DISSERTATION

THE EFFECTS OF PERSONALITY AND SOCIAL DETERMINANTS OF HEALTH ON SPORTS-RELATED CONCUSSION RISK: AN EXAMINATION OF SYMPTOM REPORTING, CONCUSSION INCIDENCE, AND RETURN TO PLAY

Submitted by

Megan Gardner Weishaar

Department of Psychology

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Doctoral Committee:

Advisor: Bradley T. Conner

Mark A. Prince
Deana B. Davalos
Jaclyn A. Stephens

ABSTRACT

THE EFFECTS OF PERSONALITY AND SOCIAL DETERMINANTS OF HEALTH ON SPORTS-RELATED CONCUSSION RISK: AN EXAMINATION OF SYMPTOM REPORTING, CONCUSSION INCIDENCE, AND RETURN TO PLAY

Sports-related concussion (SRC), a form of mild traumatic brain injury (TBI) that occurs during sport participation or recreation, has emerged as a public health concern among adolescent athletes in the United States in recent decades due to increasing knowledge of high incidence rates. Important factors such as return to play (RTP) timeline and symptom reporting behaviors have been shown to contribute to SRC incidence. As a result, recent research has called for work that identifies a parsimonious group of variables that are salient in identifying athletes most at risk of outcomes such as early RTP, higher SRC incidence, and symptom nondisclosure. A small body of work has established that certain personality characteristics and social determinants of health are associated with these SRC outcomes. However, few specific personality and social determinants of health factors have been examined, few studies have investigated predictors of SRC incidence and RTP outcomes specifically, and a small number of these studies have investigated these research questions among adolescent athletes despite high rates of athletic participation and SRC incidence. The current study sought to expand previous work to further elucidate relations between a myriad of personality and social determinants of health predictors, and time to RTP, diagnosed SRC, and symptom reporting outcomes among adolescent athletes (N = 317, ages 14-19). The ultimate goal of the study was to identify

personality and social determinants of health factors most salient in SRC outcomes to inform practical tailoring of prevention and intervention strategies.

Participants were adolescents who were currently enrolled in high school or college or were enrolled in high school within the past calendar year, participated in a high school or club sport in the past year, and either denied sustaining a diagnosed SRC in the past year (N = 156) or endorsed sustaining a diagnosed SRC in the past year (N = 161). Data were collected through a one-time online survey that took participants 20-30 minutes to complete. Participants were compensated via an online gift card or course credit. Recruitment methods included outpatient medical clinics, high school athletic trainers, sports gyms and tournaments, Twitter, and university research pools. Analyses included a series of Cox proportional hazards and logistic regression models investigating associations between personality and social determinants of health predictors and time to RTP, diagnosed SRC incidence, and symptom reporting outcomes (i.e., honesty and comfort in symptom reporting). Overall, study results bolstered the conclusion that 1. Personality and social determinants of health factors are important in predicting SRC outcomes and 2. The relations between personality and SRC outcomes are highly nuanced, depending upon specific personality facets, outcome, and sample characteristics. Study results inform athletes, peers and family of athletes, coaches, athletic trainers, and other medical professionals about which personality and social determinants of health variables are most salient in SRC risk, thus informing prevention and intervention efforts for SRC such that they can be more personalized and tailored at the individual, environmental, and systems levels.

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DEDICATION

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INTRODUCTION

Sports-Related Concussion

Sports-related concussion (SRC), a specific form of mild traumatic brain injury (TBI) that occurs during sport and recreation-related activities at a variety of competition levels, has emerged as a growing public health concern in the United States in recent decades (Bryan et al., 2016). SRC is a complex pathophysiological process that results in temporary disruption of brain function and can occur from both direct and indirect forces on the brain, including head-to-head, head-to-ball, and head-to-ground contact as well as force to the body that indirectly impacts the brain (Edwards & Bodle, 2014; Harmon et al., 2019; Khurana & Kaye, 2012; Kimbler et al., 2011). Notably, newer estimates have concluded that between 1.1 and 1.9 million sports-and recreation-related concussions occur every year in children and adolescents in the United States, with 400,000 of these injuries occurring in high school athletes (Bryan et al., 2016; Harmon et al., 2019). While recent research underscores significant SRC incidence among youth, actual SRC incidence is largely unknown and potentially even higher due to estimates that as many as 50% of SRCs remain undiagnosed for a variety of reasons (Asken et al., 2016; Register-Mihalik et al., 2013). High incidence rates of SRC among youth, including both diagnosed and undiagnosed SRC, highlight the importance of continued efforts to understand factors that contribute to these injuries.

Concussions in general, including those sustained during sport or recreation, represent the less severe end of the TBI spectrum, with complicated mild, moderate, and severe TBI often resulting in more complex, severe, and long-lasting impacts to overall health and wellbeing (Scholten et al., 2015). Individuals sustaining a concussion are expected to make a full recovery

from a neuropsychological perspective; however, concussions often result in impactful and heterogeneous symptoms and outcomes including cognitive, behavioral, emotional, physical, and sleep sequalae (Fineblit et al., 2016; Harmon et al., 2019; Howell et al., 2019; Takagi-Stewart et al., 2022; Wilmoth et al., 2019). Common symptoms of SRC that often initiate soon after injury include headache, dizziness, nausea, sleep disturbance, sensitivity to light and/or noise, fatigue, balance problems, irritability, and memory and concentration difficulty (Dillard et al., 2017; Hanson et al., 2014). Recent studies have demonstrated impactful outcomes of sports-related concussion on mental health and wellbeing, including one study that found that concussion history was significantly and positively associated with increased likelihood of experiencing suicidal ideation, making a suicide plan, and suicide attempt among youth, underscoring the importance of proper identification, management, and support throughout concussion recovery (Ziminski et al., 2022).

Concussion symptoms among youth typically take longer to resolve than in adults (Fineblit et al., 2016; Howell et al., 2019; Lumba-Brown et al., 2018; Tiwari et al., 2022; Wilmoth et al., 2019). Most youth can be expected to recover within one month post-injury with symptoms lasting longer than this considered much less common and termed “persistent post-concussive symptoms” or “prolonged post-concussive symptoms” (Simpson et al., 2021). Prolonged symptoms among youth are most commonly headache and fatigue, followed by irritability and depression (Chandler et al., 2022). Notably, acute injury characteristics have been found to impact symptoms post-concussion; for example, the effect of injury severity on symptoms and functioning has notable impact within weeks to months following injury (McNally et al., 2013). However, the influence of acute injury characteristics on symptoms diminishes over time (McNally et al., 2013; Simpson et al., 2021). Research has concluded that

preinjury and demographic factors, such as pre-existing depressive and anxious symptoms, higher fear of pain, Attention-Deficit Hyperactivity Disorder (ADHD), learning difficulties, lower cognitive ability, history of concussion, prolonged rest, disrupted sleep, family and social stressors, Hispanic ethnicity, lower socioeconomic status (SES), and female sex assigned at birth are more predictive of prolonged SRC symptoms than are attributes of the injury itself (Arnold et al., 2022; Chizuk et al., 2022; Howell et al., 2019; Lumba-Brown et al., 2018; Martin et al., 2022; Simpson et al., 2021; Stewart et al., 2022). This recent research encourages researchers and healthcare professionals to acknowledge and consider these preinjury factors and demographic characteristics during concussion recovery and symptom management.

Symptom Reporting

The primary methods by which medical professionals and athletic trainers ascertain whether an athlete has sustained an SRC are symptom reporting, neuropsychological testing scores compared to baseline, and neurological and balance testing (Khurana & Kaye, 2012). Research evidence concludes that the assessment of concussion should be multifaceted (i.e., clinical exam, self-reported symptom checklist, postural assessment, and neurocognitive testing) and include several measures to ascertain the extent of injury impact for each individual (Dessy et al., 2017). Importantly, Harmon and colleagues (2019) concluded that symptoms are the most sensitive indicator of SRC at this time, underscoring the importance of attaining accurate symptom report in diagnosis and treatment of SRC. There are several symptom checklists commonly used by medical professionals, and symptom checklists in general have remained a standard instrument used to evaluate concussions by medical professionals due to their ability to evaluate a wide variety of symptoms, symptom severity, and track progression through serial administrations over time (Dessy et al., 2017). One would expect that an athlete who is officially

diagnosed with an SRC will experience several of the primary concussion-related symptoms and will demonstrate worse performance on neuropsychological testing measures within days to weeks of injury compared to baseline (Khurana & Kaye, 2012).

Symptom reporting by youth athletes often occurs through verbal reports to an athletic trainer or medical professional and may be assessed more formally through measures such as the Post-Concussion Symptom Scale (PCSS; Lovell et al., 2006), Standardized Assessment of Concussion (SAC; McCrea et al., 1997), Standard Concussion Assessment Tool (SCAT-5; (Echemendia et al., 2017), and the computerized neurocognitive testing (e.g. Immediate Post Concussion Assessment and Cognitive Testing (ImPACT; Iverson et al., 2003) upon intake at an outpatient concussion clinic, in an athletic training office, or via sideline assessment depending upon the specific measure and the setting (Dessy et al., 2017). With these methods, symptom reporting is greatly influenced by the athlete's own assessment and self-report of their symptoms, thus misreporting of symptoms, also referred to as underreporting of symptoms or symptom non-disclosure, can happen through a variety of avenues. The most cited reasons for athletes misreporting their symptoms following a sports-related head impact are 1) lack of education regarding symptoms of SRC that subsequently impact identification of symptoms within themselves, 2) low self-awareness regarding physical and psychological symptoms which is often impacted by the injury itself, and 3) a desire to continue playing and perhaps intentionally misreport symptoms (Asken et al., 2016). A desire to continue playing as a factor associated with symptom misreporting has been cited as influenced by a number of factors: not wanting to let teammates down, anticipated loss of athletic ability during a recovery period, attitudes of peers and coaches, broader social implications, and messages communicated from sports culture at large (Bretzin et al., 2022; Cicero et al., 2022; Corman et al., 2019; Craig et al., 2020; Ernst &

Kneavel, 2022; McLeod et al., 2022). Asken and colleagues (2016) noted these reasons as the likely contributors underlying the estimate that 50% of SRCs remain undiagnosed. Thus, several recent studies have attempted to identify additional factors that may be associated with, or contribute to, symptom reporting behaviors.

All 50 states in the United States currently hold mandates to provide concussion education to athletes and coaches, demonstrating an increase in access to concussion-related information over the past decade (Cicero et al., 2022). Structured educational programs created for youth athletes, such as Heads Up and Sports Legacy Institute Community Educators (SLICE) program include videos, handouts, and presentations by experts. Several studies have assessed the degree to which there are gaps in knowledge about the symptoms of SRC due to lack of education being initially cited as a primary factor contributing to symptom misreporting; however, these studies have concluded with mixed results (Kroshus et al., 2015a; Lininger et al., 2017; McAllister-Deitrick et al., 2020; Register-Mihalik et al., 2013). Some studies have concluded that increased knowledge is related to increased symptom reporting (Anderson et al., 2021; Rawlins et al., 2020), although related findings underscored the importance of context. Results from one study demonstrated that greater SRC symptom knowledge was related to greater symptom reporting *during practice* for those eventually diagnosed with SRC and those who experienced a "bellringer", with knowledge positively influencing symptom reporting *during matches and games* just for those experiencing a "bellringer" (Register-Mihalik et al., 2013). These gaps in knowledge have been shown to vary by individual characteristics like sex assigned at birth, with female-identified athletes displaying more symptom knowledge than male-identified athletes in samples of high school and college individuals (McAllister-Deitrick et al., 2020; Wallace et al., 2017). Other studies have found that gaps in knowledge do exist among

individual youth and collegiate athletes; however, these gaps in knowledge did not ultimately relate to reporting behavior in these studies (i.e., O'Connor et al., 2020). Following a qualitative analysis of motivations for collegiate football athlete symptom reporting patterns, Lininger and colleagues (2017) concluded that these athletes were largely informed about the symptoms of SRC, including potential prolonged effects; however, these researchers determined that greater knowledge regarding SRC symptoms was not related to increased frequency of reporting. In fact, these researchers concluded that prevention and intervention efforts focused entirely on SRC symptom education would be missing a piece of the puzzle.

More recent studies have supported the idea that increased educational efforts may not be enough to increase symptom reporting (Anderson et al., 2021; Kroshus et al., 2015a; McAllister-Deitrick et al., 2020), as evidenced by implementation of SRC educational initiatives for youth over the past several years with continued large proportions of athletes assumed to be misreporting symptoms. For example, one study found that 33.2% of former collegiate athletes reporting misreporting or failing to disclose symptoms of SRC at least once in their athletic career (Kerr et al., 2016). Importantly, a study by Kroshus and colleagues (2015a) revealed that pre-season reporting knowledge did not predict in-season symptom reporting, but pre-season *intention* to report symptoms did predict in-season symptom reporting in a sample of collegiate hockey athletes. Ultimately, a systematic review concluded that educational initiatives increased knowledge of concussion by about 34%, but this knowledge did not seem to translate into symptom reporting behavior (Cicero et al., 2022; Craig et al., 2020).

Factors found to be related to symptom reporting behavior include individual-level factors such as sex assigned at birth (Anderson et al., 2021; Kerr et al., 2016; McAllister-Deitrick et al., 2020; Wallace et al., 2017), race (Wallace et al., 2020a), athlete identity (Kroshus et al.,

2015c; Lininger et al., 2017; Wayment et al., 2019), academic identity (Wayment et al., 2019), conforming to more stereotypically masculine gender norms (Kroshus et al., 2017), number and type of symptoms experienced, self-efficacy in symptom reporting (Rawlins et al., 2020), diagnosed SRC history (Anderson et al., 2021; O'Connor et al., 2020), perceived behavioral control, and specific motivations and attitudes towards reporting (Beidler et al., 2018; Rawlins et al., 2020; Register-Mihalik et al., 2013). Specifically, it has been established that male-identified athletes tend to underreport symptoms more frequently (Anderson et al., 2021; Kerr et al., 2016; McAllister-Deitrick et al., 2020; Wallace et al., 2017), Black high school athletes tend to report symptoms less frequently than White high school athletes (Wallace et al., 2020a), and those with a negative or unfavorable attitude towards reporting tend to underreport symptoms (Register-Mihalik et al., 2013).

Regarding motivations, it has been established that specific motivations for underreporting symptoms include not believing the symptoms are serious enough (Beidler et al., 2018), not identifying symptoms as those of an SRC, not wanting to leave the game/practice, and not wanting to let the team down (Kerr et al., 2016). Wallace and colleagues (2017) noted that adolescent athletes also seem to differ in the specific motivations for symptom reporting based on self-identified sex, with male-identified individuals less likely to report for a variety of reasons including: they thought their coach would get mad, their teammates would think they are weak, their coach would think they were weak, their parents would be upset, they did not want to miss a game, they did not want to lose playing time, the team was going to play-offs when they sustained an injury, and they did not want to let their team down. In a recent study examining the role of SES, race, and access to an athletic trainer among a college student sample, none of these predictors were significantly associated with symptom nondisclosure (Wallace et al., 2022). This

finding highlights the potential influence of age (i.e., high school vs. college samples) and supports the idea that greater access to resources in a college athletic setting can help mitigate symptom nondisclosure.

Factors related to symptom reporting that are influenced by the environment include pressure to continue playing from parents (Kroshus et al., 2015b), fans (Kroshus et al., 2015b), coaches (Anderson et al., 2021; Kroshus et al., 2015b; Lininger Monica R. et al., 2017), and teammates (Bonfilio & Martin, 2019; Kroshus et al., 2015b), engagement in sports with a high SRC risk (Anderson et al., 2021), specific sport played (Kerr et al., 2016), descriptive norms (Kroshus et al., 2015c), social support (Baugh et al., 2014), and trust in the athletic department, coach, and medical professionals (Baugh et al., 2020). Specifically, individuals experiencing pressure to continue playing when potentially symptomatic from all 4 groups at once – parents, fans, teammates, and coaches – are at increased likelihood of underreporting symptoms and continuing to play while symptomatic (Kroshus et al., 2015b). One study also concluded that social pressures influence symptom reporting behaviors and that this can differ by sport (McLeod et al., 2022). Additionally, communication and expectation about concussion recovery, and potential social implications influence symptom reporting as well. Further, football athletes tend to report symptoms less frequently (Kerr et al., 2016), while those with trust in medical professionals, coaches, and athletic departments and those that believe that most other athletes report their symptoms, report their own symptoms more frequently (Baugh et al., 2020; Kroshus et al., 2015c).

While not frequently investigated in the literature to date, the extent to which an athlete feels comfortable reporting or disclosing symptoms is an influential factor in symptom disclosure as well (McGlone, 2021.; Weber Rawlins et al., 2021). Specifically, one study found that Air

Force Academy Cadets were more likely to agree to seek medical attention following injury if they felt comfortable disclosing symptoms to at least one party (Weber Rawlins et al., 2021). Additionally, in a study of female-identified athletes, comfort in disclosing information to coaches depended on the specific topic and the identity of the coach (McGlone, 2021). This study found that just 74% of participants felt comfortable disclosing details about injury to coaches, indicating that comfort may play a critical role in symptom reporting and can be influenced by various individual and systems-level factors.

Personality has been added to the list of potentially influential variables in the relations between individuals and SRC outcomes, like SRC incidence, as well as behaviors that may lead to increased SRC risk like return to play (RTP) and symptom reporting (Beidler et al., 2017, 2021; Liebel et al., 2020, 2021; Webbe & Ochs, 2007; Weishaar et al., 2022a, 2022b). Two studies to date have explicitly investigated the relations between personality and symptom reporting behavior (Callahan et al., 2022; Merritt et al., 2015). Merritt and colleagues (2015) found that higher neuroticism and lower agreeableness were associated with increased symptom reporting among collegiate athletes. Additionally, one study has investigated the relations between sensation seeking and symptom reporting behavior in collegiate athletes, finding that those high in sensation seeking were more likely to continue playing while symptomatic, but no associations were found between sensation seeking and intention to disclose symptoms, self-removal from play due to concussion symptoms, and disclosing all symptoms at time of injury (Callahan et al., 2022). Other studies investigating personality and additional SRC outcomes like SRC incidence, heading frequency in soccer, and RTP have attempted to link personality to these outcomes without explicit consideration for symptom reporting (Beidler et al., 2017, 2021; Liebel et al., 2020; Webbe & Ochs, 2007; Weishaar et al., 2022a, 2022b). It is possible that the

results of these studies were impacted by the influence of symptom reporting in the relation between personality and SRC outcomes. For example, a recent study found that experience seeking, attentional impulsivity, and motor impulsivity were linked to earlier RTP in a college sample, while conscientiousness was associated with later RTP (Weishaar et al., 2022a). While these results are valuable and informative, the influence of personality on RTP timeline may be influenced by differences in symptom reporting behavior among individuals with higher levels of certain personality traits.

In recent years, several studies have emerged that use various theories to help explain symptom reporting behavior including Theory of Planned Behavior (Carpenter et al., 2020), Integrated Behavioral Model (Milroy et al., 2020), and socioecological models like Brofenbrenner's Socio-ecological Model (Cicero et al., 2022; Corman et al., 2019). Models of planned or integrated behavior include factors such as beliefs about consequences of a behavior, beliefs about others' expectations regarding a behavior, and beliefs about one's ability to perform a behavior (Cicero et al., 2022). However, these models did not demonstrate that these factors are significantly associated with symptom reporting outcomes. Self-efficacy is the only factor that has emerged as significantly associated with intention to report symptoms, demonstrating flaws in the utility of such models and resulting in several criticisms; criticisms of behavioral models include these models' potential over-focus on individual-level factors in predicting behavior and intention to report symptoms as an outcome rather than actual reporting of symptoms. Socioecological models emerged as useful in predicting symptom reporting behavior for their consideration of individual and more systemic influences on an individual's behavior (Cicero et al., 2022; Corman et al., 2019). However, socioecological models have been criticized for their reliance on higher level constructs, a high number of levels of influence, and lack of

practical utility. Cicero and colleagues (2022) present another type of behavioral model aimed at increasing practical utility by providing actionable steps that consider both the individual athlete and forces in their environment. This model of behavior analysis encourages intervention for sports-related concussion symptom reporting to include increased reinforcement and reduced punishment for symptom reporting. Overall, there is a call for more practical prevention and intervention strategies that are informed by both individual and environmental factors (Carpenter et al., 2020; Cicero et al., 2022).

Return to Play

Following diagnosis of SRC, many athletes are given guidelines to follow for RTP by a trained medical professional based on factors such as symptoms at time of injury (Lumba-Brown et al., 2018). In general, gradual, stepwise return to activity is advised. Return to activity plans are generally personalized to the individual such that athletes are encouraged to actively engage in activities that do not exacerbate symptoms, with increasing involvement in activity and contact, if applicable, throughout the course of recovery. In the case of prolonged or lingering symptoms, neuropsychological assessment and neuroimaging may be used to assess for longer term effects and progress towards return to baseline functioning before an athlete can progress in RTP. The consequences of failing to report symptoms throughout the RTP process has been found to lead to specific adverse consequences, including longer required recovery periods if additional injury is sustained and greater symptom severity upon current and subsequent injury (Barnhart et al., 2021). Recent studies have also highlighted the importance of continued assessment and encouragement of symptom reporting up to several days after an impact to the head, as 24.3% of athletes in one study experienced delayed onset of symptoms like posttraumatic migraine and sleep impacts (Eagle et al., 2022; Trbovich et al., 2023).

Additionally, studies have encouraged improved interdisciplinary communication for youth concussion due to a lack of communication and coordination of care being cited as a cause of premature RTP (Tiwari et al., 2022). The proper management of concussion symptoms is important for the course of recovery, prevention of prolonged symptoms in youth athletes, and timely return to activity, with proper management of concussion contingent upon proper identification of symptoms and diagnosis (Lumba-Brown et al., 2018).

One study found that average time to clearance for unrestricted RTP was 11 days for high school athletes, although actual RTP date was unknown in this study (Covassin et al., 2021). Other studies found athletes reported time to full clearance to RTP between several days and one week post-injury among high school athletes using ecological momentary analysis (EMA) methods (Wiebe et al., 2022). Median RTP was 22 days in another study of adolescent athletes who were evaluated within one week of injury (Worts et al., 2022). Additionally, among a sample of college students, median RTP following SRC was 3 weeks (Weishaar et al., 2022a). Altogether, a review paper concluded that 80% of studies that have investigated RTP timeline have found that individuals RTP within 21 days of their concussive injury (Wait et al., 2022). These timelines are important because there is a period of post-concussive vulnerability wherein if athletes sustain a second SRC during a 7–10-day period post-injury, they may be at even greater increased risk of adverse outcomes (Khurana & Kaye, 2012; McCrea et al., 2009). This period of post-concussive vulnerability underscores the importance of gradual, stepwise, individually tailored RTP such that athletes gradually increase physical demand and engagement with contact as symptoms resolve at each level (Harmon et al., 2019). Additionally, it has been established that history of SRC is related to increased risk of future SRC. While this risk exists even if athletes are fully recovered upon RTP, risk is greatly increased when athletes continue

playing or RTP when they are not recovered from their current injury. RTP trajectory is deemed complete when a medical professional officially "clears" the athlete to return to full sport activity. Failing to accurately diagnose or identify an SRC may lead to premature clearance to full RTP, increased vulnerability to subsequent injury, and increased symptom burden (Dessy et al., 2017).

Edwards and Bodle (2014) noted the importance of recognizing the ambiguity inherent in RTP Protocol such that there is a necessary balance of keeping an athlete out of activity long enough to heal, while also allowing them to assist their own recovery by re-engaging in sport and other activities. While premature RTP can be detrimental, so can prolonged cognitive and physical rest (Gupta et al., 2019). Recent studies have highlighted the importance of clear expectations for recovery post-concussion and connection to supportive social environments, as adolescent athletes have reported social implications as a determinant of recovery and RTP decisions following concussion (McLeod et al., 2022). Other factors, such as history of concussion, history of migraines, individual sport participation, and number of severity of symptoms significantly predicted prolonged recovery in one study of collegiate athletes (Wang et al., 2022), and factors such as learning disorder or ADHD have been found to lead to prolonged return to activity among pediatric patients (Martin et al., 2022). Factors such as male sex assigned at birth and more frequent assessment have contributed to earlier RTP (Broglio et al., 2022). Importantly, there is also a degree of personal and family choice to RTP following medical clearance, with youth athletes and their families making their own decisions about when to fully reintegrate into sport. Emerging studies have highlighted the importance of psychosocial factors in RTP, including fear, mood symptoms, stress, social support, pressure, and sense of identity (van Ierssel et al., 2022). These studies call for further investigation of the nuanced

psychosocial factors that may impact RTP timeline. Symptom reporting and RTP guidance and timeline are pivotal points in the recovery process for SRC. With as many as 44 million youth participating in sports every year in the United States, identifying factors that contribute to accurate symptom reporting and RTP timeline will help prevent potentially adverse consequences of SRC (Asken et al., 2016; Bryan et al., 2016).

Personality

Big Five and Health Risk Behaviors

The Big Five factors of personality, openness to experience, conscientiousness, extraversion, agreeableness, and neuroticism, have been investigated in relation to health risk behaviors (Beidler et al., 2017; Carvalho et al., 2020; Nicholson et al., 2005; Poropat, 2009; Vollrath & Torgersen, 2002; Weishaar et al., 2022a, 2022b). These five personality factors are traits, meaning that individuals fall along a continuum ranging from low levels of each personality trait to higher levels of each personality trait. Table 1 includes definitions of each personality trait. In general, extraversion and openness to experience are seen as personality factors positively associated with risk, while agreeableness and conscientiousness are seen as protective personality factors (Beidler et al., 2017; Nicholson et al., 2005; Vollrath & Torgersen, 2002). The role of neuroticism often depends on the specific health risk behavior in question (Vollrath & Torgersen, 2002). Regarding sport, research has concluded that higher extraversion and openness to experience, and lower conscientiousness and neuroticism are associated with increased risky sport participation (Tok, 2011).

Table 1: Big Five Personality Traits

Big Five Personality Trait	Definition
Openness to Experience	Curiosity, independence, and a variety of interests
Conscientiousness	Hardworking, goal-oriented, and organized
Extraversion	Social expressiveness and assertiveness
Agreeableness	Cooperative and trustworthy
Neuroticism	Prone to negative or unstable emotions

Impulsivity and Health Risk Behaviors

Impulsivity, or a tendency to act in a rapid, unplanned manner, with more concern for immediate reward than long-term consequences, has also been a personality factor often investigated for its role in health risk behaviors, with most studies concluding that higher levels of impulsivity are related to more engagement in a variety of health risk behaviors (Chambers & Potenza, 2003; Dick et al., 2010). Impulsivity as an independent construct has not been investigated in relation to sport as frequently as sensation seeking; however, impulsivity has shown positive relations with sport participation and injury in general (Thomson & Carlson, 2014; Weishaar et al., 2023b).

Sensation Seeking and Health Risk Behaviors

Sensation seeking, or the tendency to seek out novel experiences and the associated willingness to take risks for those experiences (Zuckerman, 2007), has been investigated for its role in a host of health risk behaviors, including risky sex (Donohew et al., 2000), substance use (Wagner, 2001), crime (Mawson et al., 1996), and suicidal behavior (Kentopp et al., 2021). Most of these studies have concluded that sensation seeking plays a significant role in contributing to greater risk in these domains. Engagement in sport, primarily extreme sport, has been positively associated with sensation seeking such that adolescent and adult individuals higher in sensation

seeking also participate more frequently in extreme sports as well as sustain more injuries while engaging in these activities (Bouter et al., 1988; Diehm & Armatas, 2004; Kopp et al., 2016; Ruedl et al., 2012; Weishaar et al., 2023b). Many of these studies have focused on the role of sensation seeking in sports such as skiing and snowboarding, although a few studies have investigated the role of sensation seeking in a host of extreme sports (e.g., Weishaar et al., 2023b).

Personality and Sports-Related Concussion

Relations between personality and SRC is a newly developing line of investigation with a paucity of studies; however, results suggest that personality factors do influence a variety of SRC outcomes (Beidler et al., 2017, 2021; Liebel et al., 2020, 2021; Merritt et al., 2015; Webbe & Ochs, 2007; Weishaar et al., 2022a, 2022b). Most of these studies have been retrospective in nature, have included college athlete or college student samples, and have investigated the outcomes of SRC incidence or history (Beidler et al., 2017, 2021; Weishaar et al., 2022b), RTP timeline (Weishaar et al., 2022a), symptom reporting (Callahan et al., 2022; Merritt et al., 2015), and heading frequency in soccer (Webbe & Ochs, 2007). Liebel and colleagues (2020) recently conducted the first prospective investigation of SRC incidence and found that sensation seeking was significantly associated with greater risk of SRC history and SRC incidence during the study period.

In sum, these studies have found that neuroticism was positively associated with symptom reporting, while agreeableness was negatively associated with symptom reporting (Merritt et al., 2015), agreeableness was positively associated with reporting of multiple undiagnosed concussions (Beidler et al., 2017), openness to experience and neuroticism were positively associated with playing a high-risk SRC sport (Beidler et al., 2017), extraversion was

associated with greater heading frequency in soccer (Webbe & Ochs, 2007) and SRC incidence (Weishaar et al., 2022b), and sensation seeking and impulsivity were positively associated with SRC incidence and history (Beidler et al., 2021; Liebel et al., 2020; Weishaar et al., 2022b) and continuing to play while symptomatic (Callahan et al., 2022). Experience seeking, attentional impulsivity, and motor impulsivity were associated with earlier RTP, while conscientiousness was associated with later RTP (Weishaar et al., 2022a). These findings underscore the importance of considering personality traits in research, treatment, and prevention efforts for SRC.

