the injury occurrence.	Life Events List	Null	Maastricht Questionnaire	Positive
		Everyday Problem Checklist	Positive	None	n/a

Wadey, Evans, Hanton, & Neil (2012)	Medical problem resulting from sport participation that prevented normal training and competition for a minimum period of 2 wk	Life Event Scale for Collegiate Athletes	Positive	None	n/a
Wadey, Evans, Hanton, & Neil (2013)	Medical problem resulting from sport participation that prevented normal training and competition for a minimum period of 2 wk	Life Event Scale for Collegiate Athletes	Positive	None	n/a
Yang et al. (2014)	Clinical signs of acute tissue damage as determined by team athletic trainers and/or team physicians, and led to the player's inability to return to practice or game the same day	None	n/a	Center for Epidemiological Studies Depression Scale	Positive

Table 4. Sample characteristics: Occupational context

Citation	Population	N	Female (%)	*M* Age	Range
A Nakata et al. (2006)	Small or medium scale enterprise workers	1770	40.70%	45.2	16-60+
Brown et al. (2011)	US working population	2151	54.70%	41.5	19-88
Chau et al. (2008)	France working population	2888	43.50%	Not reported	15-70+
De Castro et al. (2010)	Philippine Nurses Association (PNA) and the Occupational Health Nurses Association of the Philippines	655	Not reported	42.5	20-79
Dembe et al. (2005)	US working population	10,793	47.80%	Not reported	Not reported
Gillen et al. (2007)	Hospital workers	664	72.30%	45	Not reported
H.-C. Kim et al. (2009)	Small- to Medium-Sized Manufacturing workers	1209	Not reported	Not reported	<30->50
Haruyama et al. (2014)	Kitchen facility chefs	740	77%	Not reported	17-68
Hess (1997)	State agency at risk computer user	274	60%	43.4	<19-71
Hilton & Whiteford (2010)	Full time workers	60,556	57.60%	41	18-65+
Johannessen, Gravseth, & Sterud (2015)	Community-living Norwegian residents	6726	47.50%	Not reported	18-66
Johnson & Sharit (2001)	Production workers	3121	9.50%	Not reported	Not reported
Julia et al. (2013)	Insured working adults	10667	31%	Not reported	<24->55

Table 4 (continued)….

Citation	Population	N	Female (%)	Mean Age	Range
Kim, 2008	Representative sample of United States workers	101,855	Not reported	Not reported	18-64
Lombardi et al. (2014)	Workers injured in the fingers, hand, or wrist in two hand-surgery. Found in hospital.	703	25%	31.8	Not reported
McAninch et al. (2014)	Non-institutionalized civilian working adults	26,776	56%	Not reported	18-92
Nearkasen Chau et al. (2011)	Northeast France households	2882	Not reported	Not reported	Not reported
Peele & Tollerud (2005)	Individuals reporting to either of two general occupational health clinics in Pittsburgh, Pennsylvania	261	30.20%	39.10076628	14-73
S Salminen et al. (2003)	Hospital personnel	5111	93.70%	Not reported	Not reported
Sakurai et al. (2013)	Full time workers	36688	21.30%	35.4	<29->60
Simo Salminen et al. (2014)	Forest industry employees	16,385	23.30%	40.9	Not reported
Tawatsupa et al. (2013)	Thai workers	58,495	55.70%	Not reported	Not reported

Table 5. Research design characteristics: Occupational context

Citation	Design	Duration of Injury Surveillance	Quality Rating
A Nakata et al. (2006)	Cross-sectional	1 year	0
Brown et al. (2011)	Cross-sectional	1 year	0
Chau et al. (2008)	Cross-sectional	2 years	1
De Castro et al. (2010)	Cross-sectional	1 year	0
Dembe et al. (2005)	Prospective	Did not report	0
Gauchard et al. (2006)	Case control	1 year	0
Gillen et al. (2007)	Case control	Did not report	1
H.-C. Kim et al. (2009)	Prospective	4 months	1
Haruyama et al. (2014)	Cross-sectional	1 year	0
Hess (1997)	Cross-sectional	Did not report	1
Hilton & Whiteford (2010)	Cross-sectional	4 weeks	0
Johannessen, Gravseth, & Sterud (2015)	Prospective	1 year	0
Johnson & Sharit (2001)	Prospective	2 years	1
Julia et al. (2013)	Prospective	1 year	0
Kim, 2008	Cross-sectional	3 months	0
Lombardi et al. (2014)	Cross-sectional	Did not report	1
McAninch et al. (2014)	Cross-sectional	3 months	0