Social Determinants of Health

Social determinants of health are non-medical factors that influence health outcomes in both positive and negative ways (World Health Organization, 2010). The World Health Organization (2010) recognizes social determinants of health as falling into two broad categories: structural determinants and intermediary determinants. Structural determinants consist of the larger socioeconomic and political context and are also related to one's individual socioeconomic position and intermediary determinants of health. Structural social determinants of health include factors such as macroeconomic policies, social policies, public policies, cultural and societal values, the government, social class, gender, ethnicity, education, occupation, and income. Intermediary social determinants of health include factors such as material circumstances like living and working conditions and food availability, behaviors, and biological factors, as well as psychosocial factors such as early childhood development. Recent studies have found that social determinants of health may be more impactful in health outcomes than lifestyle choices, accounting for as high as 55% of health outcomes across the world. Importantly, these influences are bidirectional and cyclical in nature; for example, if someone

experiences financial disadvantage, they may experience health difficulties due to increased stress and decreased ability to afford adequate medical care. As a result, they may have even further reduced income due to missed work and other related factors. Recent research, summarized below, has emerged noting the impact of social determinants of health in SRC outcomes specifically, although there is a paucity of research in this area (Picha et al., 2022).

Access to Medical Providers/Athletic Trainers

Lack of access to healthcare has been noted as significantly negatively impacting health outcomes, with lack of access deriving from a host of specific problems like bias, cost of care, and geographic location of healthcare facilities (Graves, 2008; Riley, 2012). In a study conducted by Wallace and colleagues (2018), Black high school athletes who had access to an athletic trainer at their high school had significantly more knowledge about concussion than those who did not have access to an athletic trainer. Additionally, in settings where referral networks for SRC care are established, SRC care for Black and White athletes was found to be equitable (Wallace et al., 2021), indicating the importance of access to healthcare in preventing health disparities following SRC. Wallace and colleagues (2022) found no significant associations between high school access to an athletic trainer and current symptom nondisclosure in a sample of college athletes, supporting an overall conclusion that improved access to medical resources in college may contribute to less frequent symptom nondisclosure. Recent studies have also concluded that alternate methods of service delivery, including telehealth services for concussion assessment and treatment, may promote positive outcomes post-concussion and increase access to care across groups (McPherson et al., 2022; Shore et al., 2022).

Race

Race, a social construct based on groupings of physical characteristics such as skin color, is a known predictor of health status (World Health Organization, 2010). Individuals belonging to marginalized racial groups have been shown to experience significantly lower life expectancy. Regarding the general impact of race on health outcomes, research has determined that Black individuals suffer disparities on almost every measure of health, including morbidity, mortality, and access to healthcare (Dressler et al., 2005). Wallace and colleagues (2020a) found that Black high school athletes reported incidences of concussion and "bellringers" significantly less often than White high school athletes. Wallace and colleagues (2020b) also found that high school athletes identifying as Black performed significantly worse on neurocognitive and oculomotor baseline testing than did high school athletes who identified as White. Most recently, one study found that Black youth athletes reached symptom resolution and return to school more quickly than White adolescent athletes (Jimenez et al., 2022). Related to academic performance, students identifying with a race other than White experienced worse outcomes related to academic performance, even with history of fewer concussions than White students (Takagi-Stewart et al., 2022). Black youth and families have also been found to adhere to concussion care recommendations significantly less frequently than White youth and families, highlighting systemic barriers to healthcare equity post-concussion (Mohammed et al., 2022). However, another study found that, among a college athlete sample, race was not significantly associated with symptom nondisclosure (Wallace et al., 2022). These results highlighted the impact of race on SRC outcomes, as well as the nuance inherent in the relations between race and SRC outcomes and the intersection between race and other factors, such as age.

Sex Assigned at Birth

Research on social determinants of health has concluded that divisions in expectations of cisgender individuals falling within the gender binary (i.e., girls and boys; women and men) significantly impact health such that girls and women often experience discrimination that leads to worse health outcomes (World Health Organization, 2010). Conversely, research on sex assigned at birth and SRC has concluded that female-identified athletes engage in more help-seeking behaviors that may be protective against negative health impacts. For example, Wallace and colleagues (2017) found that female-identified and male-identified high school athletes had similar levels of concussion knowledge; however, female-identified athletes reported their SRC symptoms more of often than male-identified athletes. Additional studies have supported the finding that youth athletes assigned male at birth are less likely to report SRC symptoms than those assigned female at birth (Anderson et al., 2021), and that those assigned male at birth RTP more quickly than those assigned female at birth (Broglio et al., 2022). They are also less likely to experience prolonged symptomology (McAllister et al., 2023). Additionally, those assigned male at birth, particularly males with ADHD and/or learning disorder, were more likely to sustain a concussion (Gunn et al., 2022). Those assigned female at birth demonstrated a stronger effect of sleep on symptom reporting such that adolescents assigned female who slept less than five hours prior to ImPACT testing were more likely to meet ICD-10 criteria for post-concussive syndrome than males (Terry et al., 2022). A broad consensus statement concluded that individuals having a sex assigned at birth other than male were underrepresented in concussion-related research in general and that more studies should explicitly include more sex and gender diverse samples (D'Lauro et al., 2022).

Age

Age has been shown to be influential in health outcomes in numerous ways; for example, the influence of various risk factors increases with age across the lifespan (Mehta et al., 2019), while the detrimental health effects for individuals identifying as part of marginalized groups may also be highest among adolescents and young adults (Bränström et al., 2016). Age has been shown to be related to SRC outcomes such as time to presentation at a specialty clinic following SRC, with older adolescents presenting sooner than younger adolescents (Weishaar et al., 2023a). Adolescents have also been found to generally experience more significant neuropsychological deficits post-SRC than adults (Dougan et al., 2014). Additionally, in one study children were more likely to be hospitalized after concussion diagnosis than adolescents, demonstrating a negative effect of younger age on health and recovery post-concussion (Pate et al., 2022). Results from Wallace and colleagues (2022) demonstrated that race, SES, and access to an athletic trainer did not have a significant impact on SRC outcomes in college, while these social determinants of health did have impacts on SRC outcomes in previous studies including high school samples; these findings highlight a potential influence of age on SRC outcomes.

Socioeconomic Status

Social class and SES, to the extent that they are related to standard of living, have been shown to be strong predictors of illness and health (World Health Organization, 2010). Most research in this area has focused on household income as the primary indicator of SES. In general, lower SES has been found to be associated with negative health outcomes throughout the lifespan (Smith, 2007). Regarding SRC specifically, Wallace and colleagues (2020b) determined that high school athletes at higher SES levels performed significantly better on baseline neurocognitive and oculomotor tests than athletes at lower SES levels. Adolescents

from lower SES backgrounds, regardless of broader school-level SES, were also found to be more likely to have sustained a concussion in the past (Sidhar et al., 2022). A study investigating concussion care adherence among youth athletes post-concussion found that privately insured patients and families demonstrated greater adherence to care recommendations than publicly insured or self-pay patients (Mohammed et al., 2022). Further, another study found that concussion clinic patients were more likely to have private insurance, while those presenting to the emergency department after concussion were more likely to be Medicaid-using or self-pay families (Pate et al., 2022).

Experiences of Discrimination

Both prospective and retrospective investigations of experiences of discrimination have concluded that reported experiences of discrimination are related to both physical and mental health outcomes, including depression, anxiety, increased stress, increased blood pressure, asthma, and cancer (Lewis et al., 2015). To date, there is limited research directly investigating experiences of discrimination and impacts on SRC outcomes and related potential health disparities in this domain.

Adverse Childhood Experiences

Adverse Childhood Experiences (ACEs) are harmful, traumatic, or detrimental experiences during childhood or adolescence (Felitti, 1998). ACEs have been linked to a host of health outcomes; specifically, experience of multiple ACEs was significantly associated with negative health outcomes such as physical inactivity, diabetes, substance misuse, cancer, liver and respiratory disease, early initiation of sexual activity, depression, and violence (Hughes et al., 2017). To date, there is limited research regarding ACEs and impacts on SRC outcomes and related potential health disparities in this domain.

Pressure

Pressure to continue playing after a hit to the head, a psychosocial influence on healthcare decisions following injury and therefore a social determinant of health for athletes, is prevalent among athletes with more than one quarter of athletes experiencing pressure from at least once group in the past year, according to one study (Kroshus et al., 2015b). Pressure to continue playing from specific individuals or groups in one's life has been shown to be influential in continued engagement in risky behavior like failure to report symptoms; for example, when youth and young adult athletes experienced pressure to continue playing from coaches following a hit to the head, they were significantly more likely to avoid reporting their SRC symptoms (Anderson et al., 2021). Additionally, athletes were found to be even more unlikely to report symptoms if they experienced pressure to continue playing from 4 total sources: teammates, parents, coaches, and fans (Kroshus et al., 2015b). In a sample of collegiate ice hockey players, perceived pressure from parents, athletic administrators, and sports medicine professionals demonstrated a significant and negative relation to intention to report symptoms (Weber Rawlins et al., 2022). Adolescent athletes have also been shown to RTP prematurely if experiencing undue social influence to return from important people in their lives (McLeod et al., 2022).

Summary and Current Study

In summary, several personality and social determinants of health factors have been noted as significantly associated with health risk behavior engagement, as well as overall health and wellbeing. A small body of recent work has extended these findings to the domain of SRC in an effort to inform prevention and intervention for SRC due to high incidence rates and adverse outcomes of SRC such as increased risk of future injury and prolonged symptom experiences.

This work has established the important role of several personality and social determinants of health factors associated with SRC outcomes such as time to RTP, SRC incidence, and symptom reporting. Ultimately, this small body of previous work called for the continued examination of these factors to contribute to an improved understanding of which factors are most salient in these outcomes and to inform targeted prevention and intervention efforts with an emphasis on practical utility. The current study investigated SRC outcomes that have been deemed influential to athlete health and wellbeing, including time to RTP, SRC incidence, and symptom reporting to expand existing knowledge of these outcomes in an adolescent sample. Additionally, the current study examined personality and social determinants of health predictors of these outcomes that have been noted as influential in SRC-related outcomes or health outcomes more broadly that have not yet been examined in the realm of SRC.

Additionally, it is evident that the role of symptom reporting may be central to the relations between personality and social determinants of health predictors and outcomes like diagnosed SRC incidence and time to RTP. As a result, the current study expanded on previous work by including examination of relations between personality and social determinants of health predictors and symptom reporting outcomes, as well as the preliminary examination of the relations between symptom reporting variables and time to RTP and diagnosed SRC incidence outcomes. Taken together, the overall aim of the current study was to expand knowledge on salient predictors of SRC outcomes with high practical utility that may inform targeted prevention and intervention efforts for adolescent SRC.

Study Variables

Social Determinants of Health Variables.

Demographic Variables. Race, SES, age, sex assigned at birth.

Context Variables. Experiences of discrimination, access to healthcare, pressure to continue playing, ACEs.

Personality Variables. Sensation seeking (experience seeking and risk seeking), impulsivity, and the Big Five factors of personality (conscientiousness, agreeableness, neuroticism, openness to experience, and extraversion).

Symptom Reporting Variables. Honesty in symptom reporting, comfort in symptom reporting.

Study Aims and Hypotheses

The purpose of this study was to explicate relations between personality, social determinants of health, and SRC outcomes, such as time to RTP, diagnosed SRC incidence, and symptom reporting among adolescent athletes. All analyses examined study questions through a cross-sectional research design that included a one-time, retrospective assessment of personality, social determinants of health factors, and SRC outcomes (i.e., time to RTP, diagnosed SRC incidence, and symptom reporting). Cox proportional hazards and logistic regression models were used to examine relations among these variables. Each study hypothesis and aim below include a diagram to assist in the conceptual understanding of statistical models corresponding with study aims and hypotheses. Conceptual diagrams included are not path diagrams or structural equation modeling (SEM) diagrams that display all variables in the model and highlight latent versus observed variables; these diagrams are included to aid in overall understanding of study models.

Time to RTP Outcome

Aim 1. Determine the role of personality in time to RTP among adolescent athletes.

Hypothesis 1. Sensation seeking, impulsivity, and the Big Five factors of personality would significantly predict time to RTP, controlling for lifetime SRC history, suspected SRC, presence of official medical clearance, age, and sex assigned at birth, such that:

- **H1a**. Higher levels of conscientiousness would significantly predict lower risk of RTP ("*later* RTP") among adolescent athletes.
- **H1b**. Higher levels of experience seeking, risk seeking, and impulsivity would significantly predict higher risk of RTP ("*earlier* RTP") among adolescent athletes.

Figure 1. RTP regressed on all personality variables.

Aim 2. Determine the role of social determinants of health in time to RTP among adolescent athletes.

Hypothesis 2. Race, SES, age, sex assigned at birth, experiences of discrimination, access to healthcare, pressure to continue playing while symptomatic, and ACEs would significantly predict time to RTP, controlling for lifetime SRC history, suspected SRC, and presence of official medical clearance, such that:

- **H2a**. Identifying as White, higher SES, older adolescent age, female sex assigned at birth, fewer experiences of discrimination, more access to healthcare, less pressure to continue playing, and fewer ACEs, would significantly predict *later* RTP among adolescent athletes.

- **H2b**. Identifying as a Person of Color, lower SES, younger adolescent age, male sex assigned at birth, more experiences of discrimination, less access to healthcare, more pressure to continue playing, and more ACEs, would significantly predict *earlier* RTP among adolescent athletes.

Figure 2. RTP regressed on all social determinants of health variables.

Diagnosed SRC Incidence Outcome

Aim 3. Determine the role of personality in diagnosed SRC incidence among adolescent athletes.

Hypothesis 3. Sensation seeking, impulsivity, and the Big Five factors of personality would significantly predict diagnosed SRC incidence, controlling for concussion history, age, and sex assigned at birth, such that:

- **H3a**. Higher levels of experience seeking, impulsivity, conscientiousness, extraversion, and neuroticism would significantly predict higher odds of sustaining at least one diagnosed SRC when compared to zero in the past year.
- **H3b**. Higher levels of agreeableness and openness to experience would significantly predict lower odds of sustaining at least one diagnosed SRC when compared to zero in the past year.

Figure 3. Diagnosed SRC regressed on all personality variables.

Aim 4. Determine the role of social determinants of health in diagnosed SRC incidence among adolescent athletes.

Hypothesis 4. Race, SES, age, sex assigned at birth, experiences of discrimination, access to healthcare, pressure to continue playing while symptomatic, and ACEs would significantly predict diagnosed SRC incidence, controlling for concussion history, such that:

- **H4a**. Identifying as White, higher SES, older adolescent age, female sex assigned at birth, fewer experiences of discrimination, more access to healthcare, less pressure to continue playing, and fewer ACEs would significantly predict higher odds of sustaining at least one diagnosed SRC when compared to zero in the past year.
- **H4b**. Identifying as a Person of Color, lower SES, younger adolescent age, male sex assigned at birth, more experiences of discrimination, less access to healthcare, more pressure to continue playing, and more ACEs would significantly predict lower odds of sustaining at least one diagnosed SRC when compared to zero in the past year.

Figure 4. Diagnosed SRC regressed on all social determinants of health variables.

Symptom Reporting Outcomes

Aim 5. Determine the role of personality in symptom reporting (honesty in symptom reporting, comfort in symptom reporting) among adolescent athletes.

Hypothesis 5. Sensation seeking, impulsivity, and the Big Five factors of personality would significantly predict symptom reporting (honesty in symptom reporting, comfort in symptom reporting), controlling for concussion history or lifetime SRC history and suspected SRC, age, and sex assigned at birth, such that:

- **H5a**. Higher levels of experience seeking, conscientiousness, agreeableness, and neuroticism would significantly predict higher odds of reported honesty in symptom reporting.
- **H5b**. Higher levels of risk seeking, impulsivity, openness to experience, and extraversion would significantly predict lower odds of reported honesty in symptom reporting.
- **H5c**. Higher levels of experience seeking, conscientiousness, agreeableness, and neuroticism would significantly predict higher odds of reported comfort in symptom reporting.
- **H5d**. Higher levels of risk seeking, impulsivity, openness to experience, and extraversion would significantly predict lower odds of reported comfort in symptom reporting.

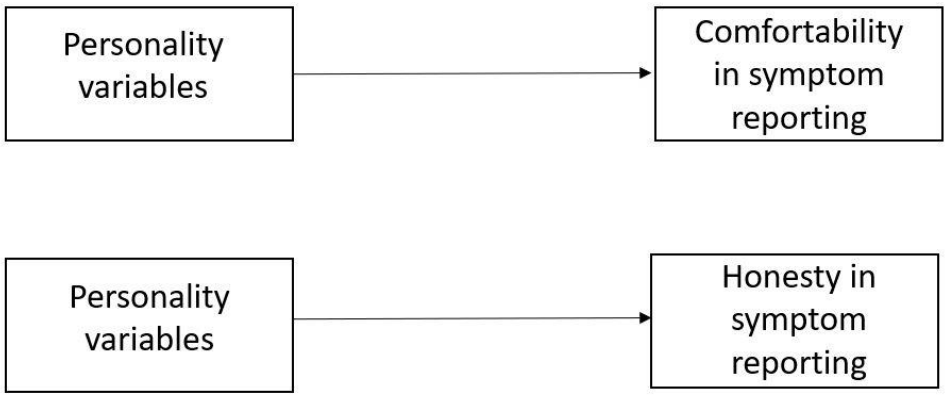

Figure 5. Binary symptom reporting variables regressed on personality predictors in four separate models (injury-specific honesty in symptom reporting, injury-specific comfort in symptom reporting, general honesty in symptom reporting, general comfort in symptom reporting).

Aim 6. Determine the role of social determinants of health in symptom reporting (honesty in symptom reporting, comfort in symptom reporting) among adolescent athletes.

Hypothesis 6. Race, SES, age, sex assigned at birth, experiences of discrimination, access to healthcare, pressure to continue playing while symptomatic, and ACEs would significantly predict symptom reporting (honesty in symptom reporting, comfort in symptom reporting), controlling for concussion history or lifetime SRC history and suspected SRC, such that:

- **H6a**. Identifying as White, higher SES, older adolescent age, female sex assigned at birth, fewer experiences of discrimination, more access to healthcare, less pressure to continue playing, and fewer ACEs would significantly predict higher odds of reported honesty in symptom reporting.
- **H6b**. Identifying as a Person of Color, lower SES, younger adolescent age, male sex assigned at birth, more experiences of discrimination, less access to healthcare, more pressure to continue playing, and more ACEs would significantly predict lower odds of reported honesty in symptom reporting.

- **H6c**. Identifying as White, higher SES, older adolescent age, female sex assigned at birth, fewer experiences of discrimination, more access to healthcare, less pressure to continue playing, and fewer ACEs would significantly predict higher odds of reported comfort in symptom reporting.
- **H6d**. Identifying as a Person of Color, lower SES, younger adolescent age, male sex assigned at birth, more experiences of discrimination, less access to healthcare, more pressure to continue playing, and more ACEs would significantly predict lower odds of reported comfort in symptom reporting.

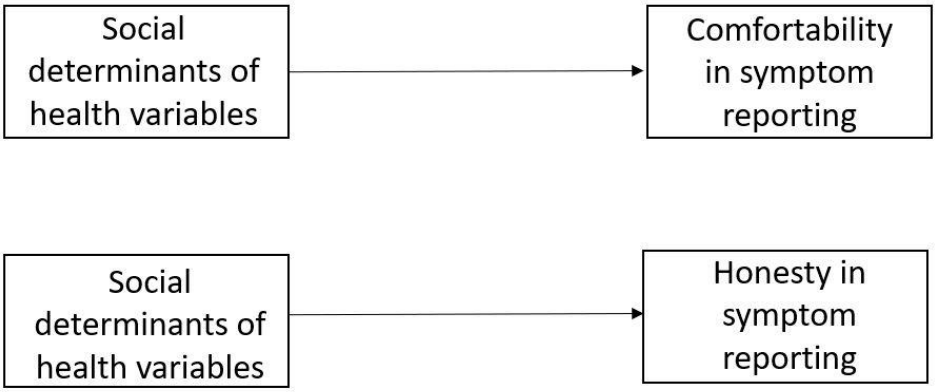

Figure 6. Binary symptom reporting variables regressed on social determinants of health predictors in four separate models (injury-specific honesty in symptom reporting, injury-specific comfort in symptom reporting, general honesty in symptom reporting, general comfort in symptom reporting).

Symptom Reporting Predictors

Aim 7. Determine the role of symptom reporting (honesty in symptom reporting, comfort in symptom reporting) in time to RTP among adolescent athletes.

Hypothesis 7. Honesty and comfort in symptom reporting would both significantly predict RTP, controlling for lifetime SRC history, suspected SRC, presence of official medical clearance, age, and sex assigned at birth, such that:

- **H7a.** Reported honesty in symptom reporting would significantly predict *later* RTP compared to those who report a lack of honesty in symptom reporting.
- **H7a.** Reported comfort in symptom reporting would significantly predict *later* RTP compared to those who report a lack of comfort in symptom reporting.

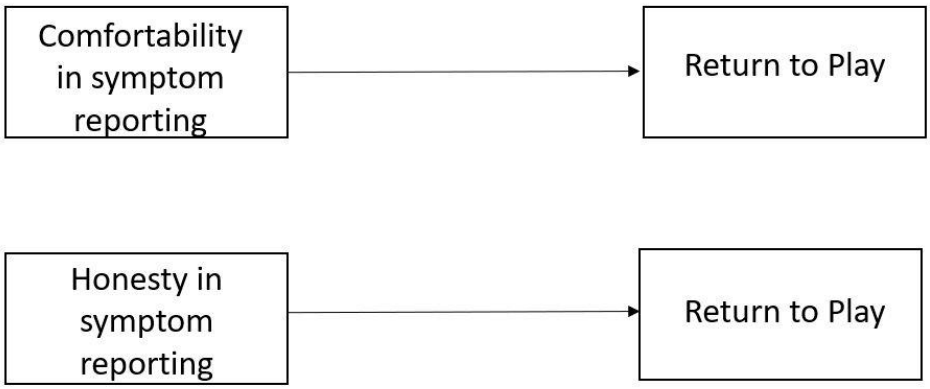

Figure 7. Time to RTP regressed on symptom reporting variables in two separate models (injury-specific honesty in symptom reporting, injury-specific comfort in symptom reporting).

Aim 8. Determine the role of symptom reporting (honesty in symptom reporting, comfort in symptom reporting) in diagnosed SRC incidence among adolescent athletes.

Hypothesis 8. Honesty and comfort in symptom reporting would both significantly predict diagnosed SRC incidence, controlling for concussion history, age, and sex assigned at birth, such that:

- **H8a.** Reported honesty in symptom reporting would significantly predict higher odds of sustaining one diagnosed SRC in the past year when compared to zero, while reported lack of honesty in symptom reporting would significantly predict lower odds of at sustaining one diagnosed SRC in the past year when compared to zero.

- **H8b.** Reported comfort in symptom reporting would significantly predict higher odds of sustaining one diagnosed SRC in the past year when compared to zero, while reported lack of comfort in symptom reporting would significantly predict lower odds of sustaining one diagnosed SRC in the past year when compared to zero.

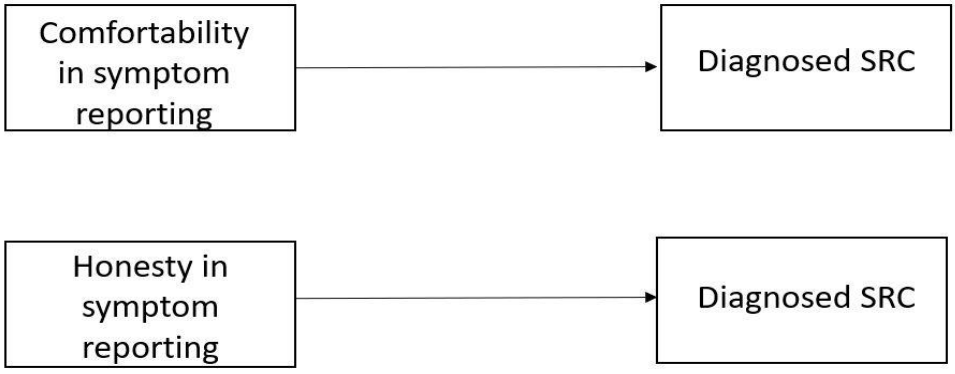

Figure 8. Diagnosed SRC incidence regressed on symptom reporting variables in two separate models (general honesty in symptom reporting, general comfort in symptom reporting).

METHOD

Participants and Procedures

Participants were enrolled in high school or their first year of college (ages 14-19), participated in high school sports during the past year, and denied sustaining a moderate to severe TBI in their lifetime. Additionally, if they recently sustained an SRC, they sustained the SRC more than five days prior to survey completion. Participants represented a variety of sports and positions (N = 317; M_{age} = 17.8, SD = 0.97, female = 55.0%, White racial identity = 81.4%). Sample demographic information is included in Table 2. Participants were recruited from several outpatient specialty clinics, medical clinics, high school athletics programs, sports training camps, youth gyms, Twitter, the Colorado State University Psychology Department listserv, the Colorado State University Research Pool, and the Colorado State University Psychology Subject Pool in the United States. Participant responses were excluded from the study if they completed the survey outside of the United States.

Data collection took place from approximately February of 2022 through March of 2023, following official Colorado State University Institutional Review Board Approval (Protocol #2816). Medical professionals, psychologists, athletic trainers, and coaches who agreed to help recruit through their medical clinics, outpatient clinics, gyms, high school teams, and training camps informed potential participants of the survey and provided them with a study flyer or posted the study flyer in their clinic or training room. Interested individuals followed the QR code on the flyer and had the opportunity to contact the study team via email to receive a link to participate if needed, although none of the participants contacted study personnel.

Table 2: Self-Reported Participant Demographics

	N	%
Assigned Sex		
Female	173	55.0
Male	140	44.4
Intersex	2	0.6
Not Specified	2	--
Gender		
Woman	168	53.3
Man	132	41.9
Non-Binary; Non-Conforming; Transgender	13	4.2
Chose Not to Respond	2	0.6
Not specified	2	--
Race		
American Indian; Alaska Native	6	1.9
Asian	4	1.2
Black or African American	24	7.6
Native Hawaiian; Other Pacific Islander	3	0.9
White	258	81.4
Mixed Race	11	3.5
Another Identity	5	1.6
Chose Not to Respond	6	1.9
Ethnicity		
Hispanic or Latinx	56	18.1
Not Hispanic or Latinx	213	68.9
Another Identity	19	6.2
Chose Not to Respond	21	6.8
Not Specified	8	--

The use of Twitter as a recruitment method included study personnel posting the survey link to a personal Twitter account allowing colleagues and interested participants to retweet the post and gain additional recruitment exposure. Colorado State University Research Pool study

posting included posting the survey flyer to the university website that advertises research studies from a variety of disciplines and recruits Colorado State University students from all majors. Distribution of study flyers to graduate students and faculty in the Colorado State University Psychology Department was also completed during the Spring 2022 semester via email. Snowball recruitment through adolescents and their peers was also encouraged through community data collection methods. All participants who were recruited through the aforementioned methods were compensated with a $10 giftcard. Colorado State University Psychology Subject Pool data collection included recruitment of students in introduction to psychology and research methods courses during the Fall 2022 and Spring 2023 semesters. Participants recruited through the subject pool received course credit for their participation. A list of recruitment sites is included below. Also included below is a table highlighting the number of participants recruited from each site by category (Table 3; i.e., clinics, high school, tournaments/camps, etc.).

Recruitment Methods

Orthopaedic and Spine Center of the Rockies Concussion Clinic

Youth Clinic of Northern Colorado

Wellington High School

Colorado State University Track Training Camp

Mile High Invitational hockey tournament

Vail Valley Cup soccer tournament

Xtreme Altitude Gymnastics gym

Colorado State University Psychology Department listserv

Colorado State University Research Pool

Colorado State University Psychology Subject Pool

Twitter

Snowball recruitment

Table 3: Number of Participants Recruited by Recruitment Method

Recruitment Method	Number of Participants
Medical or Outpatient Clinic	2
High School	2
Training Camps/Tournaments/Gyms	8
Colorado State University Research Pool	1
Colorado State University Psychology Subject Pool	212
Twitter	92

Note: Number of participants recruited from each broad recruitment method category.

Before beginning the survey, participants completed a screening portion of the survey confirming that they met inclusion criteria. If deemed eligible based on the screening questions, participants were presented with the consent form. Through the consent process, they were informed that they may discontinue participation at any time without penalty and that they may skip questions they did not wish to answer. They were also notified of the confidential nature of the survey, including that their information would not be shared with parents, coaches, or their school. A waiver of parental permission was approved by the IRB, meaning that adolescent participants under the age of 18 consented for themselves to participate in the study without parent consent (ages 14-17). Following consent, participants began the survey, which took 20-30 minutes to complete. This survey included all study measures, including personality measures, social determinants of health measures, demographics, a history of sport participation and injury, items about experiences of SRC symptoms, symptom reporting behaviors, and RTP behaviors if

relevant. Athletes completed the study in a location of their choice using a computer, tablet, or smart phone.

Upon completion of the survey, participants were presented with an online debriefing form that included information about the study, contact information for study personnel, and contact information for several mental health resources. Participants were then presented with a link to a second survey. If participants were recruited through community data collection methods, they were asked to enter their email address or phone number in this second survey to receive compensation while also keeping survey participation anonymous. Participants recruited through community resources were also asked to indicate if they were individually interested in the dissemination of the results once data analysis was complete.

A data quality check was conducted six times throughout the data collection period. Data quality checks included examining data for any evident problematic systematic missingness or errors and underrepresentation of certain demographic groups (<10% of the total sample).

Measures

All items and measures are presented in Appendix A.

Personality Measures

Ten Item Personality Inventory. The Ten Item Personality Inventory is a 10-item measure assessing the Big Five factors of personality: openness to experience (M = 10.00, SD = 2.21), conscientiousness (M = 10.17, SD = 2.42), extraversion (M = 8.50, SD = 2.70), agreeableness (M = 9.51, SD = 2.13), and neuroticism (M = 8.52, SD = 2.45; TIPI; Gosling et al., 2003). Each of the Big Five was assessed using two items rated on a seven-point Likert scale ranging from “disagree strongly” to “agree strongly”. Items required participants to rate the extent to which they believe themselves to possess certain traits. All variables were continuous

and normally distributed in this sample. Because this scale includes two-item measures of personality constructs, Pearson correlations are reported for each two-item scale as opposed to internal consistency reliability (mean r = 0.25). Average Pearson correlation for the five two-item scales fell in the acceptable range in this sample.

Barratt Impulsiveness Scale. The Barratt Impulsiveness Scale - Brief was used to assess self-report impulsivity (BIS-Brief; Mathias et al., 2018). The original Barratt Impulsiveness Scale (BIS-11) is a 30-item measure that was originally created and validated for use with adults. The BIS-Brief is an eight-item version of the BIS-11 that has been noted as more applicable to the experiences of youth, includes less participant burden due to a reduced number of items, and has demonstrated good psychometric properties (i.e., "I plan things carefully" and "I do things without thinking"). This eight-item scale was rated using a four-point Likert scale ranging from "rarely/never" to "almost always/always". While the BIS-11 is best interpreted using the scale's second order factors of attentional impulsivity, motor impulsivity, and non-planning impulsivity, the BIS-Brief is best interpreted as one unidimensional total score representing broad self-report impulsivity (Cronbach's $\alpha = 0.80$; M = 17.3, SD = 4.19). Total score impulsivity was continuous and normally distributed, and internal consistency was in the acceptable range in this sample.

Sensation Seeking Personality Trait Scale. Sensation seeking was assessed using the Sensation Seeking Personality Trait Scale (SSPT; Conner, 2022). The SSPT assesses the construct of sensation seeking using two related sub-constructs: experience seeking and risk seeking. Experience seeking (five items; Cronbach's $\alpha = 0.72$) represents the degree to which participants seek out novel or stimulating experiences (M = 19.22, SD = 2.81; e.g. "I think it's important to try as many new things as I can"). Risk seeking (five items; Cronbach's $\alpha = 0.80$) represents the degree to which participants are willing to take risks for such experiences (M =

13.92, SD = 3.90; e.g. “I enjoy participating in unsafe activities”). This 10-item scale was assessed using a five-point Likert scale with answer options ranging from “Strongly Disagree” to “Strongly Agree”. Internal consistency values for these variables were acceptable in this sample. Both experience seeking and risk seeking variables were continuous and normally distributed.

Table 4 includes means and standard deviations for each personality variable by group.

Table 4: Mean and Standard Deviation of Personality Variables by Group

	Total Sample	SRC Sub-Sample	Non-SRC Sub-Sample
Sensation Seeking			
Experience Seeking	19.22 (2.81)	19.06 (2.71)	19.39 (2.91)
Risk Seeking	13.92 (3.90)	14.60 (3.76)**	13.23 (3.94)
Impulsivity			
Total Impulsivity	17.29 (4.19)	17.46 (4.22)	17.12 (4.15)
Big Five			
Openness to Experience	10.00 (2.21)	9.58 (2.14)	10.42 (2.20)***
Conscientiousness	10.17 (2.42)	9.70 (2.41)	10.66 (2.34)***
Extraversion	8.50 (2.70)	8.41 (2.50)	8.60 (2.90)
Agreeableness	9.51 (2.13)	9.50 (2.05)	9.52 (2.21)
Neuroticism	8.52 (2.45)	8.55 (2.37)	8.49 (2.54)

Note: Significant mean differences between SRC and non-SRC group are indicated by * <= .05, ** <= .01, and *** <= .001; Mean (SD). These values reflect the data prior to imputation.
SRC sub-sample are those who reported at least one diagnosed SRC in the past year; non-SRC sub-sample are those who denied diagnosed SRC in the past year.

Social Determinants of Health Items and Measures

Race, Sex Assigned at Birth, Age. Race, sex assigned at birth, and age were each assessed using a single item. Sex assigned at birth was assessed using a list of possible options that participants could check, with the option to write in an identity that was not included in the list. The final sex assigned at birth variable used in analyses was a binary variable with “1” representing female sex assigned at birth and “0” representing male sex assigned at birth (55.0%

female, 44.4% male, 0.6% intersex). Due to those identifying as intersex representing < 10% of the sample, these two participants were excluded from study analyses. Similarly, participants were presented with options to choose to identify their race from a list and were also able to choose to identify their racial identity via a write in option. For analyses, the race variable was collapsed to be a binary variable with "1" representing White racial identity and "0" representing those identifying as a Person of Color due to limited variability in the sample (81.4% White, 18.6% Person of Color). Age was assessed using how many years old the adolescent was at the time of survey completion (14-19). The age variable was included as a left-skewed continuous variable in analyses (M = 17.8, SD = 0.97).

The Family Affluence Scale. The Family Affluence Scale is a four-item measure designed to assess material deprivation and home affluence using items that have been noted as factors that adolescents are both aware of and that are related to health outcomes (FAS-II; Boyce et al., 2006). The FAS-II was used as a measure of SES in this study ("SES"). A total score was calculated by summing FAS-II item scores for a minimum score of zero and a maximum score of nine, with higher scores indicating higher SES. Scores ranging from zero to two indicated low affluence, scores from three to five indicated middle affluence, and scores ranging from six to nine indicated high affluence. Items inquired about family ownership of a vehicle, if an adolescent has their own bedroom, traveling for vacation during the past 12 months, and family ownership of computers. FAS total score was continuous and left-skewed in this study (M = 6.76, SD = 1.86); FAS total score was used as opposed to a three-group categorical variable (low affluence, middle affluence, high affluence) due to low endorsement of low and middle affluence categories. Internal consistency of this scale was poor in this sample (Cronbach's $\alpha = 0.55$), but consistent with previous studies using this scale (i.e., $\alpha = 0.56$; Schnohr et al., 2008). Previous

studies have noted that, despite low internal consistency, good criterion validity contributes to the conclusion that the FAS-II is a suitable measure for SES in studies examining health outcomes in adolescent samples where it is assumed that participants may lack knowledge about parent income (Boyce et al., 2006).

Adverse Childhood Experiences Questionnaire. The Adverse Childhood Experiences (ACEs) Questionnaire is a 10-item measure assessing for adverse or potentially traumatic experiences in childhood, including household mental illness, household incarceration, physical abuse, neglect, divorce, substance misuse, lack of support and love in the family, intimidation and threats, and sexual abuse (Dube et al., 2003; Felitti, 1998). Questionnaire items assessed ACEs by asking participants to indicate "yes" or "no" to aforementioned experiences. ACEs scores range from zero to 10, with higher scores representing endorsement of more categories of ACEs. The total score ACEs variable was right skewed in this sample. The current sample included 52.9% of participants indicating no ACEs and 47.1% of participants indicating one or more ACEs. The ACEs total score variable was included in analyses as a right-skewed and continuous variable ($M = 1.24$, $SD = 1.88$). Internal consistency for ACEs total score was acceptable in this sample (Cronbach's $\alpha = 0.79$).

Experiences of Discrimination. Experiences of discrimination were assessed using a series of items asking participants to indicate if they had ever had an experience of discrimination based on any of their identities, estimated frequency, and an open-ended question that allowed participants to briefly explain these experiences if they chose to do so. Due to both lack of existence of an appropriate measure and survey space constraints, items were created specifically for this study. The experiences of discrimination variable used in study analyses was ultimately operationalized as a binary variable with "1" indicating that a person had experienced

discrimination at some point in their lives and "0" indicating that they had never experienced discrimination (23.7% experienced discrimination, 76.3% did not experience discrimination).

Access to Healthcare. Adolescent access to healthcare included items inquiring about access to healthcare broadly (i.e., "Are you able to go to the doctor when necessary?" "Do you have a yearly check up at the doctor?"). Participants indicated "no" or "yes" to each of these items. Due to both lack of existence of an appropriate measure and survey space constraints, items were created specifically for this study. This variable was ultimately dropped from analysis due to <10% of the participants in the sample indicating that they did not have adequate access to healthcare (2.5% indicating "0" access to medical care).

Pressure to Continue Playing. Pressure to continue playing following a hit to the head was assessed for pressure felt from coaches, parents, siblings, friends, teammates, and fans. (i.e., "Do you feel pressure, or have you felt pressure to continue playing, when you are injured or experiencing symptoms of an injury? Check all that apply"). Due to both lack of existence of an appropriate measure and survey space constraints, items were created specifically for this study. Each individual's ratings of pressure for each party was summed to create a continuous and right-skewed total score variable for overall pressure felt from important people in the participants' life ("pressure"; 0-6, M = 1.75, SD = 1.58, mean r = 0.24).

Table 5 includes information about frequencies and means by group for each social determinants of health variable.

Table 5: Social Determinants of Health Frequencies and Means by Group

	Total Sample	SRC sub-sample	Non-SRC sub-sample
Race			
White	258 (81.4%)	123 (80.4%)	127 (81.4%)
Person of Color	59 (18.6%)	30 (19.6%)	29 (18.6%)
Age	17.8 (0.97)	17.7 (1.15)	17.9 (0.77)
Sex Assigned at Birth			
Female	173 (54.9%)	64 (42.1%)	105 (67.8%)
Male	140 (44.4%)	88 (57.9%)	48 (31.0%)
Intersex	2 (0.7%)	0 (0.0%)	2 (2.2%)
SES Total Score	6.76 (1.86)	6.42 (1.92)	7.19 (1.66)
SES Categorical			
Low affluence (0-2)	8 (2.5%)	4 (2.7%)	2 (1.3%)
Middle affluence (3-5)	63 (20.1%)	41 (27.1%)	20 (12.9%)
High affluence (6-9)	243 (77.4%)	106 (70.2%)	133 (85.8%)
Experiences of Discrimination			
Yes	75 (23.7%)	34 (22.2%)	39 (25.0%)
No	242 (76.3%)	119 (77.8%)	117 (75.0%)
ACEs Total Score	1.24 (1.88)	1.41 (1.96)	1.04 (1.74)
Pressure	1.75 (1.58)	2.08 (1.58)	1.41 (1.51)
Parent(s)	88 (28.3%)	48 (32.2%)	37 (24.0%)
Sibling(s)	33 (10.7%)	17 (11.6%)	14 (9.0%)
Coach(es)	151 (47.9%)	81 (52.6%)	65 (41.7%)
Friends	56 (18.2%)	38 (26.2%)	15 (9.7%)
Teammates	143 (45.7%)	82 (54.3%)	55 (35.7%)
Fans	84 (27.1%)	52 (35.4%)	31 (20.0%)
Access to Healthcare			
No access	8 (2.5%)	2 (1.4%)	4 (2.6%)
50% access to care	26 (8.2%)	16 (10.4%)	10 (6.4%)
100% access to care	283 (89.3%)	135 (88.2%)	142 (91.0%)

Note: Race, sex assigned at birth, experiences of discrimination, access to healthcare, and a categorical version of the SES variable are included in the table as categorical variables with frequency of endorsement included for each variable category followed by percent endorsement in parentheses. SES total score (0-9), ACEs total score (0-10), and pressure to continue playing (0-6) are scales with higher numbers indicating higher SES, higher ACEs, and pressure felt from more groups in one's life,

respectively. Age is a continuous variable with values ranging from 14-19. Means are included for each of these variables with standard deviations included in parentheses.
These values reflect the data prior to imputation; frequencies are calculated out of a total number reflecting all cases without missing data for that variable.
SRC sub-sample are those who reported at least one diagnosed SRC in the past year; non-SRC sub-sample includes those who denied diagnosed SRC in the past year.

Sports-Related Concussion Items

The survey included SRC history items, including items that inquired about history of diagnosed concussion both inside and outside of sports and one item that inquired about lifetime number of diagnosed SRCs. The diagnosed concussion history variable was a binary variable used as a control variable in diagnosed SRC incidence and general symptom reporting models. This variable represented participants' diagnosed concussion history prior to their most recent SRC (for SRC group) and prior to the past year (for the non-SRC group) both inside and outside of sports ("Concussion history"; yes/no). 97 (39.3%) individuals indicated a positive diagnosed concussion history.

The lifetime number of diagnosed SRCs variable was included in analyses as a binary control variable in time to RTP and injury-specific symptom reporting models. This variable represented participants' lifetime number of SRCs, including the past year ("Lifetime SRC history"; 1/2+). 47 (30.8%) individuals indicated they experienced two or more diagnosed SRCs in their lifetime.

RTP and injury-specific symptom reporting models included participants who experienced a diagnosed SRC in the past year and included participants who experienced a "suspected" SRC, or an SRC that results in participants experiencing symptoms without official medical diagnosis. RTP and injury-specific symptom reporting models controlled for suspected SRC in the past year ("Suspected SRC"; yes/no). 60 (39.2%) of individuals reported experiencing at least one suspected SRC in the past year. These models also controlled for

presence of medical clearance. This was a binary variable representing official medical clearance from an athletic trainer or medical professional (yes/no). 131 (85.6%) individuals endorsed medical clearance following diagnosed SRC. The RTP variable ("time to RTP") was continuous and right-skewed in this sample with more participants indicating earlier RTP and less participants indicating later RTP. The time to RTP variable in this sample ranged from one day to 300 days for those who confirmed an RTP date, and one day to 365 days for the entire sample, including both those who reported a confirmed RTP date and those who had not yet returned to play (full sample median days to RTP = 17; confirmed RTP median days to RTP = 14).

The survey also included items inquiring about sport played in the past year, symptom experiences, symptom reporting behaviors, honesty in symptom reporting, and comfort in symptom reporting to teammates, non-teammate peers, coaches, parents, and medical professionals. Honesty and comfort in symptom reporting were assessed in two separate ways: injury-specific symptom reporting inquired about honesty and comfort in symptom reporting during the most recent diagnosed SRC in the past year ("injury-specific honesty", "injury-specific comfort") and general symptom reporting inquired about general habits in symptom reporting during athletic participation in the past year ("general honesty", "general comfort"). Injury-specific honesty in symptom reporting was assessed by inquiring about whether athletes felt they had honestly reported symptoms during their most recent diagnosed SRC in the past year (six-point Likert scale ranging from "Strongly Disagree" to "Strongly Agree"). Injury-specific comfort in symptom reporting was assessed by inquiring about whether athletes felt they were comfortable reporting their symptoms during their most recent diagnosed SRC in the past year (six-point Likert scale ranging from "Strongly Disagree" to "Strongly Agree"). These items were used to create two binary variables in which "1" represented that a participant indicated that

they agree that they were honest or comfortable in symptom reporting (i.e., “somewhat agree”, “agree”, and “strongly agree”). “0” represented participants who indicated that they disagree that they were honest or comfortable in symptom reporting (i.e., “somewhat disagree”, “disagree”, and “strongly disagree”). 94 (87%) individuals reported that they were honest, and 92 (81.5%) individuals reported that they were comfortable reporting symptoms during most recent diagnosed SRC.

General honesty and comfort in symptom reporting items were assessed by inquiring about participants’ general habits in honesty and comfort in symptom reporting during the past year to eight different groups or people in their life: maternal figure, paternal figure, siblings, coaches, athletic trainer, doctors, teammates, friends. Participants were also able to indicate if a particular group or person did not apply to their life or athletic participation. Binary variables were created to represent general honesty and comfort in symptom reporting during the past year. These two binary variables were created through a process whereby a percentage was calculated for each participant for the number of people or groups in their life that they agreed they felt honest or comfortable reporting symptoms to (i.e., “somewhat agree”, “agree”, and “strongly agree”). For example, if a participant indicated that six out of eight people on the list were relevant in their athletic participation, and they indicated they agree that they have been honest reporting symptoms to five of them, they were assigned a percentage of 83.3% (5/6). Binary variables were then created such that those assigned “1” were those that were 100% honest or comfortable reporting symptoms and “0” represented those that were less than 100% honest reporting symptoms. 89 (54.3%) of individuals reported 100% general honesty and 104 (52.5%) individuals reported 100% general comfort in symptom reporting.

Tables 6-8 highlight participants' level of honesty and comfort reporting symptoms and with whom.

Table 6: Injury-Specific Honesty and Comfort in Symptom Reporting

Item	Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree	N/A
Injury-Specific Honesty	25 (23.1%)	37 (34.2%)	29 (26.8%)	7 (6.5%)	3 (2.8%)	4 (3.7%)	3 (2.8%)
Injury-Specific Comfort	29 (25.2%)	44 (38.3%)	19 (16.5%)	12 (10.4%)	5 (4.3%)	4 (3.5%)	2 (1.7%)

Note: Honesty: "When I sustained my most recent diagnosed concussion in the past year, I was honest in reporting my symptoms"; Comfort: "When I sustained my most recent diagnosed concussion in the past year, I was comfortable in reporting my symptoms"; N/A indicated that this item did not apply to the participant. Frequency (% Frequency).
These values reflect the data prior to imputation.

Table 7: Injury-Specific Symptom Reporting

Injury-Specific Honesty	
Maternal figure	112 (81.8%)
Paternal figure	105 (76.6%)
Coaches	85 (62.0%)
Athletic trainer	73 (53.3%)
Doctors	89 (65.0%)
Teammates	62 (45.2%)
Friends	52 (38.0%)
Injury-Specific Comfort	
Maternal figure	117 (84.2%)
Paternal figure	102 (73.4%)
Coaches	79 (56.8%)
Athletic trainer	81 (58.3%)
Doctors	97 (69.8%)
Teammates	65 (46.8%)
Friends	61 (43.9%)

Note: Honesty: "When I sustained my most recent diagnosed concussion in the past year, I was honest reporting my symptoms to:"; Comfort: "When I sustained my most recent diagnosed concussion in the past year, I was comfortable reporting my symptoms to:". Participants checked all options that applied. Frequency (% Frequency).
These values reflect the data prior to imputation.

Table 8: General Honesty and Comfort in Symptom Reporting

Item	Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree	N/A
General Honesty							
Maternal figure	57 (32.0)	49 (27.5)	18 (10.1)	9 (5.1)	6 (3.4)	4 (2.2)	35 (19.7)
Paternal figure	51 (27.9)	47 (25.7)	32 (17.5)	9 (4.9)	2 (1.1)	6 (3.3)	36 (19.7)
Siblings	49 (26.9)	39 (21.4)	29 (15.9)	13 (7.1)	7 (3.8)	3 (1.6)	42 (23.1)
Coaches	35 (19.2)	47 (25.8)	38 (20.9)	21 (11.5)	7 (3.8)	6 (3.3)	28 (15.4)
Athletic trainer	39 (21.3)	42 (22.9)	40 (21.8)	19 (10.4)	7 (3.8)	5 (2.7)	31 (16.9)
Doctors	52 (30.2)	47 (27.3)	30 (17.4)	6 (3.5)	6 (3.5)	2 (1.2)	29 (16.9)
Teammates	37 (20.2)	44 (24.0)	43 (23.5)	21 (11.5)	3 (1.6)	5 (2.7)	30 (16.4)
Friends	45 (25.3)	41 (23.0)	27 (15.2)	22 (12.3)	9 (5.0)	5 (2.8)	29 (16.3)
General Comfort							
Maternal figure	78 (37.1)	57 (27.1)	21 (10.0)	19 (9.0)	3 (1.4)	4 (1.9)	28 (13.3)
Paternal figure	53 (27.3)	59 (30.4)	27 (13.9)	12 (6.2)	8 (4.1)	7 (3.6)	28 (14.4)
Siblings	53 (27.7)	44 (23.0)	34 (17.8)	14 (7.3)	5 (2.6)	5 (2.6)	36 (18.8)
Coaches	33 (16.3)	58 (28.7)	43 (21.3)	30 (14.8)	9 (4.4)	5 (2.5)	24 (11.9)
Athletic trainer	45 (22.8)	47 (23.8)	46 (23.3)	18 (9.1)	7 (3.5)	5 (2.5)	29 (14.7)
Doctors	63 (34.4)	54 (29.5)	22 (12.0)	14 (7.6)	4 (2.2)	3 (1.6)	23 (12.6)
Teammates	35 (17.7)	60 (30.3)	39 (19.7)	28 (14.1)	6 (3.0)	5 (2.5)	25 (12.6)
Friends	48 (26.1)	45 (24.4)	30 (16.3)	24 (13.0)	10 (5.4)	2 (1.1)	25 (13.6)

Note: Honesty: "Whether you have experienced a sports-related concussion nor not, in the past year I have been honest reporting my symptoms to _____"; Comfort: "Whether you have experienced a sports-related concussion or not, in the past year I have been comfortable reporting my symptoms to _____".
N/A indicated that this item did not apply to the participant. Frequency (% Frequency).
These values reflect the data prior to imputation.

ANALYSIS PLAN

All analyses were conducted using version 4.2.3 of R (R Core Team, 2023). Study analyses included a series of survival analysis and logistic regression models that investigated personality and social determinants of health predictors of time to RTP, diagnosed SRC incidence, and symptom reporting outcomes. The results of an a priori power analysis determined that 120 participants who sustained a diagnosed SRC in the past year would provide sufficient power to detect effects in survival analysis models, and that 150 total participants with at least 10% of those participants indicating they did not sustain a diagnosed SRC in the past year would provide sufficient power to detect effects in logistic regression models. Sample size in this study exceeded the minimum number of participants needed with total N = 315 used in analyses. There were 249 participants in diagnosed SRC and general symptom reporting models (N = 95 SRC group, N = 154 non-SRC group), and 153 participants in time to RTP and injury-specific symptom reporting models. Specific details on the sub-samples used for each analysis are included below.

Before analyzing the data, direct examination of missing data patterns and Little's Missing Completely at Random (MCAR) test were used to determine if there were significant systematic patterns in the complete and missing data in the sample (Little, 1988). Data were determined to be MCAR for the dataset inclusive of variables needed to run RTP and injury-specific symptom reporting analyses ($p = 0.24$) and the dataset inclusive of variables needed to run diagnosed SRC incidence and general symptom reporting analyses ($p = 0.16$). The amount of missing data differed by variable, with percent missing ranging from 0-5% for all personality, social determinants of health, RTP, incidence, and study control variables. The amount of

missing data fell between 15 and 30% for symptom reporting variables. The average amount of missing data across all study variables of interest was 5%.

Multiple imputation was used to manage missing data in this study because multiple imputation has also been found to be an advantageous method for managing missing data when data are MCAR, study variables have a high percentage of missing data, and study models include variables from a variety of distributions (Ambler et al., 2007; Azur et al., 2011). Multiple imputation involves imputing cases of missing data several times based on existing data and then averaging imputed values. This allows for final imputed values to capture variability in possible values for missing data. In this study, demographic variables were not imputed. The R package "mice" was used to conduct multiple imputation in this study, including five imputations and 25 iterations (van Buuren & Groothuis-Oudshoorn, 2011). The mice package uses Rubin's Rules to pool parameter estimates from all imputed datasets (Rubin, 1987). Five imputations is commonly cited as a sufficient number of imputations (Schafer, 1997; Wulff & Ejlskov, 2017). Another body of literature supports using a number of imputations consistent with average percent of missing data in the study (Graham et al., 2007). As a result of both of these bodies of literature, five imputations were used in this study. The number of iterations used in a study is most often determined by examining convergence of variables through plots (Graham et al., 2007). Plots converged in this study at 25 iterations.

Prior to conducting study analyses, model assumptions were checked. Independence of survival times, linearity between continuous predictors and log of the hazard, and time-invariant predictor Cox regression assumptions were met. Predictors in this study, including personality and social determinants of health predictors, were considered time invariant because values for these variables were considered to be the same from diagnosed SRC event through RTP and

survey completion. This is due to the relative stability of personality and identity variables in the study, the single-occurrence nature of several study variables (i.e., presence of medical clearance), and the relatively short period of time between diagnosed SRC event and survey completion. Two assumptions of Cox proportional hazards regression were not met: non-informative censoring and proportionality of hazards (Cox, 1972). Non-informative censoring assumes that a participant's likelihood of being censored, or likelihood of not having experienced the event at the time of survey completion, is not related to their likelihood of the event occurring at some point in the future. In the current study, participants were right censored, meaning that if they had not returned to play after one year, they were censored at the number of days between SRC diagnosis and survey completion. Eight participants in the study indicated that they had not returned to play by the time of survey completion (censored), but also did not intend to RTP. Of the eight individuals that were excluded due to no plan to RTP in the future, two (25%) indicated that their reason for not returning was that high school was almost over, two (25%) indicated that they did not want to return, two (25%) noted that they had persistent post-SRC symptoms, and two (25%) did not provide a reason. These eight participants were excluded from analyses due to the presence of informative censoring. Proportionality of hazards assumes that hazard functions between groups are proportional, or that the effect of a risk factor is constant over time. Cox proportional hazards regression models in this study demonstrated non-proportional hazards for the binary (yes/no) past year suspected SRC variable. This was demonstrated by Schoenfeld's residual values being $< .05$ for this variable. Each comprehensive Cox proportional hazards regression model was subsequently stratified by the past year suspected SRC variable, meaning that hazard ratios (HRs) for all other predictors were calculated for each level of the past year suspected SRC variable, and these HRs were averaged in the output. The cost of stratification in

Cox proportional hazards regression is that the stratified variable is not included in the output (Singer & Willett, 2003). Since the past year suspected SRC variable was included in analyses as a control variable, the benefit of stratification outweighed the cost in this study. Another concern about stratification is the impact it can have on power. Singer and Willett (2003) noted that each binary group for the stratified variable should be sufficiently powered to draw conclusions to mitigate overall concerns about power in stratified models. Due to the model-building method used with Cox proportional hazards regression in this study, described below, power was not a concern in stratified models.

Logistic regression model assumptions of independence, linearity between logit and continuous predictors, and lack of influential outliers were all met. Variance inflation factors (VIF) were examined to assess multicollinearity. High multicollinearity, or correlation between predictor variables, can compromise power in multivariate regression analyses and can inflate regression coefficients (Aberson et al., 2022). To preserve power in this study, variables with VIF values above 2.5 were considered to be multicollinear and were dropped from analyses. Multicollinearity was present for primary sport played (VIF = 4) in all study models. As a result, this control variable was dropped from analyses.

Data collection monitoring took place periodically throughout the data collection period, with a specific focus on distribution and variability of social determinants of health variables in the study. Data collection monitoring included checking data collection procedures at participating sites, examining data for any problematic patterns of missingness, and troubleshooting with sites to assist with recruitment. One social determinant of health predictor, access to healthcare, included representation of less than 10% for the group indicating they had limited or no access to care, so this variable was dropped from analyses to minimize chances of

convergence issues in study models (Mansournia et al., 2018). Additionally, the two participants who identified as intersex were dropped from regression models due to low representation of this demographic group (final N = 315). For all models including symptom reporting outcomes and predictors, cases wherein participants indicated that symptom reporting did not apply to them were excluded from symptom reporting analyses. Individuals indicating "N/A" for these variables ranged from 1-10% of symptom reporting data.

The significance level for all analyses was set at 0.05. This significance level was chosen to balance the risk of Type I and Type II error. Using alpha corrections protects against Type I error, while risking Type II error (i.e., Rothman, 1990). Risk of Type II error was higher in this study due to a relatively small sample size combined with a moderate number of predictors and models. The nature of this study was also more exploratory, underscoring the benefit of a higher significance level. Effect sizes (i.e., hazard ratios and odds ratios) and confidence intervals (CIs) were included with all study results to bolster conclusions about the impact of each variable on study outcomes (Cumming, 2013, 2014).

Regression Models

Regression models examined the following outcomes: Time to RTP, diagnosed SRC incidence, injury-specific honesty in symptom reporting, injury-specific comfort in symptom reporting, general honesty in symptom reporting, and general comfort in symptom reporting. Each outcome was regressed on a group of personality predictors and a group of social determinants of health predictors in separate models, with the specific structure of analyses and model-building depending on the outcome.

Time to RTP, injury-specific honesty in symptom reporting, and injury-specific comfort in symptom reporting analyses were run on a sample of those endorsing at least one diagnosed

SRC in the past year. This sample also included participants who endorsed sustaining a suspected SRC in the past year. Diagnosed SRC incidence, general honesty in symptom reporting, and general comfort in symptom reporting analyses were conducted on a sample of those who either endorsed or denied sustaining a diagnosed SRC in the past year. Those endorsing a suspected SRC in the past year were excluded from these analyses. Final sample size for time to RTP and injury-specific symptom reporting analyses was N = 153 following exclusions made for non-informative censoring, and final sample size for diagnosed SRC incidence and general symptom reporting analyses was N = 249 (N = 95 SRC group, N = 154 non-SRC group) after exclusions were made for those endorsing a suspected SRC in the past year.

A final group of analyses regressed the two primary study outcomes, time to RTP and diagnosed SRC incidence, on honesty and comfort in symptom reporting predictors to preliminarily investigate potential relations between symptom reporting and SRC risk (time to RTP, diagnosed SRC incidence).

None of the binary outcomes in this study were considered to be unbalanced outcomes (i.e., one group representing < 10% of the total). However, when binary outcomes were regressed on binary predictors, there were instances in which cell sizes were unbalanced. For example, those who identified as someone who experienced at least one discriminatory act who also felt less comfortable reporting symptoms represented a small percentage of the sample (< 10%). In each of these cases, logistic regression models converged, meaning that logistic regression analytic methods were used without Firth bias correction for unbalanced outcomes (Firth, 1993).