Nearkasen Chau et al. (2011)	Cross-sectional	2 years	0
Peele & Tollerud (2005)	Case control	1 year	0
S Salminen et al. (2003)	Prospective	2 years	0
Sakurai et al. (2013)	Cross-sectional	1 year	0
Simo Salminen et al. (2014)	Prospective	24 years	1
Tawatsupa et al. (2013)	Cross-sectional	1 year	0

Table 6. Stress-injury measures and conclusions: Occupational context

Citation	Injury	Stressor Exposure Measure	Exposure-Injury Association	Stress Response Measure	Response-Injury Association
A Nakata et al. (2006)	If they suffer a work-related injury which occurred as a result of being at your job or performing your job duties in the past year	Generic Job Stress Questionnaire (GJSQ)	Positive	Generic Job Stress Questionnaire (GJSQ)	Positive
Brown et al. (2011)	If they suffer a work-related injury which occurred as a result of being at your job or performing your job duties in the past year	Generalized Workplace Harassment	Positive	None	n/a
		Sexual Experiences Questionnaire	Positive	None	n/a
		Job Pressure and Threat (JPT)	Positive	None	n/a
Chau et al. (2008)	If they suffer a work-related injury which occurred as a result of being at your job or performing your job duties in the past year	Questionnaire Survey on job demands	Positive	None	n/a
De Castro et al. (2010)	If they suffer a work-related injury which occurred as a result of being at your job or performing your job duties in the past year	Work hours, shift length, shift, frequency of mandatory or unplanned overtime, and number of overtime hours worked per month	Null	None	n/a
Dembe et al. (2005)	Recorded information on work related injuries and illnesses from the National Longitudinal Survey of Youth	Overtime or extended hours	Positive	None	n/a

Gillen et al. (2007)	Musculoskeletal disorder	Telephone-based interview assessing job satisfaction	Positive	None	n/a
H.-C. Kim et al. (2009)	‘‘Have you ever been injured at work, including minor scratches and cuts, in the previous four-month period?’’	Brief Job Stress Questionnaire	Positive	Brief Job Stress Questionnaire	Positive
Haruyama et al. (2014)	If they suffer a work-related injury which occurred as a result of being at your job or performing your job duties in the past year	Brief Job Stress Questionnaire	Positive	Brief Job Stress Questionnaire	Positive
Hess (1997)	Repetitive strain injury symptoms	None	n/a	Perceived stress scale	Positive
Hilton & Whiteford (2010)	‘Did you have any of the following experiences at work in the past 4 weeks? (1) Any special work success or achievement. (2) Any special work failure. (3) An accident that caused either damage, work delay, a near miss, or safety risk’’	None	n/a	Kessler 6-item Psychological Distress Scale (K-6)	Positive
Johannessen, Gravseth, & Sterud (2015)	One day of absenteeism	Job Control	Null	Emotional Demands	Positive
		Job Demands	Null	None	n/a
		Job Strain	Positive	None	n/a
		Role Conflict	Positive	None	n/a

Johnson & Sharit (2001)	Any fatal or nonfatal injury which involved one or more of the following: loss of consciousness, restriction of work or motion, transfer to another job, or medical treatment	3 questionnaires sent out measuring 8h or 12 h shift	Null	None	n/a
Julia et al. (2013)	Occupational injury of at least 1 day in addition to the day when the injury happened, which occurred during the follow-up year	Lack of Organizational Support	Positive	Job Stress Survey	Null
Kim, 2008	"what were you doing when the injury happened?"	None	n/a	Kessler 6-item Psychological Distress Scale (K-6)	Positive
Lombardi et al. (2014)	Subjects were recruit from workers admitted for treatment of a sudden-onset, traumatic injury to the fingers, hand, or wrist in two hand-surgery	Rest Break Duration	Negative	None	n/a
McAninch et al. (2014)	National Health Interview Survey	None	n/a	Kessler 6-item Psychological Distress Scale (K-6)	Positive
Nearkasen Chau et al. (2011)	Defined as damage to the body, of whatever severity, caused by a work accident with resulting sick leave of at least 1 day in addition to the day on which the accident occurred and for which the subject received compensation	None	n/a	Duke Health Profile Questionnaire	Positive