Time to RTP Outcome

Personality and Social Determinants of Health Predictors. Relations between personality, social determinants of health, and time to RTP were examined using two types of analysis – Kaplan Meier analysis and Cox proportional hazards regression analysis – to best understand the degree to which time to RTP, measured in number of days following diagnosed SRC, may differ based on personality and social determinants of health factors. R packages "survminer" (Kassambra et al., 2021) and "survival" (Thernaeau, 2022) were used for these analyses. Time to RTP in this study referenced participants' most recent diagnosed SRC in the past year. Kaplan Meier analysis was conducted first as a descriptive comparison of survival curves for binary predictors in the study, followed by Cox regression models.

For both Kaplan Meier and Cox proportional hazards models the survival outcome was consistent ("time to RTP"); the outcome included both an event indicator and a length of time component (Singer & Willett, 2003). The event indicator allowed for participants in the study to fall into two groups, those who returned to play some time prior to study completion (event indicator = "1") and those who had not yet returned to play (event indicator = "0"). For those who had not yet returned to play upon study completion, their data was considered "censored", meaning that the true value of this variable was unknown due to study design not including follow-up. Censoring indicated that RTP had not yet occurred for participants in the study and did not represent their ability to or tendency to RTP. The length of time component of the outcome was defined as the number of days from SRC occurrence to either RTP (event indicator = "1") or to date of the survey (event indicator = "0") if an individual had not yet returned to play. Time to RTP was a single-event variable in this study, meaning that participants were only able to indicate that they returned to play once following a diagnosed SRC event. Additionally,

the time to event data were right truncated at one year, meaning that the longest possible RTP timeline a participant could indicate was one year.

As Kaplan Meier analyses and subsequent logrank tests are preliminary and descriptive, each binary variable deemed appropriate for these analyses was included in separate models. Kaplan Meier analyses in this study compared the effects of two groups on probability of survival, or the probability of continuing to refrain from RTP in this study. These models allowed for visual inspection and comparison of survival curves between groups (i.e., comparison of time to time to RTP curves between those who identified as female and those who identified as male). Subsequent logrank tests were conducted to find the chi-square statistics and related p-values to determine if a significant difference was present in probability of RTP between groups.

A model-building approach was used for Cox proportional hazards regression to determine which predictors, both binary and continuous, were included in one final Cox proportional hazards model. Individual preliminary models included the survival object regressed on each personality, social determinant of health, or control variable individually in separate models. Variables in models with p-values < 0.05 were used as predictors in the final model. Lifetime SRC history, past year suspected SRC, and presence of official medical clearance were considered control variables in RTP analyses.

Cox proportional hazards regression models generated outcomes in the metric log of the hazard of the outcome (Singer & Willett, 2003). For interpretability, parameter estimates in Cox regression models in this study were exponentiated to HRs, which can be interpreted as the hazard or relative risk of the event of interest occurring at any point in the time frame represented in the study. In this study, HRs were interpreted as the percent increase in the risk of

RTP at any single time point represented in the study. HRs can also be used as an effect size, representing the relative magnitude of effect of a predictor on time to RTP. Standard errors, CIs, and p-values were examined in addition to parameter estimates to determine significance and aid in overall interpretation.

Diagnosed SRC Incidence Outcome

Personality and Social Determinants of Health Predictors. Relations between personality, social determinants of health, and diagnosed SRC incidence were assessed in two regression models. In the first model, the binary diagnosed SRC incidence outcome was regressed on all personality predictors. In the second model, the binary diagnosed SRC incidence outcome was regressed on all social determinants of health predictors. All models controlled for concussion history. Personality models also controlled for sex assigned at birth and age.

In logistic regression analyses, or analyses including binary outcomes, parameter estimates are generated in the metric of log of the odds of the outcome. As a result, parameter estimates were exponentiated to find the odds ratios (ORs) associated with each predictor (Wright, 1995). ORs were interpreted as percent change in the outcome for each one-unit change in the predictor for continuous variables, and as a percent difference in the outcome for group one compared to group two for binary predictors. ORs can also be interpreted as effect sizes, representing the relative magnitude of effect of a predictor on an outcome. Standard errors, CIs, and p-values were examined in addition to parameter estimates for significance and overall interpretation. All logistic regression models were also interpreted using sensitivity, specificity, classification accuracy, area under the curve (AUC), negative predictive values (NPV), and positive predictive values (PPV) to determine model fit (Coughlin et al., 1992). The R package "ROCit" was used to find these model fit statistics (Khan & Brandenburger, 2020).

Symptom Reporting Outcomes

Personality and Social Determinants of Health Predictors. Relations between personality, social determinants of health, and symptom reporting outcomes were assessed in eight separate logistic regression models.

The binary injury-specific honesty in symptom reporting variable was regressed on personality variables in one model and social determinants of health variables in a separate model (two total models). The binary injury-specific comfort in symptom reporting variable was regressed on personality variables in one model and social determinants of health variables in a separate model (two total models). Significant predictors from each of two models were included in a single final model per outcome, including either the injury-specific honesty variable or the injury-specific comfort variable regressed on personality, social determinants of health, and control variables found significant in previous models ($p < 0.05$). All models controlled for lifetime SRC history and suspected SRC. Personality models also controlled for sex assigned at birth and age.

The general honesty in symptom reporting and general comfort in symptom reporting variables included the same analytic method as outlined above, controlling for concussion history. Personality models also controlled for sex assigned at birth and age. See previous section "Diagnosed SRC Incidence Outcomes" for details on logistic regression analysis methods and interpretation.

Symptom Reporting Predictors

Time to RTP Outcome. Relations between injury-specific honesty in symptom reporting, injury-specific comfort in symptom reporting, and time to RTP were examined in two models, one regressing time to RTP on the honesty variable and one regressing time to RTP on

the comfort variable. Each model controlled for sex assigned at birth, age, lifetime SRC history, medical clearance, and incidence of suspected SRC in the past year. See previous section "Time to RTP Outcome" for a detailed description of time to event analysis methods.

Diagnosed SRC Incidence Outcome. Relations between general honesty in symptom reporting, general comfort in symptom reporting, and the diagnosed SRC incidence outcome were examined in two models, one regressing diagnosed SRC incidence on the honesty variable and one regressing diagnosed SRC incidence on the comfort variable. Each model controlled for sex assigned at birth, age, and concussion history. See previous section "Diagnosed SRC Incidence Outcome" for a detailed description of logistic regression analysis methods.

RESULTS

Descriptive Statistics

315 participants met inclusion criteria and were included in study analyses. 216 participants (68.6%) indicated experiencing at least one diagnosed SRC in their lifetime, with 60 of these participants (27.8%) experiencing 2+ diagnosed SRC in their lifetime. Across the entire sample, 124 participants (39.4%) reported experiencing a suspected SRC during their lifetime. 161 participants (51.1%) endorsed experiencing at least one diagnosed SRC in the past year, with 29 of these participants (18.0%) experiencing 2+ diagnosed SRC in the past year. Of those who indicated that they sustained a diagnosed SRC in the past year, 64 participants (39.7%) reported also experiencing a suspected SRC in the past year. Of those who indicated that they did not experience a diagnosed SRC during the past year, 55 participants (35.7%) indicated experiencing at least one diagnosed SRC during their lifetime, with 10 of these participants (18.2%) indicating that they sustained 2+ diagnosed SRCs in their lifetime.

67 participants (21.2%) from the whole sample reported sustaining a diagnosed concussion outside of sports during their lifetime, with 15 of these participants (4.8%) endorsing 2+ diagnosed concussions outside of sports during their lifetime. Of those who experienced a diagnosed SRC in the past year, 42 of them (26.1%) reported sustaining a diagnosed concussion outside of sports during their lifetime and 11 of these participants (6.8%) reported experiencing 2+ diagnosed concussions outside of sports.

Model Results

Time to RTP Outcome

153 participants had complete data for RTP following their most recent diagnosed SRC following imputation of the time to RTP outcome. 31 participants (20.3%) were censored and had not returned to play at the time of survey completion. All participants included in the analyses who had not yet returned to play indicated that they intended to RTP to the same sport at some point in the future. Time to RTP was measured in days, with RTP values ranging from one day to 300 days among those who reported RTP. Average RTP time for those who returned to play was 29.5 days and median RTP was 14 days. Average RTP time among the whole sample, including those who were censored at 365 days, was 53.3 days and median was 17 days.

Survival data are presented in Table 9. Each time interval in the table includes data for the number of days since diagnosed SRC, number of individuals in the sample who had not yet returned to play at that specific time point, the number of people returning to play at that time, probability of continuing to refrain from RTP at that time, standard errors, and CIs. The subsequent plot (Figure 9) shows the same data. This figure should not be interpreted as an exact probability of not yet returning to play at each time point for the entire range of RTP values. However, generally, the plot shows that many individuals returned to play within the first three weeks.

Table 9: Survival Table

Time	N Risk	N Event	Survival Probability	SE	95% CI
1.0	145	4	0.972	0.014	0.928-0.990
2.0	140	4	0.945	0.019	0.892-0.972
3.0	136	4	0.917	0.023	0.858-0.952
4.0	131	1	0.910	0.024	0.850-0.947
5.0	130	9	0.847	0.030	0.777-0.896
6.0	120	1	0.840	0.031	0.769-0.891
7.0	119	12	0.755	0.036	0.676-0.818
8.0	107	2	0.741	0.037	0.661-0.805
9.0	105	3	0.720	0.038	0.638-0.786
10.0	101	3	0.698	0.038	0.616-0.767
12.0	97	3	0.677	0.039	0.593-0.747
13.0	94	3	0.655	0.040	0.571-0.727
14.0	91	10	0.583	0.041	0.497-0.660
15.0	81	6	0.540	0.042	0.454-0.618
16.0	75	1	0.533	0.042	0.447-0.611
17.0	74	4	0.504	0.042	0.419-0.583
18.0	70	1	0.497	0.042	0.412-0.576
19.0	69	2	0.482	0.042	0.398-0.562
20.0	66	5	0.446	0.042	0.362-0.489
21.0	60	3	0.424	0.042	0.341-0.504
23.0	56	1	0.416	0.042	0.334-0.496
25.0	55	1	0.408	0.042	0.326-0.489
28.0	54	1	0.401	0.042	0.319-0.481
30.0	53	8	0.340	0.040	0.262-0.420
31.0	44	1	0.333	0.040	0.255-0.412
35.0	43	4	0.302	0.040	0.227-0.380
40.0	39	2	0.286	0.039	0.213-0.364
45.0	37	1	0.278	0.039	0.206-0.356
50.0	36	2	0.263	0.038	0.192-0.339
60.0	34	1	0.255	0.038	0.185-0.331
64.0	33	1	0.248	0.037	0.178-0.323

77.0	30	1	0.239	0.037	0.171-0.314
86.0	29	1	0.231	0.037	0.164-0.306
90.0	28	1	0.223	0.036	0.156-0.297
100.0	22	1	0.213	0.036	0.147-0.287
120.0	20	1	0.202	0.036	0.137-0.276
150.0	19	1	0.191	0.035	0.127-0.265
200.0	17	1	0.180	0.035	0.118-0.253
270.0	7	1	0.154	0.038	0.089-0.237
290.0	6	1	0.129	0.040	0.064-0.217
300.0	5	1	0.103	0.040	0.043-0.194

Note: This table includes values generated prior to imputation, meaning that 8 observations were not included due to missingness. Both censored and non-censored participants were included. Values included are the time that has passed since diagnosed SRC (Time), the number of people not yet to RTP (N Risk), the number of people who did RTP at the specified time (N Event), the probability of refraining from RTP (Survival Probability), standard errors (SE), and 95% confidence intervals (95% CI).

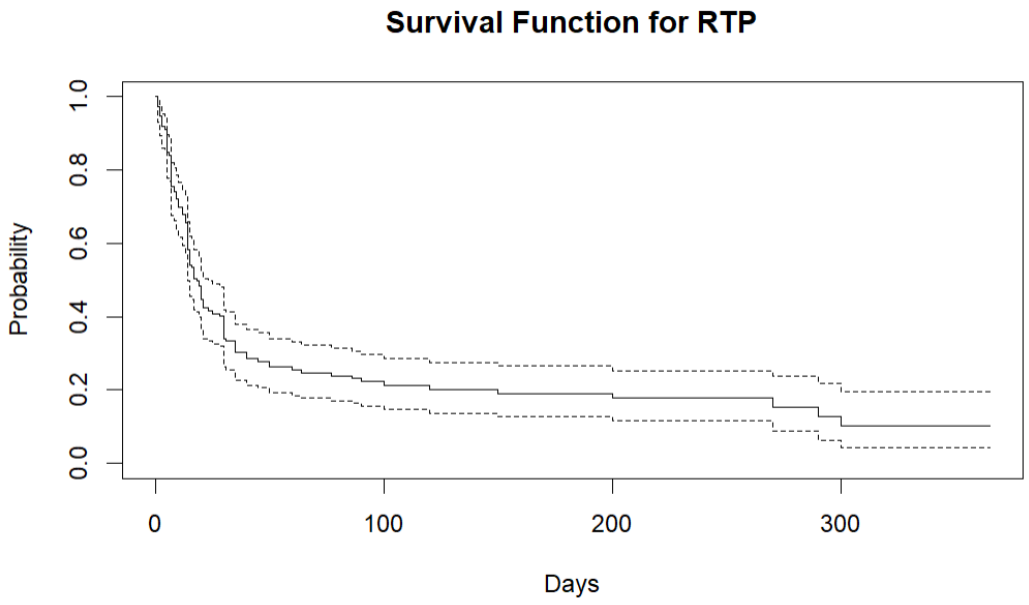

Figure 9. Number of days since RTP is included on the x-axis. The probability of refraining from RTP is included on the y-axis.

Kaplan Meier. Kaplan Meier plots are included in Figures 10-14. Results for each variable include 5 plots, one for each imputed dataset, as pooled results are not available for these analyses. Subsequent logrank test results are interpreted below for variables meeting the proportionality of hazards assumption.

Sex assigned at birth was the only binary variable that demonstrated significant differences in survival curves, such that those assigned female at birth had a higher probability of RTP in all five imputed samples (logrank p-values: 0.028, 0.036, 0.040, 0.045, 0.046). Experiences of discrimination, race, past year suspected SRC, medical clearance, and lifetime number of SRCs did not demonstrate significant differences in survival curves between the two levels of each binary variable.

Figure 15 shows Kaplan Meier plots for the past year suspected SRC variable. These plots and respective logrank p-values were not interpreted as the past year suspected SRC variable did not meet the proportionality of hazards assumption. This was demonstrated by a significant p-value of 0.01 when Schoenfeld's residuals were examined for this variable. Plots for past year suspected SRC allow visual inspection of the significant degree of overlap in the survival curves, another indicator of non-proportional hazards.

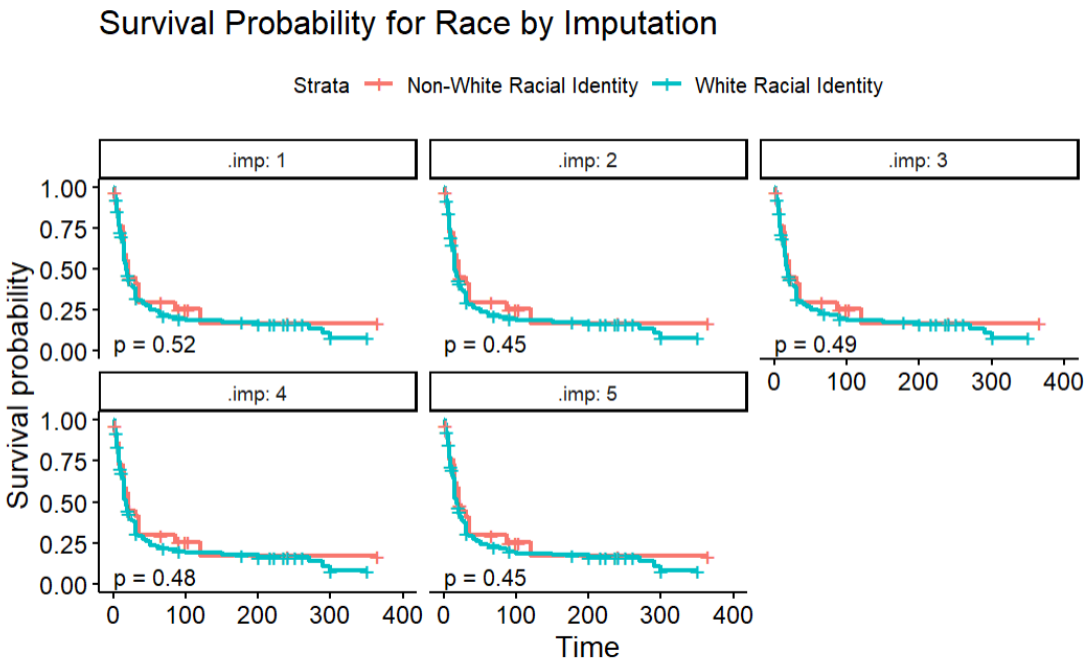

Figure 10. All five imputed datasets showed no significant difference in survival probability between those identifying as White and those identifying as a Person of Color.

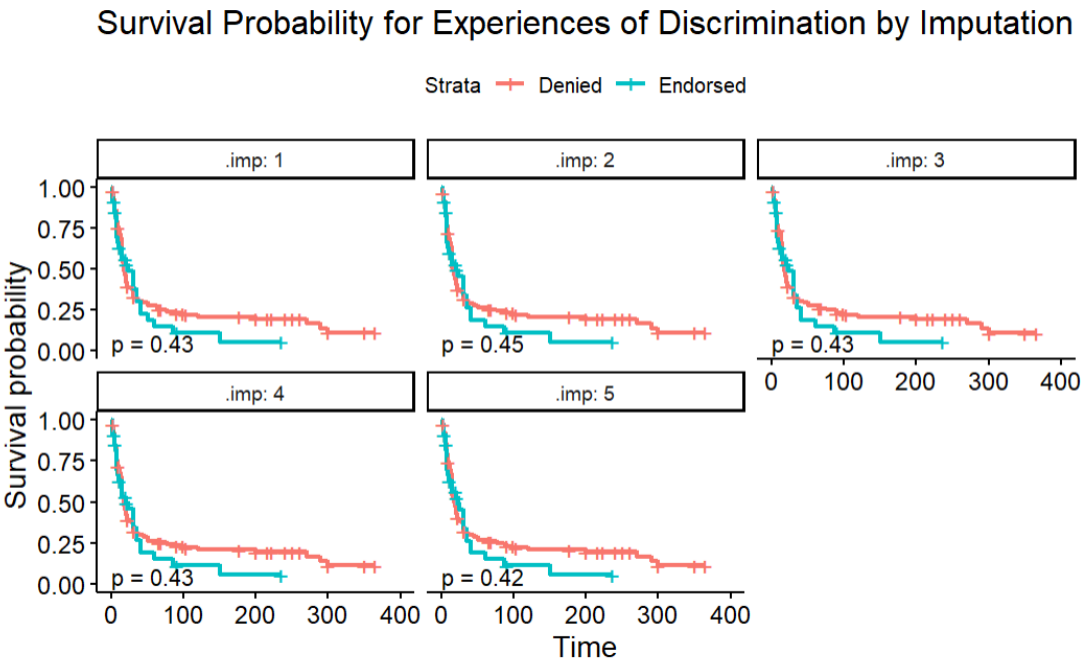

Figure 11. All five imputed datasets showed no significant difference in survival probability between those endorsing at least one experience of discrimination and those denying experiences of discrimination.

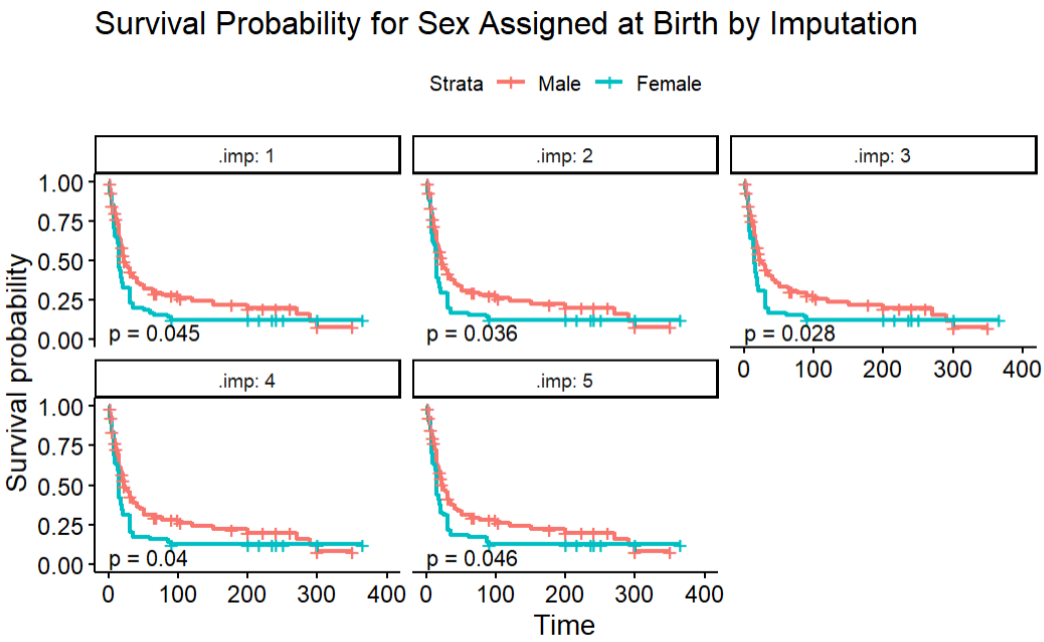

Figure 12. All five imputed datasets showed significant difference in survival probability between those identifying as assigned female at birth and those identifying as assigned male at birth. In each plot, those assigned female at birth had a higher probability of RTP across the study period.

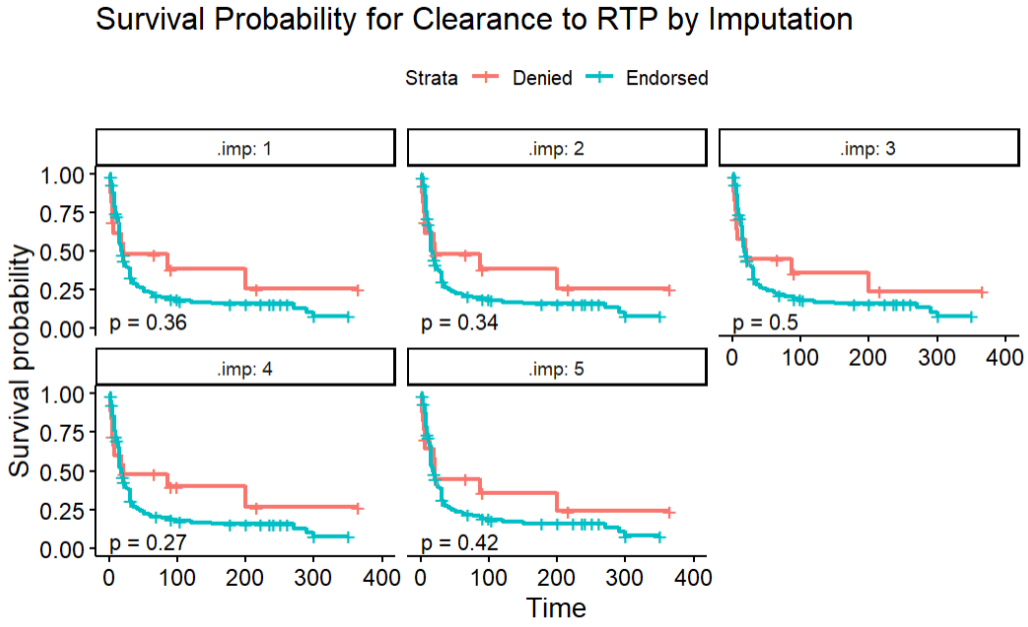

Figure 13. All five imputed datasets showed no significant difference in survival probability between those endorsing medical clearance and those denying medical clearance prior to RTP following diagnosed SRC.

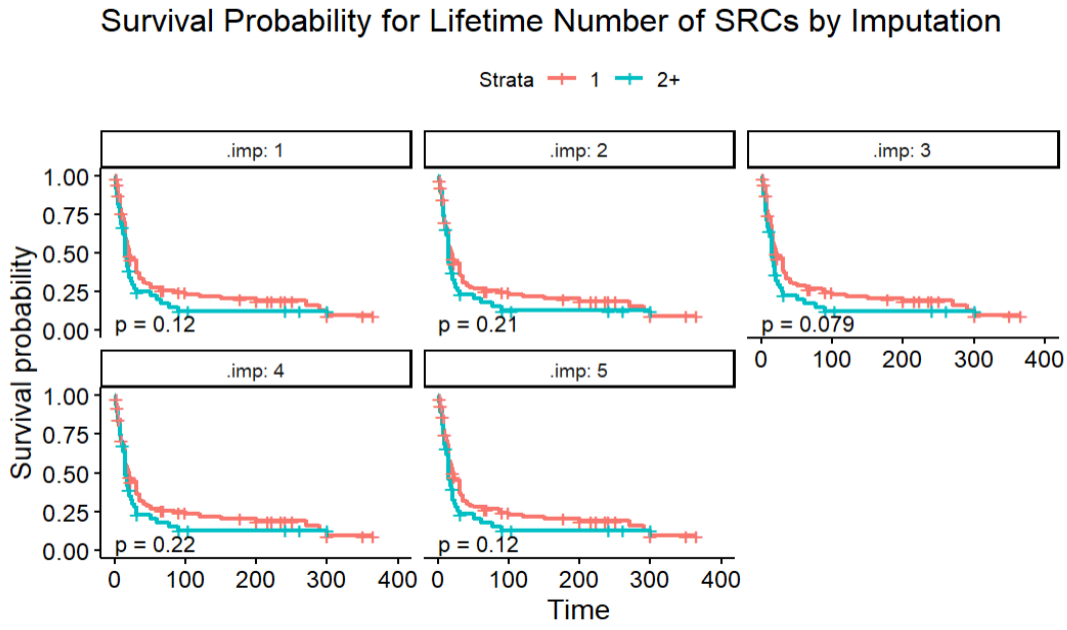

Figure 14. All five imputed datasets showed no significant difference in survival probability between those endorsing 1 vs. 2+ diagnosed SRC in their lifetime.

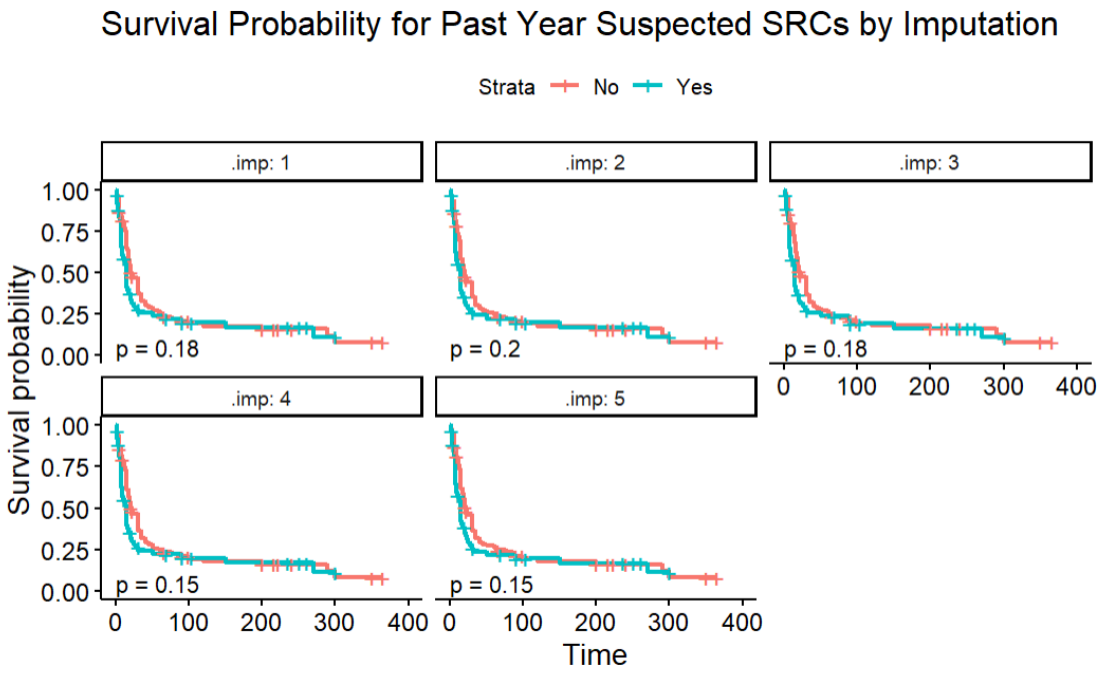

Figure 15. All five imputed datasets showed allow visual inspection of the survival curves for both those endorsing and those denying a suspected SRC in the past year. This variable did not meet the proportionality of hazards assumption, so p-values associated with the logrank test should not be interpreted.

Cox Proportional Hazards Regression. Individual Cox proportional hazards models were run for each variable of interest, with the survival object regressed on each individual predictor in a separate model. Results are pooled across imputed datasets using Rubin's Rules (Rubin, 1987). SES and sex assigned at birth were significantly associated with time to RTP. Significant results are interpreted below. All results can be found in Table 10.

- Risk of RTP was 12.6% higher for every one unit increase in SES (b = 0.119, HR = 1.126, CI = [1.017-1.247], SE = 0.051, p = 0.023).
- Risk of RTP was 47.0% higher for those assigned female at birth compared to those assigned male at birth (b = 0.385, HR = 1.470, CI = [1.016-2.126], SE = 0.186, p = 0.041).

When both of these significant variables were included together in a final model, the model was also stratified by the suspected concussion variable due to this variable not meeting the proportionality of hazards assumption. SES was significantly associated with RTP when controlling for sex assigned at birth.

- Risk of RTP was 11.1% higher for every one unit increase in SES (b = 0.105, HR = 1.111, CI = [1.005-1.229], SE = 0.051, p = 0.040).

Table 10: Cox Proportional Hazard Individual Model Results

Personality and Social Determinants of Health Predictors

	b	HR	CI	SE	p
Personality Predictors					
Experience Seeking	0.043	1.044	0.974-1.120	0.035	0.214
Risk Seeking	-0.024	0.976	0.929-1.026	0.025	0.337
Total Impulsivity	-0.001	0.999	0.953-1.047	0.023	0.971
Openness to Experience	0.021	1.021	0.933-1.117	0.046	0.646
Conscientiousness	0.042	1.043	0.963-1.131	0.040	0.296
Extraversion	0.039	1.039	0.966-1.118	0.037	0.293
Agreeableness	-0.069	0.933	0.860-1.014	0.042	0.101
Neuroticism	-0.001	0.999	0.928-1.077	0.037	0.999
Social Determinants of Health Predictors					
Race	0.169	1.184	0.741-1.890	0.236	0.476
Age	0.102	1.107	0.931-1.318	0.088	0.248
Sex Assigned at Birth	0.385	1.470	1.016-2.126	0.186	0.041*
SES	0.119	1.126	1.017-1.247	0.051	0.023*
Experiences of Discrimination	0.172	1.188	0.765-1.843	0.222	0.438
ACEs	0.029	1.030	0.937-1.132	0.047	0.535
Pressure	-0.101	0.904	0.796-1.027	0.064	0.119
Control Variables					
Lifetime SRC History	0.293	1.340	0.906-1.982	0.197	0.141
Suspected SRC	0.260	1.298	0.895-1.882	0.187	0.167
Medical Clearance	0.453	1.574	0.816-3.035	0.332	0.174
Final Model					
Sex Assigned at Birth	0.352	1.422	0.978-2.069	0.189	0.065
SES	0.105	1.111	1.005-1.229	0.051	0.040*

Note: b = unstandardized regression coefficients; HR = hazard ratio; CI = 95% confidence interval around the HR; SE = standard error; * = significant at 0.05

Diagnosed SRC Incidence Outcome

The binary diagnosed SRC incidence variable was regressed on personality predictors and social determinants of health predictors in two separate models using logistic regression. Significant predictors for each of the two models were used in a final model. Results for all three models are included in Table 11. Sensitivity, specificity, accuracy, NPV, PPV, and AUC values for each model are included in Table 12.

Personality Model. The binary diagnosed SRC incidence outcome was regressed on personality variables in one model, controlling for sex assigned at birth, age, and concussion history. Openness to experience, conscientiousness, agreeableness, and sex assigned at birth were significantly associated with odds of sustaining a diagnosed SRC in the past year when controlling for other predictors in the model. Significant results are interpreted below.

- Odds of sustaining a diagnosed SRC in the past year were 14.2% lower for every one unit increase in openness to experience (b = -0.153, OR = 0.858, CI = [0.737-0.999], SE = 0.077, p = 0.049).
- Odds of sustaining a diagnosed SRC in the past year were 17.8% lower for every one unit increase in conscientiousness (b = -0.196, OR = 0.822, CI = [0.702-0.961], SE = 0.079, p = 0.014).
- Odds of sustaining a diagnosed SRC in the past year were 21.4% higher for every one unit increase in agreeableness (b = 0.194, OR = 1.214, CI = [1.043-1.413], SE = 0.077, p = 0.012).
- Odds of sustaining a diagnosed SRC in the past year were 49.2% lower for those assigned female at birth compared to those assigned male at birth (b = -0.677, OR = 0.508, CI = [0.270-0.957], SE = 0.321, p = 0.036).

Overall, total accuracy was 70.8%, indicating that this model accurately predicted the diagnosed SRC outcome 70.8% of the time. Specificity for this model was 85.1%, indicating that the model accurately predicted if someone did not sustain a diagnosed SRC in the past year 85.1% of the time. Sensitivity for this model was 47.3%, indicating that the model accurately predicted if someone did sustain a diagnosed SRC in the past year 47.3% of the time. This model was better at predicting those who did not sustain a diagnosed SRC than those who did sustain a diagnosed SRC.

Social Determinants of Health Model. The binary diagnosed SRC incidence outcome was regressed on social determinants of health variables in one model, controlling for concussion history. Sex assigned at birth and SES were significantly associated with odds of diagnosed SRC in the past year when controlling for other predictors in the model. Significant results are interpreted below.

- Odds of sustaining a diagnosed SRC in the past year were 58.1% lower for those assigned female at birth compared to those assigned male at birth (b = -0.868, OR = 0.419, CI = [0.235-0.747], SE = 0.293, p = 0.003).
- Odds of sustaining a diagnosed SRC in the past year were 20.8% lower for every one unit increase in SES (b = -0.232, OR = 0.792, CI = [0.667-0.941], SE = 0.087, p = 0.008).

Overall, total accuracy was 67.6%, indicating that this model accurately predicted the diagnosed SRC outcome 67.6% of the time. Specificity for this model was 85.9%, indicating that the model accurately predicted if someone did not sustain a diagnosed SRC in the past year 85.9% of the time. Sensitivity for this model was 37.9%, indicating that the model accurately predicted if someone sustained a diagnosed SRC in the past year 37.9% of the time. This model

was better at predicting those who did not sustain a diagnosed SRC than those who did sustain a diagnosed SRC.

Final Model. Significant predictors from the two previous models were included in a final model. The binary diagnosed SRC incidence outcome was regressed on agreeableness, openness to experience, conscientiousness, sex assigned at birth, and SES. Conscientiousness, agreeableness, and sex assigned at birth were significantly associated with this outcome when controlling for the other predictors in the model. Significant results are interpreted below.

- Odds of sustaining a diagnosed SRC in the past year were 13.7% lower for every one unit increase in conscientiousness (b = -0.147, OR = 0.863, CI = [0.760-0.980], SE = 0.064, p = 0.024).
- Odds of sustaining a diagnosed SRC in the past year were 19.0% higher for every one unit increase in agreeableness (b = 0.174, OR = 1.190, CI = [1.030-1.374], SE = 0.073, p = 0.018).
- Odds of sustaining a diagnosed SRC in the past year were 53.5% lower for those assigned female at birth compared to those assigned male at birth (b = -0.765 OR = 0.465, CI = [0.261-0.827], SE = 0.292, p = 0.009).

Overall, total accuracy was 67.9%, indicating that this model accurately predicted the diagnosed SRC outcome 67.9% of the time. Specificity for this model was 83.4%, indicating that the model accurately predicted if someone did not sustain a diagnosed SRC in the past year 83.4% of the time. Sensitivity for this model was 44.2%, indicating that the model accurately predicted if someone did sustain a diagnosed SRC in the past year 44.2% of the time. This model was better at predicting those who did not sustain an SRC than those who did sustain a diagnosed SRC.

Overall, model accuracy for all three models fell in the acceptable (60-69.9%) to good (70-90%) ranges.

Table 11: Diagnosed SRC Incidence Logistic Regression Model Results

Personality and Social Determinants of Health Predictors

	b	OR	CI	SE	p
Personality Model					
Experience Seeking	-0.023	0.977	0.863-1.106	0.063	0.714
Risk Seeking	0.053	1.054	0.964-1.154	0.046	0.247
Total Impulsivity	-0.044	0.957	0.867-1.056	0.050	0.376
Openness to Experience	-0.153	0.858	0.737-0.999	0.077	0.049*
Conscientiousness	-0.196	0.822	0.702-0.961	0.079	0.014*
Extraversion	0.023	1.024	0.920-1.139	0.054	0.667
Agreeableness	0.194	1.214	1.043-1.413	0.077	0.012*
Neuroticism	-0.003	0.997	0.874-1.137	0.067	0.961
Age	0.021	1.022	0.758-1.377	0.152	0.887
Sex Assigned at Birth	-0.677	0.508	0.270-0.957	0.321	0.036*
Concussion History	-0.349	0.706	0.391-1.274	0.300	0.246
Social Determinants of Health Model					
Race	0.595	1.814	0.821-4.007	0.402	0.140
Age	0.070	1.073	0.798-1.441	0.150	0.640
Sex Assigned at Birth	-0.868	0.419	0.235-0.747	0.293	0.003**
SES	-0.232	0.792	0.667-0.941	0.087	0.008**
Experiences of Discrimination	-0.512	0.599	0.287-1.253	0.374	0.173
ACEs	0.026	1.026	0.861-1.223	0.089	0.773
Pressure	0.205	1.227	0.998-1.508	0.104	0.052
Concussion History	-0.333	0.716	0.401-1.280	0.295	0.259
Final Model					
Openness to Experience	-0.117	0.890	0.778-1.017	0.068	0.087
Conscientiousness	-0.147	0.863	0.760-0.980	0.064	0.024*
Agreeableness	0.174	1.190	1.030-1.374	0.073	0.018*
Sex Assigned at Birth	-0.765	0.465	0.261-0.827	0.292	0.009**
SES	-0.140	0.870	0.737-1.026	0.084	0.098

Note: b = unstandardized regression coefficients; OR = odds ratio; CI = 95% confidence interval around the OR; SE = standard error; * = significant at 0.05, ** = significant at 0.01

Table 12: Diagnosed SRC Incidence Model Logistic Regression Model Fit

Personality and Social Determinants of Health Predictors

	Sensitivity	**Specificity**	**NPV**	**PPV**	**AUC**	**Accuracy**
Personality Model	47.3%	85.1%	0.73	0.66	0.72	70.8%
Social Determinants of Health Model	37.9%	85.9%	0.69	0.62	0.71	67.6%
Final Model	44.2%	83.4%	0.71	0.62	0.72	67.9%

Note: Sensitivity = percentage of those predicted to have one diagnosed SRC who were diagnosed with SRC; Specificity = percentage of those predicted to have zero diagnosed SRC who were not diagnosed with an SRC; NPV = negative predictive value, ratio of true negative predictions taking into account all negative predictions; PPV = positive predictive value, ratio of true positive predictions considering all positive predictions; AUC = area under the ROC curve, which compares the relation between true positive rate and false positive rate; Accuracy = the percentage of true predictions, both positive and negative.

Symptom Reporting Outcomes

Injury-Specific Symptom Reporting Outcomes. The binary injury-specific honesty and comfort in symptom reporting variables were regressed on personality and social determinants of health variables in four separate models using logistic regression. Honesty in symptom reporting results are included in Table 13. Comfort in symptom reporting results are included in Table 14. Sensitivity, specificity, accuracy, NPV, PPV, and AUC for each model are included in Table 15.

Injury-Specific Honesty in Symptom Reporting. The binary injury-specific honesty in symptom reporting outcome was regressed on personality variables in one model, controlling for sex assigned at birth, age, lifetime SRC history, and past year suspected SRC. Openness to experience was significantly associated with odds of being honest in symptom reporting during a participant's most recent diagnosed SRC when controlling for all other predictors in the model. Significant results are interpreted below.

- Odds of being honest in reporting symptoms during the most recent diagnosed SRC were 44.8% higher for every one unit increase in openness to experience (b = 0.370, OR = 1.448, CI = [1.027-2.041], SE = 0.173, p = 0.035).

Overall, total accuracy for this model was 85.4%, indicating that this model accurately predicted honesty in symptom reporting during the most recent diagnosed SRC 85.4% of the time. Specificity for this model was 12.9%, indicating that the model accurately predicted if someone was not honest in symptom reporting during their most recent diagnosed SRC in the past year 12.9% of the time. Sensitivity for this model was 98.5%, indicating that the model accurately predicted if someone was honest in reporting their symptoms during most recent

diagnosed SRC in the past year 98.5% of the time. This model was better at predicting those who were honest than those who were not honest.

The binary injury-specific honesty in symptom reporting outcome was regressed on social determinants of health, controlling for lifetime SRC history and past year suspected SRC. None of these predictors were significantly associated with odds of being honest in symptom reporting during participants' most recent diagnosed SRC. Due to an absence of significant predictors emerging in the social determinants of health model, a final model for this outcome was not included in analyses.

Model fit statistics were not available for this model potentially due to the unbalanced cell sizes compromising the estimation of fit statistics for injury-specific honesty outcome. More specifically, the intersection of low endorsement of lack of honesty and low endorsement of one of the binary categories for several social determinants of health predictors resulted in small cell size although the overall model converged, and standard errors were not exceedingly high.

Table 13: Injury-Specific Honesty in Symptom Reporting Logistic Regression Results

Personality and Social Determinants of Health Predictors

	b	OR	CI	SE	p
Personality Model					
Experience Seeking	-0.124	0.883	0.682-1.143	0.130	0.340
Risk Seeking	0.079	1.082	0.881-1.329	0.103	0.445
Total Impulsivity	-0.047	0.954	0.768-1.184	0.109	0.665
Openness to Experience	0.370	1.448	1.027-2.041	0.173	0.035*
Conscientiousness	-0.023	0.977	0.720-1.325	0.153	0.880
Extraversion	-0.084	0.919	0.660-1.280	0.162	0.608
Agreeableness	0.110	1.116	0.794-1.569	0.170	0.521
Neuroticism	-0.168	0.845	0.622-1.148	0.154	0.277
Age	-0.236	0.790	0.429-1.453	0.307	0.444
Sex Assigned at Birth	-0.511	0.599	0.147-2.440	0.705	0.470
Lifetime SRC History	-0.800	0.449	0.116-1.741	0.678	0.242
Suspected SRC	-0.286	0.751	0.194-2.911	0.682	0.676
Social Determinants of Health Model					
Race	0.465	1.591	0.318-7.970	0.805	0.566
Age	-0.318	0.728	0.404-1.310	0.296	0.288
Sex Assigned at Birth	-0.095	0.909	0.269-3.071	0.608	0.877
SES	-0.186	0.830	0.571-1.206	0.188	0.324
Experiences of Discrimination	-0.763	0.466	0.107-2.034	0.742	0.306
ACEs	0.079	1.082	0.749-1.563	0.185	0.672
Pressure	0.210	1.234	0.806-1.887	0.212	0.327
Lifetime SRC History	-0.434	0.648	0.166-2.529	0.676	0.524
Suspected SRC	-0.136	0.872	0.270-2.816	0.590	0.817

Note: b = unstandardized regression coefficients; OR = odds ratio; CI = 95% confidence interval around the OR; SE = standard error; * = significant at 0.05

Injury-Specific Comfort in Symptom Reporting. The binary injury-specific comfort in symptom reporting outcome was regressed on personality variables in one model, controlling for sex assigned at birth, age, lifetime SRC history, and past year suspected SRC. Past year

suspected SRC was significantly associated with odds of feeling comfortable in symptom reporting during participants' most recent diagnosed SRC when controlling for all other predictors in the model. Significant results are interpreted below.

- Odds of feeling comfortable reporting symptoms during the most recent diagnosed SRC were 72.4% lower for those endorsing a suspected SRC in the past year compared to those who denied suspected SRC in the past year (b = -1.286, OR = 0.276, CI = [0.080-9.560], SE = 0.625, p = 0.042).

Overall, total accuracy for this model was 82.8%, indicating that this model accurately predicted comfort in symptom reporting at most recent diagnosed SRC 98.2% of the time. Model accuracy fell in the excellent range for this model. Specificity for this model was 16.0%, indicating that the model accurately predicted if someone was not comfortable reporting symptoms during their most recent diagnosed SRC in the past year 16.0% of the time. Sensitivity for this model was 98.2%, indicating that the model accurately predicted if someone was comfortable in reporting symptoms during their most recent diagnosed SRC in the past year 98.2% of the time. This model was better at predicting those who were comfortable reporting symptoms than those who were not comfortable.

The binary injury-specific comfort in symptom reporting outcome was regressed on social determinants of health, controlling for lifetime SRC history and past year suspected SRC. None of these predictors were significantly associated with odds of feeling comfortable in symptom reporting for a participant's most recent diagnosed SRC. Due to an absence of significant predictors emerging in the social determinants of health model, a final model was not included in analyses.

Model fit statistics were not available for this model potentially due to the unbalanced cell sizes compromising the estimation of fit statistics for the lack of comfort outcome. More specifically, the intersection of low endorsement of lack of comfort and low endorsement of one of the binary categories for several social determinants of health predictors resulted in a small cell size although the overall model converged and standard errors were not exceedingly high.

Table 14: Injury-Specific Comfort in Symptom Reporting Logistic Regression Model Results

Personality and Social Determinants of Health Predictors

	b	OR	CI	SE	p
Personality Model					
Experience Seeking	-0.105	0.900	0.711-1.140	0.119	0.378
Risk Seeking	0.100	1.106	0.931-1.313	0.086	0.249
Total Impulsivity	-0.194	0.824	0.669-1.014	0.104	0.067
Openness to Experience	0.230	1.259	0.935-1.694	0.149	0.127
Conscientiousness	-0.143	0.866	0.625-1.200	0.161	0.379
Extraversion	0.079	1.082	0.854-1.371	0.119	0.510
Agreeableness	-0.126	0.881	0.634-1.225	0.164	0.446
Neuroticism	-0.098	0.906	0.692-1.185	0.135	0.467
Age	0.083	1.086	0.641-1.841	0.264	0.754
Sex Assigned at Birth	0.213	1.237	0.346-4.427	0.641	0.740
Lifetime SRC History	-0.038	0.963	0.284-2.530	0.612	0.950
Suspected SRC	-1.286	0.276	0.080-9.560	0.625	0.042*
Social Determinants of Health Model					
Race	-1.496	0.224	0.038-1.312	0.891	0.096
Age	0.212	1.236	0.732-2.087	0.262	0.422
Sex Assigned at Birth	0.263	1.300	0.412-4.107	0.579	0.651
SES	-0.052	0.949	0.684-1.318	0.164	0.752
Experiences of Discrimination	-0.326	0.721	0.196-2.658	0.656	0.620
ACEs	0.033	1.034	0.745-1.433	0.165	0.840
Pressure	0.162	1.176	0.755-1.830	0.217	0.461
Lifetime SRC History	-0.304	0.738	0.234-2.325	0.578	0.601
Suspected SRC	-1.013	0.363	0.124-1.065	0.542	0.064

Note: b = unstandardized regression coefficients; OR = odds ratio; CI = 95% confidence interval around the OR; SE = standard error; * = significant at 0.05

Table 15: Injury-Specific Honesty and Comfort in Symptom Reporting Logistic Regression Model Fit

Personality and Social Determinants of Health Predictors

	Sensitivity	Specificity	NPV	PPV	AUC	Accuracy
Honesty Model						
Personality Model	98.5%	12.9%	0.56	0.86	0.74	85.4%
Comfort Model						
Personality Model	98.2%	16.0%	0.73	0.83	0.73	82.8%

Note: Sensitivity = percentage of those predicted to have one diagnosed SRC who were diagnosed with SRC; Specificity = percentage of those predicted to have zero diagnosed SRC who were not diagnosed with an SRC; NPV = negative predictive value, ratio of true negative predictions taking into account all negative predictions; PPV = positive predictive value, ratio of true positive predictions considering all positive predictions; AUC = area under the ROC curve, which compares the relation between true positive rate and false positive rate; Accuracy = the percentage of true predictions, both positive and negative.

General Symptom Reporting Outcomes. The binary general honesty and comfort in symptom reporting variables were regressed on personality and social determinants of health variables in separate models using logistic regression. Honesty in symptom reporting results are included in Table 16. Comfort in symptom reporting results are included in Table 17. Sensitivity, specificity, accuracy, NPV, PPV, and AUC for each model are included in Table 18.

General Honesty in Symptom Reporting. The binary general honesty in symptom reporting outcome was regressed on personality variables in one model, controlling for sex assigned at birth, age, and concussion history. Openness to experience was significantly associated with odds of being generally honest in symptom reporting when controlling for all other predictors in the model. Significant results are interpreted below.

- Odds of being generally honest in reporting symptoms were 21.4% higher for every one unit increase in openness to experience (b = 0.194, OR = 1.214, CI = [1.022-1.441], SE = 0.087, p = 0.027).

Overall, total accuracy for this model was 59.3%, indicating that this model accurately predicted general honesty in symptom reporting 59.3% of the time. Specificity for this model was 39.5%, indicating that the model accurately predicted if someone was generally less than 100% honesty in symptom reporting 39.5% of the time. Sensitivity for this model was 74.5%, indicating that the model accurately predicted if someone reported being generally honest in symptom reporting 74.5% of the time. This model was better at predicting those who were generally honest than predicting those who were less than 100% honest.

The binary general honesty in symptom reporting outcome was regressed on social determinants of health, controlling for concussion history. Pressure to continue playing while

symptomatic was significantly associated with odds of being generally honest in symptom reporting when controlling for all other predictors in the model. Significant results are interpreted below.

- Odds of being generally honest in symptom reporting were 29.7% lower for every one unit increase in pressure to continue playing while symptomatic (b = -0.353, OR = 0.703, CI = [0.548-0.900], SE = 0.124, p = 0.006).

Overall, total accuracy for this model was 66.0%, indicating that this model accurately predicted general honesty in symptom reporting 66.0% of the time. Specificity for this model was 49.4%, indicating that the model accurately predicted if someone was generally less than 100% honesty in symptom reporting 49.4% of the time. Sensitivity for this model was 78.9%, indicating that the model accurately predicted if someone reported being generally honest in symptom reporting 78.9% of the time. This model was better at predicting those who were generally 100% honest than predicting those who were less than 100% honest.

Significant predictors from the previous two models, openness to experience and pressure to continue playing while symptomatic, were included in a final model. Pressure to continue playing was significantly associated with odds of being generally honesty in symptom reporting when controlling for openness to experience. Significant results are interpreted below.

- Odds of being generally honest in symptom reporting were 27.3% lower for every one unit increase in pressure to continue playing while symptomatic (b = -0.319, OR = 0.727, CI = [0.571-0.926], SE = 0.119, p = 0.011).

Overall, total accuracy for this model was 61.8%, indicating that this model accurately predicted general honesty in symptom reporting 61.8% of the time. Specificity for this model

was 42.9%, indicating that the model accurately predicted if someone was generally less than 100% honesty in symptom reporting 42.9% of the time. Sensitivity for this model was 76.3%, indicating that the model accurately predicted if someone reported being generally honest in symptom reporting 76.3% of the time. This model was better at predicting those who were generally 100% honest than predicting those who were less than 100% honest.

Overall, model accuracy fell within the acceptable range for these models, with the social determinants of health model demonstrating the highest accuracy.

Table 16: General Honesty in Symptom Reporting Logistic Regression Model Results

Personality and Social Determinants of Health Predictors

	b	OR	CI	SE	p
Personality Model					
Experience Seeking	-0.090	0.913	0.790-1.056	0.073	0.220
Risk Seeking	-0.062	0.940	0.850-1.040	0.050	0.226
Total Impulsivity	-0.072	0.930	0.831-1.041	0.056	0.206
Openness to Experience	0.194	1.214	1.022-1.441	0.087	0.027*
Conscientiousness	-0.031	0.969	0.819-1.147	0.085	0.715
Extraversion	-0.008	0.992	0.869-1.132	0.066	0.900
Agreeableness	-0.038	0.963	0.822-1.128	0.080	0.639
Neuroticism	-0.056	0.946	0.820-1.090	0.072	0.440
Age	0.129	1.138	0.772-1.675	0.191	0.502
Sex Assigned at Birth	-0.200	0.818	0.388-1.728	0.376	0.596
Concussion History	-0.450	0.637	0.320-1.271	0.346	0.198
Social Determinants of Health Model					
Race	0.144	1.155	0.474-2.814	0.451	0.750
Age	0.129	1.138	0.791-1.635	0.181	0.479
Sex Assigned at Birth	0.081	1.084	0.522-2.250	0.365	0.826
SES	-0.006	0.994	0.773-1.279	0.122	0.961
Experiences of Discrimination	0.813	1.156	0.945-5.384	0.440	0.067
ACEs	-0.069	0.933	0.763-1.142	0.101	0.497
Pressure	-0.353	0.703	0.548-0.900	0.124	0.006**
Concussion History	-0.285	0.752	0.370-1.527	0.354	0.424
Final Model					
Open	0.084	1.088	0.945-1.251	0.071	0.238
Pressure	-0.319	0.727	0.571-0.926	0.119	0.011*

Note: b = unstandardized regression coefficients; OR = odds ratio; CI = 95% confidence interval around the OR; SE = standard error; * = significant at 0.05, ** = significant at 0.01

General Comfort in Symptom Reporting. The binary general comfort in symptom reporting outcome was regressed on personality variables in one model, controlling for sex

assigned at birth, age, and concussion history. Total impulsivity and openness to experience were significantly associated with odds of being generally comfortable in symptom reporting when controlling for all other predictors in the model. Significant results are interpreted below.

- Odds of feeling generally comfortable in symptom reporting were 11.2% lower for every one unit increase in impulsivity (b = -0.119, OR = 0.888, CI = [0.799-0.987], SE = 0.053, p = 0.027).
- Odds of feeling generally comfortable in symptom reporting were 26.8% higher for every one unit increase in openness to experience (b = 0.237, OR = 1.268, CI = [1.069-1.502], SE = 0.086, p = 0.006).

Overall, total accuracy for this model was 65.4%, indicating that this model accurately predicted the diagnosed SRC outcome 65.4% of the time. Specificity for this model was 58.6%, indicating that the model accurately predicted if someone was generally less than 100% comfortable in reporting symptoms 58.6% of the time. Sensitivity for this model was 71.8%, indicating that the model accurately predicted if someone was generally comfortable in symptom reporting 71.8% of the time. This model was better at predicting those who were generally comfortable reporting symptoms than those who were less than 100% comfortable.

The binary general comfort in symptom reporting outcome was regressed on social determinants of health, controlling for concussion history. Pressure to continue playing was significantly associated with comfort in symptom reporting when controlling for all other predictors in the model. Significant results are interpreted below.

- Odds of feeling generally comfortable in symptom reporting were 33.0% lower for every one unit increase in pressure to continue playing while symptomatic (b = -0.400, OR = 0.670, CI = [0.536-0.838], SE = 0.113, $p < 0.001$).

Overall, total accuracy for this model was 64.5%, indicating that this model accurately predicted the diagnosed SRC outcome 64.5% of the time. Specificity for this model was 56.7%, indicating that the model accurately predicted if someone was generally less than 100% comfortable in reporting symptoms 56.7% of the time. Sensitivity for this model was 70.0%, indicating that the model accurately predicted if someone was generally comfortable in symptom reporting 70.0% of the time. This model was better at predicting those who were generally comfortable reporting symptoms than those who were less than 100% comfortable.

Significant predictors from the two previous models were included in a final model. The binary general comfort in symptom reporting variable was regressed on total impulsivity, openness to experience, and pressure to continue playing. Pressure to continue playing was significantly associated with general comfort in symptom reporting while controlling for all other predictors in the model. Significant results are interpreted below.

- Odds of feeling generally comfortable in symptom reporting were 29.6% lower for every one unit increase in pressure to continue playing while symptomatic (b = -0.351, OR = 0.704, CI = [0.570-0.868], SE = 0.106, $p < 0.001$).

Overall, total accuracy for this model was 63.8%, indicating that this model accurately predicted the general comfort in symptom reporting outcome 63.8% of the time. Specificity for this model was 57.5%, indicating that the model accurately predicted if someone was generally less than 100% comfortable in reporting symptoms 57.5% of the time. Sensitivity for this model

was 70.8%, indicating that the model accurately predicted if someone was generally comfortable in symptom reporting 70.8% of the time. This model was better at predicting those who were generally comfortable reporting symptoms than those who were less than 100% comfortable.

Overall, model accuracy for comfort in symptom reporting models fell in the acceptable range.

Table 17: General Comfort in Symptom Reporting Logistic Regression Model Results

Personality and Social Determinants of Health Predictors

	b	OR	CI	SE	p
Personality Model					
Experience Seeking	-0.080	0.923	0.806-1.057	0.067	0.243
Risk Seeking	-0.060	0.941	0.857-1.034	0.047	0.204
Total Impulsivity	-0.119	0.888	0.799-0.987	0.053	0.027*
Openness to Experience	0.237	1.268	1.069-1.502	0.086	0.006**
Conscientiousness	-0.109	0.897	0.763-1.055	0.082	0.187
Extraversion	0.039	1.040	0.925-1.168	0.059	0.509
Agreeableness	-0.022	0.978	0.835-1.146	0.080	0.783
Neuroticism	-0.059	0.942	0.820-1.083	0.071	0.402
Age	0.091	1.095	0.789-1.522	0.166	0.585
Sex Assigned at Birth	-0.545	0.580	0.285-1.178	0.359	0.131
Concussion History	-0.583	0.558	0.298-1.043	0.317	0.067
Social Determinants of Health Model					
Race	0.026	1.026	0.421-2.500	0.451	0.955
Age	0.078	1.081	0.783-1.492	0.163	0.635
Sex Assigned at Birth	-0.359	0.698	0.365-1.337	0.329	0.277
SES	0.102	1.108	0.915-1.340	0.097	0.292
Experiences of Discrimination	0.460	1.584	0.722-3.475	0.398	0.250
ACEs	0.057	1.059	0.888-1.263	0.089	0.522
Pressure	-0.400	0.670	0.536-0.838	0.113	0.0005***
Concussion History	-0.461	0.631	0.338-1.178	0.316	0.147
Final Model					
Total Impulsivity	-0.073	0.929	0.859-1.005	0.039	0.066
Openness to Experience	0.101	1.106	0.963-1.270	0.070	0.152
Pressure	-0.351	0.704	0.570-0.868	0.106	0.001***

Note: b = unstandardized regression coefficients; OR = odds ratio; CI = 95% confidence interval around the OR; SE = standard error; * = significant at 0.05, ** = significant at 0.01; *** = significant at 0.001

Table 18: General Honesty and Comfort in Symptom Reporting Logistic Regression Model Fit

Personality and Social Determinants of Health Predictors

	Sensitivity	Specificity	NPV	PPV	AUC	Accuracy
Honesty Model						
Personality	74.5%	39.5%	0.55	0.61	0.63	59.3%
Social Determinants of Health	78.9%	49.4%	0.67	0.66	0.69	66.0%
Final Model	76.3%	42.9%	0.59	0.63	0.68	61.8%
Comfort Model						
Personality	71.8%	58.6%	0.66	0.65	0.68	65.4%
Social Determinants of Health	70.0%	56.7%	0.65	0.64	0.68	64.5%
Final Model	70.8%	57.5%	0.64	0.64	0.69	63.8%

Note: Sensitivity = percentage of those predicted to have one diagnosed SRC who were diagnosed with SRC; Specificity = percentage of those predicted to have zero diagnosed SRC who were not diagnosed with an SRC; NPV = negative predictive value, ratio of true negative predictions taking into account all negative predictions; PPV = positive predictive value, ratio of true positive predictions considering all positive predictions; AUC = area under the ROC curve, compares the relation between true positive rate and false positive rate; Accuracy = the percentage of true predictions.