Peele & Tollerud (2005)	To be eligible for the injured group, workers must present to the clinic within 72 hours of a work-related injury. To be eligible for the noninjured group, workers must have been free from any work-related injury for the past 12 months	Patient Health Questionaire (PHQ-9) Survey	Positive	Patient Health Questionaire (PHQ-9) Survey	Positive
S Salminen et al. (2003)	If they had been certified by a physician which is a requirement for workers' compensation in Finland	Job content Questionnaire	Positive	12-item General Health Questionnaire	Null
		Harris scale	Positive	None	n/a
Sakurai et al. (2013)	If they suffer a work-related injury which occurred as a result of being at your job or performing your job duties in the past year	Brief Job Stress Questionnaire (BJSQ)	Positive	Brief Job Stress Questionnaire (BJSQ)	Positive
Simo Salminen et al. (2014)	Identified from the database of the National Population Register Centre	None	n/a	"Stress refers to a situation where a person feels tense, restless, nervous, or anxious, or is unable to sleep at night because his/her mind is troubled all the time. Do you feel that kind of stress these days?"	Positive
Tawatsupa et al. (2013)	"In the last 12 months how many serious injuries have you had that were enough to interfere with daily activities and/or required medical treatment?"	None	n/a	Thai cohort survey: "During the last 12 months, how often did you experience high temperatures making you uncomfortable	Positive

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Harnoor Singh
Academic Vita

EDUCATION:

The Pennsylvania State University, University Park, PA
Bachelor of Science in Biology Schreyer Scholar

Expected graduation: May 2017

RESEARCH EXPERIENCES:

Penn State University Park, Dr. Conroy **November 2015-Present**

- Researched in a kinesiology lab with a focus a stress and injury
- Acquired an understanding of database searching, data coding, and meta-analysis techniques
- Publication under review for "Systematic Review of Stress-Related Injury Vulnerability in Athletic and Occupational Contexts"

Penn State University Park, Dr. Newman **March 2015 – November 2015**

- Researched in a psychophysiology lab studying anxiety and hormone levels
- Helped create experiments designs and served as a proctor for these designs

Penn State Schuylkill, Dr. Lee Silverberg **January 2013 – May 2014**

- Researched the synthesis of biochemical compounds with a primary focus on synthesis, structure, spectroscopic properties, and biological activity of compounds
- Publication in Acta Crystallographyca journal was achieved on synthesis of 2,3-Diphenyl-2,3-di-hydro4H-pyrido[3,2-e][1,3]thiazin-4-one
- Acquired an understanding of crystallization, column chromatography, and other organic chemistry based techniques

Penn State Schuylkill, Dr. Darcy Medica **October 2013 – August 2014**

- Researched bio-environmental science with a primary focus on experimenting with mosquitoes in order to find repellency effects in natural insecticides
- Created experimental designs allowing for a strong understanding of the scientific method
- Acquired an understanding of population creation and control of mosquitoes/mice

Costa Rica Biological Research Station, Dr. Diego Dierick **July 2014**

- Completed field study on watersheds and carbon fluxes between rivers with/without an inter-ground water basin source
- Acquired an understanding of field work

WORK AND LEADERSHIP:

Resident Assistant, *Resident Assistant* **July 2015 – June 2016**

- Interacted with residents and helped create community on the floor

The Learning Center, *Tutor* **December 2013 – May 2014**

- Provided additional academic support by facilitating study groups to better meet the needs of students

The Honor Society, *President* **Fall 2013- Spring 2014**

- Provided foundation for the current executive board by creating goals, plans, and a mission statement
- Interacted with the local community through academic debates, forums, and news articles

Raw Aesthetic Movements, *Vice President* **Spring 2015-Spring 2016**

- Organization involved in spreading love for expression through hip hop dance styles
- Engaged with local community by teaching workshops, and having performances