Symptom Reporting Predictors

The injury-specific honesty and comfort in symptom reporting variables were investigated as predictors of RTP timeline using survival analysis. General honesty and comfort in symptom reporting were investigated as predictors of diagnosed SRC incidence using logistic regression. All results can be found in Table 19.

Time to RTP.

Kaplan Meier. Kaplan Meier plots are included in Figures 16 and 17 below. Results for each variable include five plots, one for each imputed dataset as pooled results are not available for these analyses. Subsequent logrank test results are interpreted below plots for variables meeting the proportionality of hazards assumption.

Survival curves for binary injury-specific honesty in symptom reporting were significantly different, such that those who reported lack of honesty in symptom reporting had a higher probability of RTP in two imputed datasets (log rank p-values = .018, .042, .050, .060, .094).

Survival curves binary injury-specific comfort in symptom reporting were significantly different, such that those who reported lack of comfort in symptom reporting had a higher probability of RTP in all five imputed datasets (logrank p-values < .01).

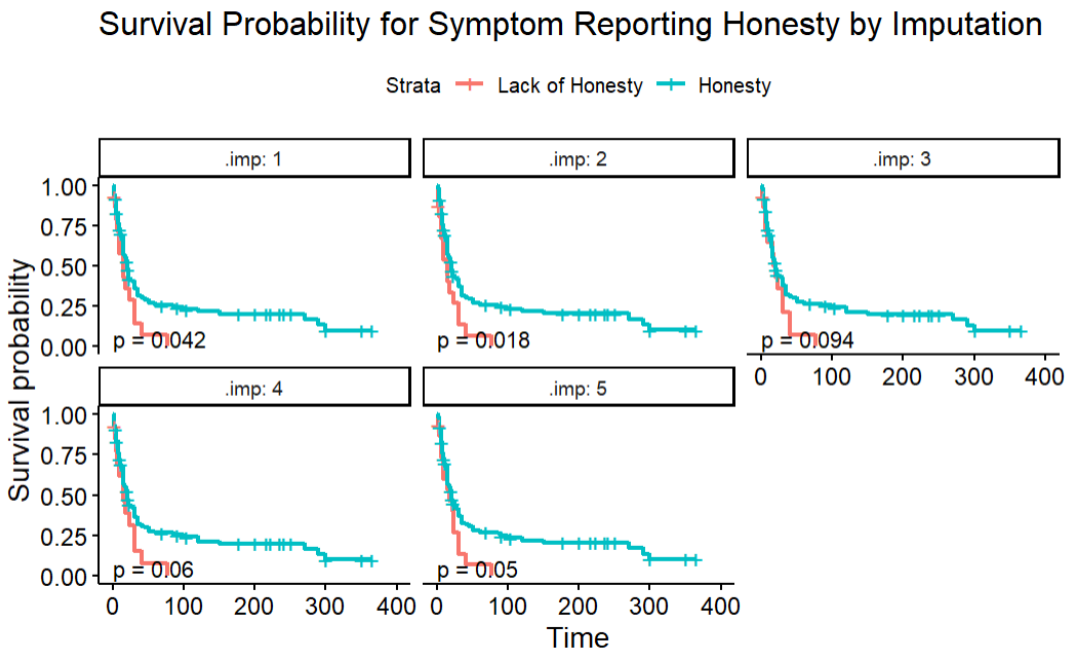

Figure 16. Three imputed datasets showed significant differences in survival curves between those who reported honesty in symptom reporting and those who denied honesty in symptom reporting. Those who reported honesty in symptom reporting had a significantly higher probability of RTP.

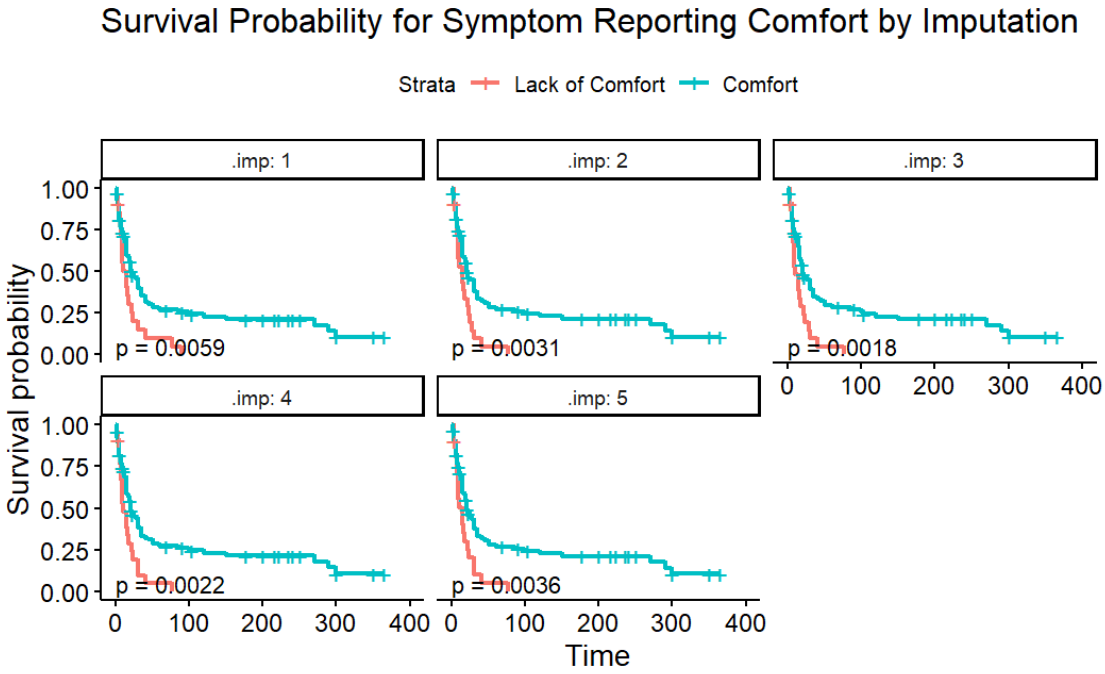

Figure 17. All five imputed datasets showed significant differences in survival curves between those who reported comfort in symptom reporting and those who denied comfort in symptom reporting. Those who denied comfort in symptom reporting had a significantly higher probability of RTP.

Cox Proportional Hazard Regression. Individual Cox proportional hazards models were run for each variable of interest, with the survival object regressed on injury-specific honesty in symptom reporting, injury-specific comfort in symptom reporting, sex assigned at birth, age, SRC history, suspected SRC, and medical clearance in separate individual models. Results were pooled across imputed datasets using Rubin's Rules (Rubin, 1987). Sex assigned at birth and comfort in symptom reporting were significantly associated with RTP. Significant results are interpreted below.

- Risk of RTP was 56.6% lower for those who reported comfort in symptom reporting compared to those who reported lack of comfort (b = -0.833, HR = 0.434, CI = [0.260-0.726], SE = 0.260, p = 0.002).
- Risk of RTP was 55.6% higher for those assigned female at birth compared to those assigned male at birth (b = 0.442, HR = 1.556, CI = [1.071-2.260], SE = 0.188, p = 0.021).

These significant variables were included together in a final model, stratified by the past year suspected SRC variable. Both injury-specific comfort in symptom reporting and sex assigned at birth were significantly associated with time to RTP when controlling for the other variables in the model. Significant results are interpreted below.

- Risk of RTP was 57.7% lower for those who reported comfort in symptom reporting compared to those who reported lack of comfort (b = -0.859, HR = 0.423, CI = [0.245-0.730], SE = 0.274, p = 0.002).
- Risk of RTP was 69.5% higher for those assigned female at birth compared to those assigned male at birth (b = 0.528, HR = 1.695, CI = [1.099-2.614], SE = 0.218, p = 0.020).

Table 19: Cox Proportional Hazards Model Results

Injury-Specific Honesty and Comfort in Symptom Reporting Predictors

	b	HR	CI	SE	p
Symptom Reporting Predictors					
Comfort	-0.833	0.434	0.260-0.726	0.260	0.002**
Honesty	-0.535	0.585	0.329-1.041	0.289	0.068
Control Variables					
Age	0.110	1.116	0.934-1.334	0.090	0.222
Sex Assigned at Birth	0.442	1.556	1.071-2.260	0.188	0.021*
Lifetime SRC History	0.244	1.277	0.854-1.909	0.203	0.231
Suspected SRC	0.236	1.266	0.862-1.861	0.194	0.227
Medical Clearance	0.342	1.408	0.729-2.719	0.332	0.305
Final Comfort Model					
Comfort	-0.859	0.423	0.245-0.730	0.274	0.002**
Sex Assigned at Birth	0.528	1.695	1.099-2.614	0.218	0.020*

Note: b = unstandardized regression coefficients; HR = hazard ratio; CI = 95% confidence interval around HR; SE = standard error; * = significant at 0.05, ** = significant at 0.01

Diagnosed SRC Incidence. Diagnosed SRC incidence was regressed on general honesty and general comfort in symptom reporting in two separate models, each controlling for age, sex assigned at birth, and concussion history. Sex assigned at birth was significantly associated with odds of diagnosed SRC in the past year in both models. Significant results are interpreted below. All results are included in Table 20. Sensitivity, specificity, accuracy, NPV, PPV, and AUC are included in Table 21.

- Odds of diagnosed SRC in the past year were 60.5% lower for those assigned female at birth compared to those assigned male at birth in the honesty in symptom reporting model (b = -0.927, OR = 0.396, CI = [0.216-0.725], SE = 0.307, p = 0.003).

- Odds of diagnosed SRC in the past year were 58.2% lower for those assigned female at birth compared to those assigned male at birth in the comfort in symptom reporting model (b = -0.869, OR = 0.419, CI = [0.230-0.763], SE = 0.304, p = 0.005).

Overall, total accuracy for this model was 66.5%, indicating that this model accurately predicted the diagnosed SRC outcome 66.5% of the time. Specificity for the honesty model was 77.7%, indicating that the model accurately predicted if someone did not sustain a diagnosed SRC in the past year 77.7% of the time. Sensitivity for this model was 51.1%, indicating that the model accurately predicted if someone did sustain a diagnosed SRC in the past year 51.1% of the time. This model was better at predicting those who did not sustain an SRC than those who did.

Overall, total accuracy for this model was 66.0%, indicating that this model accurately predicted the diagnosed SRC outcome 66.0% of the time. Specificity for the comfort model was 76.1%, indicating that the model accurately predicted if someone did not sustain a diagnosed SRC in the past year 76.1% of the time. Sensitivity for this model was 51.8%, indicating that the model accurately predicted if someone did sustain a diagnosed SRC in the past year 51.8% of the time. This model was better at predicting those who did not sustain an SRC than those who did.

Overall, accuracy for both models fell in the acceptable range for model accuracy.

Table 20: Diagnosed SRC Incidence Logistic Regression Model Results

General Honesty and Comfort in Symptom Reporting Predictors

	b	OR	CI	SE	p
Honesty Model					
Honesty	-0.307	0.736	0.397-1.364	0.313	0.328
Age	-0.037	0.964	0.712-1.304	0.153	0.809
Sex Assigned at Birth	-0.927	0.396	0.216-0.725	0.307	0.003**
Concussion History	-0.393	0.674	0.363-1.253	0.314	0.211
Comfort Model					
Comfort	-0.342	0.710	0.390-1.291	0.303	0.260
Age	-0.032	0.968	0.717-1.308	0.152	0.834
Sex Assigned at Birth	-0.869	0.419	0.230-0.763	0.304	0.005**
Concussion History	-0.451	0.637	0.344-1.179	0.312	0.150

Note: b = unstandardized regression coefficients; OR = odds ratio; CI = 95% confidence interval around the OR; SE = standard error; * = significant at 0.05, ** = significant at 0.01

Table 21: Diagnosed SRC Incidence Logistic Regression Model Fit

General Honesty and Comfort in Symptom Reporting Predictors

	Sensitivity	**Specificity**	**NPV**	**PPV**	**AUC**	**Accuracy**
Honesty Model	51.1%	77.7%	0.69	0.62	0.63	66.5%
Comfort Model	51.8%	76.1%	0.69	0.61	0.65	66.0%

Note: Sensitivity = percentage of those predicted to have one diagnosed SRC who were diagnosed with SRC; Specificity = percentage of those predicted to have zero diagnosed SRC who were not diagnosed with an SRC; NPV = negative predictive value, ratio of true negative predictions taking into account all negative predictions; PPV = positive predictive value, ratio of true positive predictions considering all positive predictions; AUC = area under the ROC curve, compares the relation between true positive rate and false positive rate; Accuracy = the percentage of true predictions.

Summary of Results

Tables B1-B3 in Appendix B include summaries of significant preliminary model results from all analyses, significant final model results from all analyses, and model fit statistics for logistic regression analyses. Preliminary models are those that included just one predictor (in Cox regression models) or included only personality or social determinants of health predictors (in logistic regression models) before significant predictors were investigated together in final models. The only models that did not include both preliminary and final models were those in which diagnosed SRC incidence was regressed on general honesty and general comfort in symptom reporting in two separate models; these models were considered final models.

DISCUSSION

Adolescents in the United States have high rates of athletic participation and experience high incidence of SRC (Bryan et al., 2016; Harmon et al., 2019). Recent findings underscore the idea that SRC incidence is likely even higher due to as many as 50% of SRCs remaining undiagnosed (Asken et al., 2016). As a result, recent research has called for studies that bolster the ability to predict and identify those most at risk of SRC and related outcomes (i.e., lack of symptom reporting, premature RTP) to mitigate risk of prolonged symptoms and future injury (Harmon et al., 2019). Research that has investigated *comprehensive* models of SRC-related behaviors, like lack of symptom reporting, has resulted in criticism that studies including *comprehensive* models contribute results that have lower practical utility due to the high amount of detailed information needed to predict outcomes (Carpenter et al., 2020; Cicero et al., 2022; Milroy et al., 2020). In response, recent literature has attempted to identify a parsimonious group of predictors associated with SRC outcomes that also has high practical utility (i.e., using information that is easily attained from athletes). This work has concluded that nuanced constellations of factors are associated with specific SRC outcomes; for example, factors that are most salient in predicting earlier RTP are not necessarily most salient in predicting higher incidence of SRC (i.e., Weishaar et al., 2022a, 2022b). Among the limited number of studies investigating these questions are those that have identified salient personality and social determinants of health factors that impact outcomes such as SRC incidence, time to RTP, and symptom reporting (Callahan et al., 2022; Wallace et al., 2020b; Weishaar et al., 2022a, 2022b). Ultimately, this study aimed to answer calls from previous literature to continue identifying both

individual difference and environmental factors that are most strongly associated with SRC outcomes, with a particular focus on predictors that have high practical utility.

The overarching specific aim of the current study was to explicate the relations between personality and social determinants of health predictors and SRC outcomes that have been deemed important or pivotal in the health outcomes of adolescent athletes; these outcomes included time to RTP, diagnosed SRC incidence, and symptom reporting. Ultimately, this study aimed to identify which predictors, both at the individual and environmental levels, are most informative in predicting these outcomes to inform targeted prevention and intervention efforts.

Time to RTP

RTP has been established as a pivotal process in SRC recovery, with a gradual stepwise protocol advised such that cardiovascular effort and contact are increased along with decreasing symptom presentation over time until an athlete is officially medically cleared to RTP (Edwards & Bodle, 2014; Harmon et al., 2019; Lumba-Brown et al., 2018). Time to RTP is important such that premature RTP could increase one's risk of subsequent SRC and symptom burden at current and future injury (Barnhart et al., 2021; Dessy et al., 2017; McCrea et al., 2009). Longer than advised time to RTP can also have adverse effects such that athlete's symptoms are exacerbated due to factors such as low mood and decreasing cardiovascular fitness (Edwards & Bodle, 2014). The current study investigated personality and social determinants of health factors for their relations to time to RTP to expand on limited existing literature that has identified factors that impact individual tendencies to RTP earlier or later.

The current study results demonstrated that median days to RTP was 17. Recent studies using varied methodology have concluded median RTP for adolescent and/or young adult athletes ranged from 1 to 7 days in an EMA study (Wiebe et al., 2022) and 21 to 22 days in

cross-sectional studies (Weishaar et al., 2022a; Worts et al., 2022). Wait and colleagues (2022) found that 80% of individuals RTP within 21 days following diagnosed SRC. Current study results were consistent with these previous findings. It is also important to note that RTP timeline is influenced by presence or absence of official medical clearance to RTP and subsequent timeline of medical clearance (Covassin et al., 2021). Covassin and colleagues (2021) found that mean time to medical clearance for high school athletes was 11 days. However, individual and family decisions to engage in official RTP outside of medical clearance decisions are also an important consideration (i.e., Broglio et al., 2022).

The current study investigated personality and social determinants of health factors that may influence individual time to RTP following an SRC that was diagnosed in the past year. Results from the current study demonstrated that personality factors did not emerge as significantly associated with time to RTP, which was different from the prediction that higher conscientiousness would be significantly associated with lower risk of RTP ("later RTP"), and higher experience seeking, risk seeking, and impulsivity would be significantly associated with higher risk of RTP ("earlier RTP"). These results were also counter to a previous study that found that higher levels of experience seeking, attentional impulsivity, and motor impulsivity were significantly associated with earlier RTP and higher levels of conscientiousness were significantly associated with later RTP (Weishaar et al., 2022a).

Social determinants of health factors in this study, sex assigned at birth and SES, emerged as significantly associated with time to RTP, such that those assigned female at birth and those reporting higher SES demonstrated earlier RTP, or higher risk of RTP. Those assigned female at birth also demonstrated significantly higher likelihood of RTP across the study time frame in Kaplan Meier analyses. These results were counter to study predictions that female sex assigned

at birth and higher SES would be associated with later RTP. No other social determinants of health emerged as significantly associated with this outcome, which is counter to the study prediction that social determinants of health typically associated with more privilege would be associated with later RTP.

Limited previous work examining social determinants of health and RTP has found that those identifying as assigned male at birth tended to RTP more quickly (Broglio et al., 2022), or that sex assigned at birth did not have a significant impact on time to RTP (Weishaar et al., 2022a). The current study findings demonstrated that the effect of sex assigned at birth on time to RTP may vary by sample due to differences in sample characteristics; for example, the current study included adolescent athletes, while other studies have included samples of college students or athletes. In the context of this study, it is possible that those higher in SES had more access to resources and medical professionals to assist with RTP timeline and provide official medical clearance, thus returning to play more quickly. Wallace and colleagues (2020b) found that high school students reporting higher SES performed significantly better on neurocognitive and oculomotor testing, often used to assess SRC and inform RTP. Additionally, individuals from higher SES backgrounds have been found to be significantly more likely to follow medical recommendations and to present to a specialty concussion clinic as opposed to the emergency department (Mohammed et al., 2022; Pate et al., 2022). These studies support current findings that those at higher SES had higher risk of RTP across the study timeframe.

When significant predictors from individual personality and social determinants of health models, sex assigned at birth and SES, were included in a final model SES emerged as positively and significantly associated with earlier RTP. It is evident that SES is an important factor in time to RTP following diagnosed SRC among adolescent athletes, but the specific mechanism that

may help explain why those at higher SES report earlier RTP remains unclear. The current study is the first to investigate many of these social determinants of health for their relations to RTP timeline and the field would benefit from further investigation to substantiate results and identify other potentially influential social determinants of health among specific groups of athletes.

Diagnosed SRC Incidence

1.1-1.9 million SRCs occur among youth in the United States every year, with 400,000 of these injuries occurring in high school athletes (Bryan et al., 2016; Harmon et al., 2019). This incidence rate is likely even higher than cited due to research concluding that as many as 50% of SRCs remain undiagnosed (Asken et al., 2016). With high incidence rates of SRCs, research calls for identification of factors that contribute to SRC risk to inform prevention and intervention efforts. To date, several studies have investigated associations between personality and identify-related factors and SRC incidence, finding that higher levels of extraversion (Weishaar et al., 2022b), sensation seeking (Beidler et al., 2021; Liebel et al., 2020; Weishaar et al., 2022b), impulsivity (Beidler et al., 2021; Weishaar et al., 2022b), male sex assigned at birth (Gunn et al., 2022; Wallace et al., 2017), and lower SES (Sidhar et al., 2022) were associated with higher SRC incidence, although few of these studies have investigated these research questions in a sample of adolescent athletes.

Regarding the diagnosed SRC incidence outcome in the current study, several personality variables were significantly associated with odds of sustaining a diagnosed SRC in the past year. Higher levels of agreeableness were significantly associated with higher odds of diagnosed SRC, while higher levels of conscientiousness and openness to experience were significantly associated with lower odds of sustaining a diagnosed SRC in the past year. Openness to experience results were consistent with predictions, while agreeableness and conscientiousness

results were counter to study predictions. Study hypotheses also predicted that higher levels of experience seeking, impulsivity, extraversion, and neuroticism would be significantly associated with higher odds of diagnosed SRC incidence, and none of these variables were significant in this study.

The limited number of existing studies investigating the associations between personality and SRC history and/or incidence have found significant and positive relations between sensation seeking, impulsivity, and SRC incidence outcomes (Beidler et al., 2017, 2021; Liebel et al., 2020; Weishaar et al., 2022b); however, these personality traits were not significantly associated with SRC incidence in this study. The current study is the first to investigate relations between personality and SRC incidence in an adolescent sample; results of the current study likely speak to the nuanced and sample-specific nature of the relations between personality and diagnosed SRC incidence. While several of the current study results were counter to predictions, current study results were consistent in many ways with previous literature. For example, conscientiousness is often conceptualized as a protective personality factor such that those higher in this personality trait are more cautious and rule driven (Poropat, 2009). In this study, those higher in conscientiousness were less likely to have sustained a diagnosed SRC in the past year. Additionally, higher odds of SRC in this study are consistent with a recent study that found that agreeableness was positively associated with multiple undiagnosed SRC incidents (Beidler et al., 2017). Because the outcome was *diagnosed* SRC incidence in this study, both the *diagnosed* aspect of the outcome and the *incidence* aspect of this outcome are relevant. For example, openness to experience, typically associated with greater health risk behavior engagement, may be less associated with *diagnosis* of SRC and more associated with *incidence* of the injury in general. Additionally, this finding is consistent with another study in which the current author

examined associations between personality and SRC incidence in a college student sample (Weishaar et al., 2023b). More research is needed to contribute greater understanding about the degree to which both the diagnosed status of the injury, and injury incidence itself, are differentially related to study predictors.

In these analyses, sex assigned at birth and SES emerged as significantly associated with diagnosed SRC incidence such that those assigned male at birth and those reporting lower SES were more likely to sustain a diagnosed SRC in the past year. These results were counter to predictions; hypotheses included female sex assigned at birth and higher SES as risk factors for diagnosed SRC in the past year. Additionally, no other social determinants of health emerged as significantly associated with this outcome, which is counter to the study prediction that social determinants of health typically associated with more privilege would be associated with higher odds of diagnosed SRC. These results can be understood in the context of the existing body of literature. For example, while those assigned female at birth are cited as more likely to report symptoms of SRC (Anderson et al., 2021; Wallace et al., 2017), those assigned male at birth have been found to sustain more SRC (Gunn et al., 2022). A recent study found that those from lower SES backgrounds were likely to have a positive SRC history, regardless of diagnosed status of SRC (Sidhar et al., 2022).

When significant results from preliminary models were included together in a final model, conscientiousness, agreeableness, and sex assigned at birth were significantly associated with diagnosed SRC incidence. Higher levels of conscientiousness were associated with lower odds of diagnosed SRC, while higher levels of agreeableness and male sex assigned at birth were significantly associated with higher odds of diagnosed SRC. These results were consistent in directionality and magnitude to results of the preliminary models. These predictors emerging as

significant in this final model demonstrated that these factors are most salient in predicting diagnosed SRC incidence in this sample.

The current study also examined sensitivity, specificity, and classification accuracy of study models in predicting odds of diagnosed SRC. Similar to Weishaar and colleagues (2022b), the current study found that models were significantly better at predicting those who did not sustain a diagnosed SRC (specificity) than those who did sustain a diagnosed SRC (sensitivity). For both the current study and previous study models, model prediction of those who did sustain a diagnosed SRC was ~37-51% accurate, landing in the poor range for sensitivity. Specificity between these studies ranged from 76-94%, indicating a "good" ability to predict those who did not sustain an SRC. Overall accuracy for the models fell in the acceptable to good ranges. The current study provides further evidence that models examining personality and social determinants of health provide important information in the accurate prediction of those at risk for SRC, while also leaving room for other future predictors to improve model accuracy.

Symptom Reporting Outcomes

Symptom reporting has been identified as the most sensitive indicator of SRC among athletes and is considered a primary mechanism by which SRCs are diagnosed and time to RTP is informed (Harmon et al., 2019; Khurana & Kaye, 2012). Several studies have attempted to create comprehensive models that contain factors such as participant beliefs about their own ability to report symptoms, others' perceptions of their symptoms, and consequences of behavior (Carpenter et al., 2020). These models have demonstrated limited ability to predict actual symptom reporting behavior and have been criticized for an over-emphasis on individual-level factors and lack of practical utility. Recent literature has also cited the importance of *ongoing* symptom reporting, as some athletes experience delayed onset of symptoms following injury

(Eagle et al., 2022; Trbovich et al., 2023). However, limited work has investigated athlete tendencies to report symptoms.

Limited previous literature on predictors of symptom reporting has concluded that higher levels of neuroticism and lower levels of agreeableness were associated with higher report of symptoms (Merritt et al., 2015). However, the design of this study was such that symptom reports were assessed at pre-season baseline; thus, this study measured a tendency to have and/or report symptoms at baseline more than a tendency to report symptoms upon injury. Another recent study that investigated associations between sensation seeking and SRC help-seeking behaviors did not find significant associations between sensation seeking and symptom reporting (Callahan et al., 2022). Related to athlete identities, numerous studies have found that those identifying as female are more likely to report symptoms (Anderson et al., 2021; Kerr et al., 2016; Register-Mihalik et al., 2013; Wallace et al., 2017), those experiencing pressure to continue playing after a hit to the head are less likely to report symptoms (Kroshus et al., 2015b), those identifying as White are more likely to report symptoms (Wallace et al., 2018), and those with a positive concussion history are less likely to report symptoms (Anderson et al., 2021; O'Connor et al., 2020).

In the current study, openness to experience was positively associated with several of the symptom reporting outcomes, injury-specific honesty, general honesty, and general comfort in symptom reporting, such that at higher levels of openness to experience individuals were more likely to be honesty and/or comfortable reporting their symptoms of SRC. These results were counter to predictions, but consistent with literature that suggests that those higher in openness to experience may be more emotionally aware; thus, these individuals may label and communicate symptoms more often and more comfortably than other individuals (Poropat, 2009). Pressure to

continue playing also was negatively and significantly associated with several of the symptom reporting outcomes such that higher levels of pressure to continue playing resulted in less general honesty and comfort in reporting symptoms. These results were consistent with predictions and consistent with literature suggesting that individuals who experience pressure to continue playing from more parties in their life are more likely to refrain from symptom reporting (Kroshus et al., 2015b).

Additionally, impulsivity was significantly and negatively associated with general comfort in symptom reporting such that at higher levels of impulsivity, individuals were less likely to feel comfortable reporting symptoms. This finding was consistent with study predictions. Since the impulsivity measure used in the study assesses general impulsivity, conclusions cannot be drawn about specific implications for the relation between type of impulsivity and comfort in symptom reporting. A possible explanation could be that those who are less inclined towards planning may be less comfortable thinking ahead to determine a time or person to report symptoms to (Fossati et al., 2002; Patton et al., 1995; Stanford et al., 2009).

Additionally, higher levels of experience seeking, conscientiousness, agreeableness, and neuroticism were predicted to be associated with higher levels of honesty and comfort in symptom reporting, while higher levels of risk seeking and extraversion were predicted to be significantly associated with lower odds of honesty and comfort in symptom reporting; however, none of these factors emerged as significantly associated with symptom reporting outcomes. This is consistent with a recent study that found that sensation seeking was not significantly associated with symptom reporting behaviors (Callahan et al., 2022). Outside of pressure to continue playing, there were no other social determinants of health that were significantly associated with these symptom reporting outcomes despite predictions that social determinants

of health typically associated with more privilege would be associated with more honesty and comfort in symptom reporting.

Since both personality and social determinants of health factors emerged as significantly associated with general honesty and general comfort outcomes, final models including significant predictors from preliminary models were run for these outcomes. Final models were not run for injury-specific symptom reporting outcomes due to lack of significant predictors in preliminary models. General honesty in symptom reporting was regressed on openness to experience and pressure to continue playing, with pressure being negatively and significantly associated with general honesty in symptom reporting in this final model. General comfort in symptom reporting was regressed on impulsivity, openness to experience, and pressure to continue playing. Pressure to continue playing was negatively and significantly associated with general comfort in symptom reporting in this final model. Results of these final models demonstrated that pressure to continue playing is the most salient predictor of general tendencies to be honesty or comfortable reporting symptoms in this sample.

Model fit for symptom reporting outcomes demonstrated an interesting trend; these models were exceptionally sensitive (i.e., predicting those who were honest accurately ~98% of the time), but were not very specific (i.e., predicting those who were not honest accurately ~15% of the time). These results followed an opposite trend to diagnosed SRC incidence models in this study, which were far more accurate in predicting those who did not sustain an SRC than those who did. These results were also in contrast to a study on symptom nondisclosure that found that models including gender, SRC knowledge, pressure to continue playing, and SRC history were exceptionally specific, but not sensitive (O'Connor et al., 2020).

Symptom Reporting Predictors

Due to the cited importance of symptom reporting in RTP and SRC diagnosis (i.e., Lumba-Brown, 2018), the current study included models regressing primary study outcomes of time to RTP and diagnosed SRC incidence on symptom reporting variables to preliminarily investigate symptom reporting as influential in these outcomes. I predicted that those who felt more comfortable and were more honest in reporting symptoms would RTP later and have higher odds of diagnosed SRC in the past year.

In descriptive Kaplan Meier plots, both lack of comfort and lack of honesty in symptom reporting were associated with significantly earlier RTP than those who reported being honest or comfortable reporting symptoms. In Cox regression models, comfort in symptom reporting emerged as significantly associated with time to RTP such that those reporting comfort in symptom reporting demonstrated later RTP, or lower risk of RTP across the time span in the current study. Comfort in symptom reporting also emerged as negatively and significantly associated with the time to RTP outcome in a final model, controlling for sex assigned at birth. This demonstrated that comfort in symptom reporting is one of the most salient predictors of time to RTP in this study. These results were consistent with predictions. Honesty in symptom reporting did not emerge as significantly associated with time to RTP. In both honesty and comfort models, sex assigned at birth emerged as significantly associated with time to RTP such that those assigned female at birth had significantly earlier RTP than those assigned male at birth, which was consistent with other RTP models in this study.

In models examining symptom reporting predictors of diagnosed SRC incidence, both honesty and comfort in symptom reporting emerged as negatively associated with incidence of diagnosed SRC, although these results were not significant. The directions of these effects were

counter to predictions. Additionally, sex assigned at birth was significantly associated with diagnosed SRC incidence in both models such that those assigned female at birth had significantly lower odds of diagnosed SRC than those assigned male at birth, which is consistent with previous literature and other diagnosed SRC model results in this study (Gunn et al., 2022).

Symptom prediction models generally supported the idea that symptom reporting is positively associated with less adverse outcomes such as lower odds of diagnosed SRC and later RTP. Additionally, although comfort in symptom reporting was created and operationalized for this study, previous literature supports the idea that higher levels of trust or comfort in symptom reporting supports health-promoting outcomes associated with SRC (Baugh et al., 2020; Weber Rawlins et al., 2021).

Diagnosed SRC incidence and symptom reporting models were also examined for model fit. Specifically, model sensitivity, specificity, and classification accuracy were examined to determine model accuracy in predicting diagnosed SRC incidence. Overall, these models were better at predicting those that did not sustain a diagnosed SRC (sensitivity) than those who did (specificity); however, sensitivity in these models was somewhat improved over the models that included personality and social determinants of health predictors of diagnosed SRC incidence. Overall accuracy remained like other diagnosed SRC models, indicating that honesty and comfort predictive models fell in the acceptable range for predicting odds of diagnosed SRC.

Summary

Overall, study results bolstered the conclusion that 1. Personality and social determinants of health factors are important in predicting SRC outcomes and 2. The relations between personality and SRC outcomes are highly nuanced, depending upon the specific personality facet, outcome, and sample characteristics. Specifically, results from this study demonstrated that

personality is more meaningful in determining likelihood of diagnosed SRC incidence and symptom reporting behaviors than time to RTP. Additionally, openness to experience emerged as one of the most salient personality facets in the study. Those higher in openness to experience were less likely to sustain a diagnosed SRC in the past year and were more likely to be both honest and comfortable reporting symptoms.

Regarding social determinants of health, sex assigned at birth, SES, pressure to continue playing were most salient in study outcomes, although differential relations emerged here as well. Higher SES predicted earlier RTP and lower odds of diagnosed SRC in the sample. Pressure to continue playing had a negative impact on both honesty and comfort in symptom reporting. Female sex assigned at birth was associated with earlier RTP and lower odds of diagnosed SRC. Additionally, race and experiences of discrimination were not significantly associated with any study outcomes, but showed higher relative effect sizes (hazard ratio (HR), odds ratio (OR)) than other study predictors that did not emerge as significantly associated with study outcomes. Participants identifying as a Person of Color returned to play later, had lower odds of diagnosed SRC, demonstrated lower odds of symptom reporting honesty, and showed higher odds of comfort in symptom reporting. These results are consistent with previous literature that found that individuals identifying as White are more likely to report a history of SRC, which may be related to actual incidence of SRC or SRC reporting (Takagi-Stewart et al., 2022; Wallace et al., 2020a). Those experiencing discrimination returned to play more quickly, had lower odds of diagnosed SRC, were less honest in symptom reporting at their most recent injury, but more comfortable reporting symptoms in general. However, results for higher HRs and ORs should be interpreted in light of wide CIs, and therefore less precision in study results. Importantly, in addition to race and experiences of discrimination, ACEs and age did not emerge

as significantly associated with study outcomes, indicating that these factors may not be influential in time to RTP, diagnosed SRC incidence, and symptom reporting outcomes. Taken together, these results also demonstrated that there are likely complex and nuanced relations between individuals and their symptom reporting behaviors. The nuance and sample-specific nature of this study is supported by other recent studies that have concluded that social determinants of health that emerged as risk factors in a high school athlete sample did not emerge as risk factors in a college student sample (Wallace et al., 2022).

Regarding accuracy of predicting diagnosed SRC and symptom reporting outcomes, models predicting diagnosed SRC incidence and symptom reporting showed significantly better accuracy when predicting the more health-promoting outcomes, meaning that models were better at predicting those who did not sustain a diagnosed SRC and those who were honest and comfortable in reporting symptoms than they were at predicting those who had higher odds of diagnosed SRC and refrained from symptom reporting. Future work should continue focusing on bolstering accuracy of predicting those most at risk of earlier RTP and SRC incidence.

Limitations and Future Directions

The current study was designed to be inclusive of a variety of predictors known to be associated with SRC-related outcomes; however, it has been established that many psychosocial factors, including mental health, are related to both risk taking in sport and SRC-related outcomes specifically (Asken et al., 2016; Hanson et al., 2014; Khurana & Kaye, 2012; Kimbler et al., 2011; O'Jile et al., 2004). Many mental health factors, as well as many other psychosocial factors that may potentially be related to RTP, symptom reporting, and diagnosed SRC incidence, were not included in this study. Future work should continue to include potentially relevant variables and considerations.

Due to recruitment limitations, the original proposed study analyses that included SEM and mediation were not conducted. Additionally, due to this study originally including both diagnosed and suspected SRC as outcomes, study hypotheses aimed to parse personality and social determinants of health that might be differentially associated with *diagnosed* SRC and *suspected* SRC; thus, a number of study findings did not support predictions. Future work should continue to investigate potential differential associations between both diagnosed and suspected SRC, as well as the ways in which individuals with history of suspected SRC may differ in characteristics such as symptom reporting tendencies, personality, and demographic factors.

Other variables not included in this study may be influential in the relations proposed in the current study. For example, since symptom reporting and neuropsychological testing are both important factors in identifying SRC, neuropsychological testing performance may be a potential mediator in the relations between personality and social determinants of health predictors and SRC outcomes (Dessy et al., 2017; Khurana & Kaye, 2012). Additionally, the symptom reporting variables chosen, comfort and honesty, were chosen and created from review of the literature and theoretical considerations. To date, these variables conceptualized in this way have not been explicitly used in studies of youth SRC. It is possible that other components of symptom reporting, such as lack of awareness and identification of symptoms in oneself, may be salient in the relations between predictors and outcomes in this study as well (Asken et al., 2016). It is also possible that comfort and honesty are not defined most optimally due to lack of previous definition and use of these variables in other studies. In the current study, 88.5% of those who reported being honest in reporting symptoms during a recent SRC also reported feeling comfortable reporting symptoms; 79.5% of those who reported being generally honest in reporting symptoms also reported being generally comfortable reporting symptoms. These

symptom reporting variables are highly correlated with one another; future studies should continue investigating the extent to which these variables are separate constructs, as well as which conceptualizations of symptom reporting have the most practical utility. Additionally, as symptom reporting emerged as both associated with study predictors (personality and social determinants of health) and associated with a primary study outcome (time to RTP), future work should investigate symptom reporting as a potential explanatory mechanism and point of intervention in the relationship between these predictors and outcomes, with the aim of ultimately improving predictive accuracy of these models.

Notably, a body of literature exists that investigates the extent to which personality may be impacted post-concussion. It is well documented that many individuals experience personality changes for the first several weeks following concussion, with a focus on increased impulsivity (i.e., Byrd et al., 2021). Due to the retrospective nature of reporting, it is outside the scope of this study to differentiate between personality factors that may be pre-existing or that may have shifted as a result of SRC. Future research should attempt to capture these potential shifts in personality when examining similar research questions and aims. Additionally, the current sample was lower in experience seeking, extraversion, and openness experience, and higher in conscientiousness than a previous, similar study by the current author (Weishaar et al., 2022a, 2022b). While personality is relatively stable for individuals throughout their lifetime starting in late adolescence (Steinberg, 2008), the average age of this sample was significantly younger than previous studies that have examined similar research questions. Age, or other characteristics of the sample, may help explain differences in results. Regardless of the reason for these differences, personality differences between samples may help explain differential results between this study and previous studies.

While the current study aimed to investigate the role of symptom reporting in the relations between personality, social determinants of health, and time to RTP and diagnosed SRC incidence, there may be inconsistencies in athlete reporting of their own SRC history and symptom reporting tendencies (Asken et al., 2016; Beidler et al., 2017, 2021; Covassin et al., 2021; Khurana & Kaye, 2012; Kimbler et al., 2011; Merritt et al., 2015). The current study attempted to mitigate these concerns by reminding subjects that participation was confidential; however, it is possible that factors such as fear of losing playing time, mis-remembering of information, or hurried survey completion may have influenced response patterns among participants (Asken et al., 2016). Additionally, RTP results in the current study differed from results from a previous study by the current author; a primary difference was the frame of recall, with participants recalling SRC details up to 10 years in the past during a previous study, while the current study assessed the past calendar year. Future work should include a method such as EMA to determine RTP timeline more specifically, as well as assess feelings and behaviors related to symptom reporting in real time.

Additionally, the current study aimed to attain a sample representative of adolescent athletes in general; however, there were constraints on the demographic characteristics and experiences of the sample due to concerns such as timeframe to complete data collection (~1 year), geographic location, study resources, and adolescent athlete access to clinics and trainers who advertise the study, among other considerations. Notably, this resulted in sample restriction such that one social determinant of health factor, access to healthcare, was dropped from study models. Further, binary study predictors in models with outcomes that were binary, primarily the symptom reporting outcome that showed lower endorsement of one of the binary groups (i.e., 15% endorsing lack of honesty in symptom reporting at previous injury), demonstrated wider CIs

around ORs in study models. This is likely due to the intersection of lower endorsement on binary predictors and lower endorsement on binary outcomes resulting in smaller cell sizes in some cases. These models did not warrant penalized regression methods to bolster results, but results from these models were likely impacted by lower endorsement and representation from certain groups (Firth, 1993). Further, a number of social determinants of health factors and the symptom reporting outcomes in this study were dichotomized due to limited variability in participant responses. Dichotomizing these variables limited the implications and interpretations that could be made for these variables. For example, the small number of participants in the sample that indicated a racial identity other than White were grouped together into the racial category "Person of Color". There was likely nuance and important differences in SRC outcomes by specific racial group that could not be investigated in this study. Additionally, there may have been nuance in conclusions that could be drawn for those that indicated they "strongly agree" that they were honest in reporting symptoms and those who reported they "somewhat agree", for example; however, these responses were included together in one variable category in this study. Results of this study must be interpreted with consideration for these contextual factors and generalized to samples with similar characteristics. Future studies should work to include more diverse identities to further explicate nuance that may exist between certain identities, social determinants of health, and SRC risk.

The current study sample differed from previous studies in additional important ways. Results should be interpreted considering these differences, and future work should intentionally focus on samples and recruitment methods that serve specific research questions. For example, the current study assessed diagnosed SRC in the past year, among a sample of individuals who had diagnosed and suspected SRC prior to the past year. Previous studies have included an

assessment of diagnosed SRC history, with those in the non-SRC group denying all history of diagnosed SRC (Weishaar et al., 2022b). Additionally, previous work has investigated similar research questions among a sample entirely comprised of college students (Weishaar et al., 2022a, 2022b) or college athletes (Beidler et al., 2017, 2021; Liebel et al., 2020; Webbe & Ochs, 2007). Weishaar and colleagues (2022b) inquired about first diagnosed SRC after the age of 12 when assessing time to RTP. As a result, conclusions from that study represented both adolescent and young adult SRC with RTP timelines ranging from zero days to five years. Additionally, this previous study included time to RTP as weeks since RTP, with the current study using days to RTP as the outcome. Survival analysis recommendations encourage researchers to use a measure of time that best represents the data; however, this metric for RTP may influence results (Singer & Willett, 2003). As a result of this timeframe difference, there were less participants censored in the previous study (~7%) compared to the current study (~20%). Lastly, Weishaar and colleagues (2022a) only included individuals in analyses that had been officially medically cleared to RTP, while the current study controlled for medical clearance in an effort to maximize study sample size and answer research questions about social determinants of health. Specifically, only including those who experienced medical clearance in the sample when examining social determinants of health may assume a certain level of access to care.

Regarding RTP, the current study examined time to RTP without direct consideration for specific recommendations made to participants about RTP due to the wide variety of RTP experiences that are present between sports and individuals. Future work should make an effort to further parse apart RTP analyses such that results could identify associations between study predictors and RTP timelines that are “too early” and those that are “too prolonged”. The current study can only identify those at risk of earlier vs. later RTP compared to others in the sample.

Future work should continue to investigate the relations between personality, social determinants of health, time to RTP, diagnosed SRC incidence, and symptom reporting among different age groups, with representation from more social determinants of health groups, including types of SRC (diagnosed vs. suspected), number of past SRC, different competition levels, and with athletes from different sports to determine if meaningful differences exist between predictors and outcomes used in this study. Ultimately, to provide optimum utility of this information in medical and sports team settings, future work should continue to identify variables most salient to SRC outcomes such that future prevention and intervention efforts may be tailored to a parsimonious group of traits. Ideally, research would determine profiles of risk and protective factors that can be used to inform prevention and intervention of youth SRC. Following identification of these factors, research should investigate tailored prevention initiatives and intervention strategies at the individual, environment, and systems levels to determine effectiveness in preventing outcomes such as early RTP, SRC incidence, and symptom nondisclosure.

Implications and Conclusions

Results of this study have implications for athletes, peers and family members of athletes, coaches, athletic trainers, and medical professionals. Previous work investigating comprehensive models of SRC symptom reporting concluded with limited significant results, limited practical utility, and an over-emphasis on individual-level factors and implications (Carpenter et al., 2020; Cicero et al., 2022; Milroy et al., 2020). As a result, it is important to note the implications of this work with an emphasis on practical utility at all levels, including individual, environmental, and systems levels.

Regarding practical utility, specific predictors in this study were chosen for their hypothesized impact on study outcomes and the availability of this information; an individual athlete's personality and social determinants of health information is either already available to coaches, athletic trainers, and medical professionals, or can be attained in a preseason screening or intake packet in a short amount of time (~10 minutes). Based on the results of this study, this level of information (i.e., personality and social determinants of health) can contribute "good" accuracy in identifying study outcomes. Conclusions from this study support the idea of striving for a balance in using more easily available information to predict SRC outcomes that can also contribute solid predictive accuracy.

At the individual level, participants who demonstrate risk factors for earlier RTP, higher odds of SRC, and higher odds of symptom nondisclosure may benefit from intentional inquiry at doctor's visits around SRC symptoms and additional monitoring by athletic trainers and coaches during sports participation to aid in both prevention and intervention for injury. Specific to prevention of SRC, early RTP, and symptom nondisclosure, individual athletes may benefit from receiving presentations and psychoeducation around the relations between personality, social determinants of health, and SRC risk. A number of studies have supported the conclusion that psychoeducation, or providing specific information that we have about risk and wellbeing related to mental health and health behavior engagement, can be exceedingly impactful in mitigating negative outcomes (Sanford et al., 2006). Individual athletes may also benefit from receiving this information in individual one-on-one meetings at the beginning of a sports season.

Regarding individual intervention, new research is emerging that underscores the importance of multidisciplinary care in concussion treatment (O'Neill et al., 2022; Tiwari et al., 2022). The results of this study support the idea that professionals, including psychologists or other mental

health professionals, are a valuable part of post-SRC care. Mental health professionals could be influential in helping target presenting concerns such as lack of impulse control, problem solving difficulties, and difficulty communicating and interacting with authority figures to ultimately mitigate SRC risk. Mental health professionals are also trained to intervene using cognitive interventions to facilitate health-promoting behaviors, which can be applied to return to activity behaviors post-SRC. One recent study found beneficial effects of personalized cognitive strategies on functional goals and symptom management following concussion (Wright et al., 2022). The results from the current study support the idea that tailored cognitive interventions towards impulse control and problem solving, particularly related to the study results linking higher levels of impulsivity to lower comfort in symptom reporting, could be beneficial for increasing symptom reporting in adolescent athletes. Further, although not included in this study, one notable avenue that has been cited as contributing to symptom reporting is lack of awareness around one's own emotions of physical symptoms (Asken et al., 2016). Mental health professionals could be pivotal in working with individual athletes on bolstering emotion identification and communication skills through interventions like mindfulness, which is a skill that has been cited as helpful in mitigating health risk behavior engagement (Broderick & Jennings, 2012). Overall, the idea of personalizing mental health or behavioral interventions for SRC based on individual factors is emerging as a helpful strategy for reducing risk associated with SRC. The current study informs these findings, and future work should continue to investigate the specific ways that individual personality and identity characteristics may inform individual-level interventions.

At the environmental and systemic levels, the current study provides implications for both prevention and intervention. Regarding prevention efforts, recent studies on behavioral models

have concluded that there is promising evidence to suggest that increasing positive reinforcement for symptom reporting and reducing punishment for lack of symptom reporting may be a helpful avenue for improving accuracy and frequency of reporting (Cicero et al., 2022). It may be beneficial for coaches and athletic trainers to consult with mental health professionals on how to best bolster positive reinforcement and reduce felt punishment for symptom reporting. One potential avenue for reducing punishment in this context would be that athletes do not automatically lose starting spots on their team if they miss one to two weeks for SRC recovery as this has been cited as a common fear and deterrent for symptom reporting in previous studies (Wallace et al., 2017). Related to the findings from this study, there may be differential relationships between individuals and reinforcement/punishment based on their individual identities and personalities. For example, individuals experiencing pressure to continue playing may experience more negative outcomes (punishment) in their social lives if they report symptoms. Additionally, those higher in impulsivity were found to be less comfortable reporting symptoms in the current study. Individuals higher in impulsivity tend to be more sensitive to reward in general, often preferring short-term reward over longer-term reward (Chambers & Potenza, 2003; Dick et al., 2010). For individuals higher in impulsivity, identifying something rewarding or reinforcing about symptom reporting in the short term may help encourage these individuals to report symptoms more often. Importantly, continued emphasis in medical and athletic training programs for creating an environment that is comfortable and does not include shaming around symptom reporting may result in more symptom reporting and less risk associated with RTP. On sports teams and clubs, hiring coaches that prioritize SRC-related safety and symptom reporting and create an environment that facilitates comfort in symptom reporting may be beneficial. Based on the findings from the current study and a previous study

by Kroshus and colleagues (2015b), it would also be beneficial to continue counseling parents and guardians to avoid pressuring athletes to continue playing while symptomatic as this can result in adverse SRC-related outcomes.

At the environmental level, intervention efforts should include focus on bolstering communication between multidisciplinary treatment teams as this has been cited as pivotal in post-SRC care; improved communication between care providers can mitigate pre-mature RTP (Tiwari et al., 2022). This may be even more pivotal when working with SRC patients from marginalized groups as these individuals have been cited as at more at risk of certain SRC outcomes while also being less likely to present for treatment to specialized clinics (Mohammed et al., 2022; Sidhar et al., 2022).

Ultimately, health disparities related to race, experiences of discrimination, sex assigned at birth, and SES that emerged in this study are broader systemic issues that impact the domain of adolescent SRC. It is exceedingly important that coaches and medical professionals are trained in diversity, equity, inclusion, and justice principles related to their practice (Marmot, 2017). This includes involvement in advocacy work as well as developing critical consciousness, or the practice of critically examining systems that contribute to inequity (Todic´ et al., 2022). Similar to other areas of health behavior and mental health research, an over-emphasis on the *individual* in health behavior change largely misses the mark for prevention and intervention and creates further disparities in healthcare. Healthcare professionals, both inside and outside of providers who work with individuals post-SRC, are encouraged to take a systems-level perspective in understanding their patients, including patient behaviors and decisions (Todic´ et al., 2022). A practical step for coaches or athletic trainers that may help bolster comfort in symptom reporting and that increase equity would be to establish a system on sports teams where athletes may

anonymously report inequity that is occurring on their teams to school principals or club directors. Future work should investigate these strategies to determine which are most effective and feasible for mitigating risk associated with SRC.

Taken together, results from this study demonstrated that personality and social determinants of health factors are important to consider in identifying adolescent athletes most at risk of outcomes such as early RTP, diagnosed SRC incidence, and symptom reporting non-disclosure. This work has clear implications at the individual, environmental, and systems levels. For everyone involved in adolescent sports participation, joint awareness and dedication to preventing risk associated with SRC includes a dedication to identifying and working against health disparities and inequities. Future work would benefit from continuing to investigate these research questions to determine if the salient predictors identified in this study are those that should be focused on in clinical prevention and intervention, if these results generalize to other samples of athletes, and eventually, to determine if interventions tailored to these findings are effective in preventing adverse SRC outcomes.

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APPENDICES

Appendix A: Survey Measures

Screening Questions

Are you at least 14 years old and no older than 19?

- o No
- o Yes

Select your age below.

- o I'm between 14 and 17 years old
- o I'm 18 or 19 years old

Were you enrolled in high school in the past 12 months?

- o No
- o Yes

Have you played a club or high school sport while enrolled in high school in the past year?

- o No
- o Yes

Have you ever sustained a sports-related concussion?

A concussion has occurred anytime you have had a blow to the head, face, neck, or elsewhere on the body with force transmitted to the head that caused you to have symptoms for any amount of time. These symptoms can include: blurred or double vision, seeing stars, sensitivity to light or noise, headache, dizziness, balance problem, or loss of consciousness

- o No
- o Yes

Have you sustained a **diagnosed** sports-related concussion in the past year while playing a high school sport or high school club sport?

Diagnosed sports-related concussion means officially diagnosed by an athletic trainer or other medical professional.

A concussion has occurred anytime you have had a blow to the head, face, neck, or elsewhere on the body with force transmitted to the head that caused you to have symptoms for any amount of

time. These symptoms can include: blurred or double vision, seeing stars, sensitivity to light or noise, headache, dizziness, balance problem, or loss of consciousness.

- No
- Yes

Have you sustained a **suspected** sports-related concussion in the past year while playing a high school or club sport?

Suspected sports-related concussion means that you believe you sustained a sports-related concussion but were never diagnosed by a medical professional due to not reporting symptoms.

- No
- Yes

Have you sustained a moderate or severe traumatic brain injury (more severe than a concussion)?

- No
- Yes

Assent Form

The Effects of Personality and Social Determinants of Health on Sports-Related Concussion Risk: An Examination of Symptom Reporting, Concussion Incidence, and Return to Play: Assent Form

Hi! I'm a researcher at Colorado State University. For my research, I study concussions that happen during sports. Specifically, my research is about what personality characteristics and other characteristics about teenagers may be related to certain behaviors like return to play and symptom reporting, as well as concussion risk. I am asking you if it is OK that I study you. If you say it is OK, I'll ask you to answer some questions in a survey that you will complete on a laptop, computer, tablet, or smart phone. It will ask questions about your personality and other characteristics about yourself. There will also be questions about your concussion if you have had a diagnosed concussion in the past year – the sport you were playing when you got the concussion, what symptoms you had or have, and some questions about symptom reporting and return to play. There will also be questions about past concussions if you have had any. If you have never had a concussion, you will only be asked general questions about sports, your personality, and other characteristics about yourself. There isn't a right or wrong answer --- it is just about what you think.

It will take 10-20 minutes, and you can choose to stop answering the questions at any point. Your name won't be on the survey, so no one will know how you answered or what you did. Although data collection does not include identifying information about yourself (for example, your name), if you choose to provide identifying information that describes abuse (i.e. physical, emotional, or sexual) or neglect in the free form text entry of the survey, we may be required to report this to a court or tell authorities. Agreeing to be in this project cannot hurt you.

It won't help you, either. You don't have to do it. If you say "yes" now but later change your mind, you can stop being in the research any time by just telling me. Also, it's important to know that we will not share your answers with anyone and we won't be able to tell that you were the one who gave your specific answers to the questions. You will get half a credit of participation for your psychology class. If you want to be in this research, click continue. If you do not want to be in this research, click "I do not want to continue" below.

Do you wish to participate?

- Continue
- I do not want to continue

You may continue with the survey. Thank you for your participation!

Consent Form

Adult Consent to Participate in a Research Study

TITLE OF STUDY: The Effects of Personality and Social Determinants of Health on Sports-Related Concussion Risk: An Examination of Symptom Reporting, Concussion Incidence, and Return to Play

Principal Investigator: Bradley T. Conner, Ph.D., Department of Psychology, (970) 491-6197, brad.conner@colostate.edu.

Student Investigator(s): Megan Gardner Weishaar, M.S., megan.gardner@colostate.edu

WHY AM I BEING INVITED TO TAKE PART IN THIS RESEARCH? You are being asked to participate in the study because you fit these criteria: you are between the ages of 14 and 18, either have no sports-related concussion history of have a diagnosed sports-related concussion during the past year, have been enrolled in high school in the past year, have played a high school or club sport in the past year, and have a laptop, computer, tablet, or phone to use to complete the survey.

WHO IS DOING THE STUDY? Megan Gardner Weishaar, M.S. is conducting this dissertation study, under the mentorship of Bradley T. Conner, PhD.

WHAT IS THE PURPOSE OF THIS STUDY? The purpose of this study is to determine personality and social determinants of health factors that contribute to greater risk of negative outcomes of sports-related concussion. The goal is tailor sports-related concussion prevention and intervention efforts to the individual.

WHERE IS THE STUDY GOING TO TAKE PLACE AND HOW LONG WILL IT LAST? If you are interested in participating, you will be asked to complete the survey on a laptop,

computer, tablet, or smart phone in whichever location you choose. The survey should take between 10 and 20 minutes to complete.

WHAT WILL I BE ASKED TO DO? If you volunteer to participate in this study, you will be asked to do the following: answer survey questions about your personality, background, other characteristics, and history of concussion.

ARE THERE REASONS WHY I SHOULD NOT TAKE PART IN THIS STUDY? If you are under the age of 14 or over the age of 18 you are not eligible to participate in this study. Further, if you were diagnosed with a sports-related concussion less than 5 days ago, if you have experienced a moderate or severe traumatic brain injury, if you weren't enrolled in high school in the past year, and if you haven't participated in a high school or club sport during the past year you are not eligible to complete the survey. If you do not meet the criteria for this study you should click cancel below.

WHAT ARE THE POSSIBLE RISKS AND DISCOMFORTS? The possible risks and discomforts from participating in this study are those similar to normal computer viewing and usage. You will be asked to a complete a survey as part of this study, and thus there is a risk of becoming fatigued from reading and answering all of the questions. You may also experience some minimal discomfort in viewing a screen if symptomatic from concussion. In addition, you will be asked to think about and report potentially sensitive information regarding your previous behaviors and characteristics; this may cause you some psychological discomfort. You are free to leave any question blank that you do not feel comfortable answering. It is not possible to identify all potential risks in research procedures, but the researchers have taken reasonable safeguards to minimize any known and potential, but unknown, risks.

ARE THERE ANY BENEFITS FROM TAKING PART IN THIS STUDY? There is little to no known benefit for participating in this study, but you may learn more about yourself by observing you answers to the questionnaires. We also hope to learn more about what influences the behaviors of athletes once they get a concussion. This may help create improved return to play protocol and pre-season screening measures to keep athletes safe and allow them to return to play at the best of their ability. You may also learn about the research process, which you may find interesting. Knowing that you are participating in research that will benefit in the identification and understanding of sensation seeking and health risk behaviors, which will benefit the overall welfare of society, may also provide you with some beneficial feelings.

DO I HAVE TO TAKE PART IN THE STUDY? Your participation in this research is voluntary. If you decide to participate in the study, you may withdraw your consent and stop participating at any time without penalty or loss of benefits to which you are otherwise entitled.

WHO WILL SEE THE INFORMATION THAT I GIVE? All information gathered in this study will be kept as confidential as possible. Your privacy is very important to us, and the researchers will take every measure to protect it. Your information may be given out if required by law; however, the researchers will do their best to make sure that any information that is released will not identify you. No reference will be made in written or oral materials that could link you to this study. For this study, your answers to the survey will be anonymous, which is why you will enter

your email address on a second survey that does not link your email address to your survey answers. There will be no link kept between your identifying information and your survey answers. All records will be stored on a secure sever at CSU for three years after completion of the study. After the storage time, the information gathered will be destroyed. We may be asked to share the research files with the CSU Institutional Review Board ethics committee for auditing purposes. Your identity/record of receiving compensation (NOT your data) may be made available to CSU officials for financial audits. Although data collection is anonymous, if you choose to provide identifying information that describes abuse (i.e. physical, emotional, or sexual) or neglect in the free form text entry of the survey, we may be required to report this to a court or tell authorities. The research team works to ensure confidentiality to the degree permitted by technology. It is possible, although unlikely, that unauthorized individuals could gain access to your responses because you are responding online. However, your participation in this online survey involves risks similar to a person's everyday use of the internet. You may withdraw at any time without prejudice to your relations with CSU or your healthcare provider.

WILL I RECEIVE ANY COMPENSATION FOR TAKING PART IN THIS STUDY? You will receive half a credit of participation for your psychology class.

WHAT IF I HAVE QUESTIONS? Before you decide whether to accept this invitation to take part in the study, please ask any questions that might come to mind now by emailing Megan Weishaar (megan.gardner@colostate.edu). You can also contact the principal investigator, Bradley T. Conner, Ph.D. at brad.conner@colostate.edu or 970-491-6197. If you have any questions about your rights as a volunteer in this research, contact the CSU IRB at: RICRO_IRB@mail.colostate.edu or 970-491-1553. We will provide this information to you on a webpage that you can save or print out when you finish participating in the study. This consent form was approved by the CSU Institutional Review Board for the protection of human subjects in research on Clicking Continue below acknowledges that you have read the information stated and willingly consent to participate in this research.

If you do not wish to participate, please click that option below.

IRB Approval Date: January 14th, 2022

Do you wish to participate?

- o Continue
- o I do not want to continue

You may continue with the survey. Thank you for your participation!

Demographic Questions

What is your age? (in years)

_____

How do you define your Race?

Used for Reporting of Demographic Statistics to Federal Funding Agencies.

Choose all that apply.

- American Indian or Alaska Native
- Asian
- Black or African American
- Native Hawaiian or Other Pacific Islander
- White
- Another _____
- Do not wish to respond

How do you define your Ethnicity?

Used for Reporting of Demographic Statistics to Federal Funding Agencies.

Choose one.

- Hispanic or Latinx
- Not Hispanic or Latinx
- Another _____
- Do not wish to respond

Choose a number that best describes your Sexual Orientation/Preference:

We are attempting to better understand relations between sexual orientation/preference and behavior.

- Exclusively Homosexual 1
- 2
- 3
- Bisexual 4
- 5
- 6
- Exclusively Heterosexual 7
- Asexual
- Pansexual
- Do not wish to respond

How do you define your Gender Identity?

Note that Cis Man and Cis Woman refers to people whose gender identity is the same as their sex assigned at birth. For example, a cis woman/girl is someone who was assigned female at birth and also identifies as a girl/woman.

We are attempting to better understand relations between gender identity and behavior.

Choose all that apply.

- o Cis Man/boy
- o Man/boy
- o Cis Woman/girl
- o Woman/girl
- o Gender Fluid
- o Gender Non-Binary
- o Gender Non-Conforming
- o Genderqueer
- o Trans Man/boy
- o Trans Woman/girl
- o Transgender
- o Transperson
- o Another _____
- o Choose not to respond

What was the sex assigned to you at birth?

Used for Reporting of Demographic Statistics to Federal Funding Agencies.

Choose one.

- o Male
- o Female
- o Intersex
- o Another _____
- o Do not wish to respond

What grade are you in? If it is summer when you are completing this survey, please choose the grade you just completed.

- o 9th grade
- o 10th grade
- o 11th grade
- o 12th grade
- o First year of college

What high school sports did you play? *Check all that apply.*

- Baseball
- Softball
- Basketball
- Cheerleading
- Cross Country
- Dance
- Field Hockey
- Ice Hockey
- Football
- Golf
- Gymnastics
- Lacrosse
- Soccer
- Swimming
- Diving
- Tennis
- Track and Field
- Volleyball
- Wrestling
- Another _____
- I did not play any high school sports in the past year

What club sports did you play? *Check all that apply.*

- Baseball
- Softball
- Basketball
- Cheerleading
- Cross Country
- Dance
- Field Hockey
- Ice Hockey
- Football
- Golf
- Gymnastics
- Lacrosse
- Rugby
- Soccer
- Swimming
- Diving

- Tennis
- Track and Field
- Volleyball
- Wrestling
- Another _____
- I did not play any club sports in the past year

Select which sport you consider to be the primary sport you play and/or the sport that is most important to you.

- Baseball
- Softball
- Basketball
- Cheerleading
- Cross Country
- Dance
- Field Hockey
- Ice Hockey
- Football
- Golf
- Gymnastics
- Lacrosse
- Rugby
- Soccer
- Swimming
- Diving
- Tennis
- Track and Field
- Volleyball
- Wrestling
- Another _____

Do you plan to play sports in future high school or club seasons?

- No
- Yes
- I'm not sure

Which sport(s) do you plan to play in future high school or club sports seasons? *Check all that apply.*

- o Baseball
- o Softball
- o Basketball
- o Cheerleading
- o Cross Country
- o Dance
- o Field Hockey
- o Ice Hockey
- o Football
- o Golf
- o Gymnastics
- o Lacrosse
- o Rugby
- o Soccer
- o Swimming
- o Diving
- o Tennis
- o Track and Field
- o Volleyball
- o Wrestling
- o Another _____

Do you plan to play sports in college?

- o No
- o Yes
- o I'm not sure

Which sport(s) do you plan to play college? *Check all that apply.*

- o Baseball
- o Softball
- o Basketball
- o Cheerleading
- o Cross Country
- o Dance
- o Field Hockey
- o Ice Hockey
- o Football

- Golf
- Gymnastics
- Lacrosse
- Rugby
- Soccer
- Swimming
- Diving
- Tennis
- Track and Field
- Volleyball
- Wrestling
- Another _____

Have you ever been diagnosed with and/or treated by a professional for any of the following conditions? *Please check all that apply.*

- Depression
- Anxiety
- Bipolar Disorder
- Post-Traumatic Stress Disorder (PTSD)
- Obsessive Compulsive Disorder (OCD)
- Attention Deficit and Hyperactivity Disorder (ADHD)
- Schizophrenia and/or any other Psychosis Spectrum Disorder
- Substance Misuse and/or Addiction (Alcohol and/or Drugs)
- Anorexia, Bulimia, and/or any other Eating Disorder
- Insomnia and/or any other Sleep Disorder
- Other Mental Health Condition
- Learning Disorder
- None of the Above

Which of the following conditions are you currently diagnosed with and/or receiving treatment by a professional for? *Please check all that apply.*

- Depression
- Anxiety
- Bipolar Disorder
- Post-Traumatic Stress Disorder (PTSD)
- Obsessive Compulsive Disorder (OCD)
- Attention Deficit and Hyperactivity Disorder (ADHD)
- Schizophrenia and/or any other Psychosis Spectrum Disorder
- Substance Misuse and/or Addiction (Alcohol and/or Drugs)
- Anorexia, Bulimia, and/or any other Eating Disorder

- Insomnia and/or any other Sleep Disorder
- Other Mental Health Condition
- Learning Disorder
- None of the Above

Family Affluence Scale (FAS-II)

Does your family own a car, van, or truck?

- No
- Yes, one
- Yes, two or more

Do you have your own bedroom for yourself?

- No
- Yes

In the past 12 months, how many times did you travel away on holiday/vacation with your family?

- Not at all
- Once
- Twice
- More than twice

How many computers does your family own?

- None
- One
- Two
- More than two

Access to Healthcare

Are you able to go to the doctor when necessary?

- No
- Yes

Do you typically have a yearly check up/physical at the doctor?

- No
- Yes

When playing a sport affiliated with your high school, is there an athletic trainer available if you need them?

- No
- Yes
- I don't know
- This doesn't apply to me

When playing a sport affiliated with your club sports team, is there an athletic trainer available if you need them?

- No
- Yes
- I don't know
- This doesn't apply to me

Experiences of Discrimination

Do you feel you have ever been the victim of discrimination related to your gender, sex, sexual orientation, disability, ethnicity, race, or another characteristic about yourself?

Definition of discrimination: Treating a person unfairly based on characteristics they have.

- No
- Yes
- I'm not sure

How many times do you think you have been the victim of discrimination?

- Once in my lifetime
- 2-6 times in my lifetime
- 7-13 times in my lifetime
- About once a year
- About once a month
- About once a week
- About once a day
- More than once per day

Where have you experienced discrimination?

Check all that apply.

- At home
- At school
- In public places like the grocery store, shopping, restaurants, etc.

- At the doctor
- Another _____

Pressure to Continue Playing

Do you feel pressure or have you felt pressure to continue playing when you are injured or experiencing symptoms of an injury? *Check all that apply.*

	Yes	No
I feel pressure from my parent/guardian	☐	☐
I feel pressure from my sibling(s)	☐	☐
I feel pressure from my coach(es)	☐	☐
I feel pressure from my friends (not teammates)	☐	☐
I feel pressure from my teammates	☐	☐
I feel pressure from fans	☐	☐

Adverse Childhood Experiences (ACEs)

While you were growing up, during your first 18 years of life:

Did a parent or other adult in the household often or very often swear at you, insult you, put you down, or humiliate you? Or Act in a way that made you afraid that you might be physically hurt?

- o No
- o Yes

Did a parent or other adult in the household often or very often push, grab, slap, or throw something at you? Or Ever hit you so hard that you had marks or were injured?

- o No
- o Yes

Did an adult or person at least 5 years older than you ever touch or fondle you or have you touch their body in a sexual way? Or Attempt or actually have oral, anal, or vaginal intercourse with you?

- o No
- o Yes

Did you often or very often feel that no one in your family loved you or thought you were important or special? Or Your family didn't look out for each other, feel close to each other, or support each other?

- o No
- o Yes

Did you often or very often feel that you didn't have enough to eat, had to wear dirty clothes, and had no one to protect you? Or Your parents were too drunk or high to take care of you or take you to the doctor if you needed it?

- o No
- o Yes

Were your parents ever separated or divorced?

- o No
- o Yes

Did your parent or other adult in the house:

Often or very often pushed, grabbed, slapped, or had something thrown at her? Or Sometimes, often, or very often kicked, bitten, hit with a fist, or hit with something hard? Or Ever repeatedly hit for at least a few minutes or threatened with a gun or knife?

- o No
- o Yes

Did you live with anyone who was a problem drinker or alcoholic, or who used street drugs?

- o No
- o Yes

Was a household member depressed or mentally ill, or did a household member attempt suicide?

- o No
- o Yes

Did a household member go to prison?

- o No
- o Yes

Ten Item Personality Inventory (TIPI)

Here are a number of personality traits that may or may not apply to you. Please indicate the extent to which you agree or disagree with that statement. You should rate the extent to which the pair of traits applies to you, even if one characteristic applies more strongly than the other.

	Disagree strongly	Disagree moderately	Disagree a little	Neither agree nor disagree	Agree a little	Agree moderately	Agree strongly
Extraverted, enthusiastic	○	○	○	○	○	○	○
Critical, quarrelsome	○	○	○	○	○	○	○
Dependable, self-disciplined	○	○	○	○	○	○	○
Anxious, easily upset	○	○	○	○	○	○	○
Open to new experiences, complex	○	○	○	○	○	○	○
Reserved, quiet	○	○	○	○	○	○	○
Sympathetic, warm	○	○	○	○	○	○	○
Disorganized, careless	○	○	○	○	○	○	○
Calm, emotionally stable	○	○	○	○	○	○	○
Conventional, uncreative	○	○	○	○	○	○	○

Sensation Seeking Personality Trait Scale (SSPT)

The following scale consists of a series of statements regarding preference for engaging in new or exciting tasks. For each of the following items, you will be asked to indicate how much you agree or disagree with the statement. There are no right or wrong answers and we ask that you respond honestly.

I enjoy participating in unsafe activities.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

I don't enjoy trying new things.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

I think it is important to try as many new things as I can.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

I do things even if I know that doing them will get me in trouble.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

I love challenging myself with new and interesting tasks.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

I think that excitement is more important than safety.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

I have the most fun when I am doing risky or dangerous things.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

I rarely do things that seem risky.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

I like to experience anything and everything I can.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

I like to explore new areas.

- Strongly Disagree
- Disagree
- Neutral
- Agree
- Strongly Agree

Barratt Impulsiveness Scale – Brief (BIS-Brief)

DIRECTIONS: People differ in the ways they act and think in different situations. This is a test to measure some of the ways in which you act and think. Read each statement and mark the appropriate circle on the right side of this page. Do not spend too much time on any statement. Answer quickly and honestly.

	Rarely/Never	Occasionally	Often	Almost Always/Always
I plan things carefully.	○	○	○	○
I do things without thinking.	○	○	○	○
I don't "pay attention".	○	○	○	○
I am self controlled.	○	○	○	○
I concentrate easily.	○	○	○	○
I am a careful thinker.	○	○	○	○
I say things without thinking.	○	○	○	○
I act on the spur of the moment.	○	○	○	○

Concussion-Related Questions

The following questions about concussions in the past year are referring to concussions sustained in the past year while enrolled in high school AND participating in a high school or club sport.

Have you ever sustained a concussion while participating in a sport that was **diagnosed** by a medical professional or athletic trainer?

Remember: A concussion has occurred anytime you have had a blow to the head, face, neck, or elsewhere on the body with force transmitted to the head that caused you to have symptoms for

any amount of time. These symptoms include: blurred or double vision, seeing stars, sensitivity to light or noise, headache, dizziness, balance problems, or loss of consciousness.

- o No
- o Yes

How many **diagnosed** concussions have you sustained in your lifetime while participating in sports?

- o 1
- o 2+

Have you ever sustained a concussion-like injury that you did not report and, thus, **was not diagnosed** by a medical professional? These will be referred to as "**suspected/undiagnosed concussions**."

- o No
- o Yes

How many **suspected** concussions have you sustained in your lifetime while participating in sports?

- o 1
- o 2+

In the past year, have you sustained a concussion while participating in a sport that was **diagnosed** by a medical professional?

- o No
- o Yes

How many **diagnosed** concussions have you sustained in the past year while participating in sports?

- o 1
- o 2+

In the past year, have you sustained a concussion-like injury that you did not report and, thus, **was not diagnosed** by a medical professional? These will be referred to as "**suspected/undiagnosed concussions**."

- o No
- o Yes

How many **suspected** concussions have you sustained in the past year while participating in sports?

- 1
- 2+

Have you ever sustained any **diagnosed** concussions outside of sports?

- No
- Yes

How many **diagnosed** concussions have you sustained outside of sports?

- 1
- 2+

Have you ever sustained any **suspected/undiagnosed** concussions outside of sports?

- No
- Yes

How many **suspected/undiagnosed** concussions have you sustained outside of sports?

- 1
- 2+

In general, if you are sick, injured, or not feeling well, how well are you usually able to detect and identify these symptoms?

- Not very well
- Average. Sometimes I can tell I'm sick, injured, and not feeling well and sometimes I can't tell.
- Very well. I usually identify that I'm sick or injured fairly quickly.

The next few questions are going to ask you about your **most recent diagnosed** sports-related concussion that you experienced within the past year. Remember to answer as honestly as you can, and that there will be no way to link your answers back to you.

Most recent means that if you experienced more than 1 sports-related concussion in the past year, you would think about the one that happened mostly recently when answering these questions.

What sport were you playing while you sustained this sports-related concussion?

- Baseball
- Softball
- Basketball
- Cheerleading
- Cross Country
- Dance
- Field Hockey
- Ice Hockey
- Football
- Golf
- Gymnastics
- Lacrosse
- Soccer
- Softball
- Swimming
- Diving
- Tennis
- Track and Field
- Volleyball
- Wrestling
- Another _____

Were you in a practice or a game?

- Practice
- Game

How did the concussion happen?

- Head to head collision
- Head to ball collision
- Head to ground collision
- Body to body collision (no direct head impact)
- Another way

Enter a date (or approximate date) when you sustained this diagnosed concussion.

_____

How many days ago was this concussion?

_____

Have you returned to play following this concussion?

- o No
- o Yes

Do you plan to return to play at some point?

- o No
- o Yes

Why will you not be returning to play? *Check all that apply.*

- o I have concussion symptoms that are lasting a long time
- o I've had several concussions
- o High school is almost over
- o I just don't want to

How many days do you think it will be until you return to play?

_____

Why haven't you returned to play yet? *Check all that apply.*

- o I'm not cleared yet
- o I still have symptoms
- o I don't want to return to play right now
- o I'm on a break between seasons of my sport

Did you return to playing the same sport following this concussion?

- o No
- o Yes

Enter a date (or approximate date) when you returned to play following concussion (full return to play, meaning no restrictions)?

_____

How many days were there from the time you sustained the concussion to the time you returned to play? If this was less than 1 day, round up to 1 full day.

_____

Were you cleared by a medical professional to return to play following your **diagnosed** concussion?

- o No
- o Yes

I felt pressure to continue playing after I suspected I may have a concussion by the following people. *Check all that apply.*

- o My parents/guardians
- o My sibling(s)
- o My coach
- o My teammates
- o My friends that aren't teammates
- o Fans
- o Other _____
- o None of these

When you sustained this diagnosed concussion, which symptoms did you have? *Please check all that apply.*

- o Dizziness or balance problems
- o Saw stars
- o Vomited or felt nauseous
- o Forgetfulness or memory loss
- o Headaches or pressure in the head
- o Had trouble studying, concentrating, or doing work
- o Felt sensitive to light or noise
- o Felt sleepy
- o Felt more sad than normal
- o Had trouble falling or staying asleep
- o Felt more irritable or easily annoyed
- o Felt confused or in a fog

Which of these symptoms do you still currently have? *Please check all that apply.*

- o Dizziness or balance problems
- o Saw stars
- o Vomited or felt nauseous
- o Forgetfulness or memory loss
- o Headaches or pressure in the head
- o Had trouble studying, concentrating, or doing work
- o Felt sensitive to light or noise
- o Felt sleepy
- o Felt more sad than normal
- o Had trouble falling or staying asleep
- o Felt more irritable or easily annoyed
- o Felt confused or in a fog

Do you feel like you can accurately identify concussion symptoms in yourself when/if you are experiencing them?

- o No
- o Yes

Do you think most athletes report symptoms of concussion if they have them?

- o No
- o Yes

Has there ever been a time when you didn't report symptoms of concussion even though you were experiencing them?

- o No
- o Yes

Regarding the concussions (**diagnosed or undiagnosed**) you experienced in the past year, was there ever a time during your recovery that you didn't report symptoms of concussion even though you were experiencing them?

- o No
- o Yes

In the past, what is the reason you have not reported your concussion symptoms even though you were having them? *Check all that apply.*

- o I didn't know what the symptoms of concussion were.
- o I couldn't identify if I was experiencing concussions symptoms or symptoms of something else.
- o I was afraid of losing playing time.
- o I was afraid of what others might think (including parents, friends, teammates, coaches)

Do you intend to report your symptoms of concussion in the future?

- o No
- o Yes
- o Maybe

Whether you have experienced a sports-related concussion or not...

In the past year, I have been mostly comfortable reporting my symptoms of concussion to my **mom/stepmom/maternal figure**.

Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree	This does not apply to me
1	2	3	4	5	6	

Whether you have experienced a sports-related concussion or not...

In the past year, I have been mostly comfortable reporting my symptoms of concussion to my **dad/stepdad/paternal figure**.

Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree	This does not apply to me
1	2	3	4	5	6	

Whether you have experienced a sports-related concussion or not...

In the past year, I have been mostly comfortable reporting my symptoms of concussion to my **sibling(s).**

Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree	This does not apply to me
1	2	3	4	5	6	

Whether you have experienced a sports-related concussion or not...

In the past year, I have been mostly comfortable reporting my symptoms of concussion to my **coach(es).**

Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree	This does not apply to me
1	2	3	4	5	6	

Whether you have experienced a sports-related concussion or not...

In the past year, I have been mostly comfortable reporting my symptoms of concussion to my **athletic trainer(s).**

Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree	This does not apply to me
1	2	3	4	5	6	

Whether you have experienced a sports-related concussion or not...

In the past year, I have been mostly comfortable reporting my symptoms of concussion to my **doctor(s).**

Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree	This does not apply to me
1	2	3	4	5	6	

Whether you have experienced a sports-related concussion or not...

In the past year, I have been mostly comfortable reporting my symptoms of concussion to my **teammates**.

Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree	This does not apply to me
1	2	3	4	5	6	

Whether you have experienced a sports-related concussion or not...

In the past year, I have been mostly comfortable reporting my symptoms of concussion to my **friends that aren't teammates**.

Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree	This does not apply to me
1	2	3	4	5	6	

When I sustained my **most recent diagnosed** concussion in the past year, I was comfortable reporting my symptoms of concussion.

Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree	This does not apply to me
1	2	3	4	5	6	

When I sustained my **most recent diagnosed** concussion in the past year, I was comfortable reporting my symptoms of concussion to the following people. *Check all that apply.*

- o My mom
- o My dad
- o My coach
- o An athletic trainer
- o A doctor
- o Teammates
- o Friends that aren't teammates

When I sustained my **most recent suspected** concussion in the past year, I was comfortable reporting my symptoms of concussion.

Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree	This does not apply to me
1	2	3	4	5	6	

When I sustained my **most recent suspected** concussion in the past year, I was comfortable reporting my symptoms of concussion to the following people. *Check all that apply.*

- o My mom
- o My dad
- o My coach
- o An athletic trainer
- o A doctor
- o Teammates
- o Friends that aren't teammates

Whether you have experienced a sports-related concussion or not...

In the past year, I have been mostly honest in reporting my symptoms of concussion to my **mom/stepmom/maternal figure**.

Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree	This does not apply to me
1	2	3	4	5	6	

Whether you have experienced a sports-related concussion or not...

In the past year, I have been mostly honest in reporting my symptoms of concussion to my **dad/stepdad/paternal figure**.

Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree	This does not apply to me
1	2	3	4	5	6	

Whether you have experienced a sports-related concussion or not...

In the past year, I have been mostly honest in reporting my symptoms of concussion to my **sibling(s).**

Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree	This does not apply to me
1	2	3	4	5	6	

Whether you have experienced a sports-related concussion or not...

In the past year, I have been mostly honest in reporting my symptoms of concussion to my **coach(es).**

Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree	This does not apply to me
1	2	3	4	5	6	

Whether you have experienced a sports-related concussion or not...

In the past year, I have been mostly honest in reporting my symptoms of concussion to my **athletic trainer(s).**

Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree	This does not apply to me
1	2	3	4	5	6	

Whether you have experienced a sports-related concussion or not...

In the past year, I have been mostly honest in reporting my symptoms of concussion to my **doctor(s).**

Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree	This does not apply to me
1	2	3	4	5	6	

Whether you have experienced a sports-related concussion or not...

In the past year, I have been mostly honest in reporting my symptoms of concussion to my **teammates**.

Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree	This does not apply to me
1	2	3	4	5	6	

Whether you have experienced a sports-related concussion or not...

In the past year, I have been mostly honest in reporting my symptoms of concussion to my **friends that aren't teammates**.

Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree	This does not apply to me
1	2	3	4	5	6	

When I sustained my most recent **diagnosed** concussion in the past year, I was honest in reporting my symptoms of concussion.

Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree	This does not apply to me
1	2	3	4	5	6	

When I sustained my most recent **diagnosed** concussion in the past year, I was honest in reporting symptoms of concussion to the following people. *Check all that apply.*

- o My mom
- o My dad
- o My coach
- o An athletic trainer
- o A doctor
- o Teammates
- o Friends that aren't teammates

When I sustained my most recent **suspected/undiagnosed** concussion in the past year, I was honest in reporting my symptoms of concussion.

Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree	This does not apply to me
1	2	3	4	5	6	

When I sustained my most recent **suspected/undiagnosed** concussion in the past year, I was honest in reporting symptoms of concussion to the following people. *Check all that apply*.

- o My mom
- o My dad
- o My coach
- o An athletic trainer
- o A doctor
- o Teammates
- o Friends that aren't teammates

Other Sports-Related Injury Questions

Have you sustained another injury while playing a sport that was not a concussion?

- o No
- o Yes
- o I'm not sure

What was the injury/what were the injuries?

- o Strain/pulling a muscle
- o Sprain
- o Knee Injury (ACL, MCL, dislocation, etc.)
- o Shoulder Injury (dislocation or other condition)
- o Fracture/broken bone
- o Tennis elbow
- o Back injury/back pain/sciatica
- o Shin splints or plantar fasciitis

Appendix B: Tables

Table B1: Summary of Significant Results from Study Preliminary Models

	b	ES	CI	SE	p
Return to Play Outcome					
Social Determinants of Health Predictors					
Sex Assigned at Birth	0.385	1.470	1.016-2.126	0.186	0.041*
SES	0.119	1.126	1.017-1.247	0.051	0.023*
Injury-Specific Symptom Reporting Predictors					
Comfort	-0.833	0.434	0.260-0.726	0.260	0.002**
Sex Assigned at Birth	0.442	1.556	1.071-2.260	0.188	0.021*
Incidence Outcome					
Personality Model					
Openness to Experience	-0.153	0.858	0.737-0.999	0.077	0.049*
Conscientiousness	-0.196	0.822	0.702-0.961	0.079	0.014*
Agreeableness	0.194	1.214	1.043-1.413	0.077	0.012*
Sex Assigned at Birth	-0.677	0.508	0.270-0.957	0.321	0.036*
Social Determinants of Health Model					
Sex Assigned at Birth	-0.868	0.419	0.235-0.747	0.293	0.003**
SES	-0.232	0.792	0.667-0.941	0.087	0.008**
General Honesty Model					
Sex Assigned at Birth	-0.927	0.396	0.216-0.725	0.307	0.003**
General Comfort Model					
Sex Assigned at Birth	-0.869	0.419	0.230-0.763	0.304	0.005**
Symptom Reporting Outcomes					
Injury-Specific Honesty Outcome					
Personality Model					
Openness to Experience	0.370	1.448	1.027-2.041	0.173	0.035*
Injury-Specific Comfort Outcome					
Personality Model					
Suspected SRC	-1.286	0.276	0.080-9.560	0.625	0.042*
General Honesty Outcome					
Personality Model					
Openness to Experience	0.194	1.214	1.022-1.441	0.087	0.027*
Social Determinants of Health Model					

Pressure	-0.353	0.703	0.548-0.900	0.124	0.006**
General Comfort Outcome					
Personality Model					
Total Impulsivity	-0.119	0.888	0.799-0.987	0.053	0.027*
Openness to Experience	0.237	1.268	1.069-1.502	0.086	0.006**
Social Determinants of Health Model					
Pressure	-0.400	0.670	0.536-0.838	0.113	0.0005***

Note: Significant results from all preliminary models at a .05 significance level or below. Preliminary models were those that included just one predictor (Cox models) or those that only included personality or social determinants of health groups of predictors (logistic regression models). b = unstandardized regression coefficients; ES = effect size – hazard ratio for RTP outcomes and odds ratio for logistic regression outcomes; CI = 95% confidence interval around the ES; SE = standard error; * = significant at .05; ** = significant at .01; *** = significant at .001

Table B2: Summary of Significant Results from Study Final Models

	b	ES	CI	SE	p
RTP Outcome					
Personality and Social Determinants of Health Final Model					
SES	0.105	1.111	1.005-1.229	0.051	0.040*
Comfort in Symptom Reporting Final Model					
Comfort	-0.859	0.423	0.245-0.730	0.274	0.002**
Sex Assigned at Birth	0.528	1.695	1.099-2.614	0.218	0.020*
Incidence Outcome					
Personality and Social Determinants of Health Final Model					
Conscientiousness	-0.147	0.863	0.760-0.980	0.064	0.024*
Agreeableness	0.174	1.190	1.030-1.374	0.073	0.018*
Sex Assigned at Birth	-0.765	0.465	0.261-0.827	0.292	0.009**
Symptom Reporting Outcomes					
General Honesty Outcome					
Personality and Social Determinants of Health Final Model					
Pressure	-0.319	0.727	0.571-0.926	0.119	0.011*
General Comfort Outcome					
Personality and Social Determinants of Health Final Model					
Pressure	-0.351	0.704	0.570-0.868	0.106	0.001***

Note: All analyses that resulted in significant personality and social determinants of health predictors concluded with a final model inclusive of all significant predictors from final models; b = unstandardized regression coefficients; ES = effect size – hazard ratio for RTP outcomes and OR for logistic regression outcomes; CI = 95% confidence interval are the ES; SE = standard error; * = significant at .05; ** = significant at .01; *** = significant at .001

Table B3: Summary of Model Fit Statistics

All Logistic Regression Models

	Sensitivity	Specificity	NPV	PPV	AUC	Accuracy
Diagnosed SRC Incidence Outcome						
Personality Model	47.3%	85.1%	0.73	0.66	0.72	70.8%
Social Determinants of Health Model	37.9%	85.9%	0.69	0.62	0.71	67.6%
Final Model	44.2%	83.4%	0.71	0.62	0.72	67.9%
Honesty Model	51.1%	77.7%	0.69	0.62	0.63	66.5%
Comfort Model	51.8%	76.1%	0.69	0.61	0.65	66.0%
Injury-Specific Symptom Reporting Outcomes						
Honesty Outcome						
Personality Model	98.5%	12.9%	0.56	0.86	0.74	85.4%
Comfort Outcome						
Personality Model	98.2%	16.0%	0.73	0.83	0.73	82.8%
General Symptom Reporting Outcomes						
Honesty Outcome						
Personality	74.5%	39.5%	0.55	0.61	0.63	59.3%
Social Determinants of Health	78.9%	49.4%	0.67	0.66	0.69	66.0%
Final Model	76.3%	42.9%	0.59	0.63	0.68	61.8%
Comfort Outcome						
Personality	71.8%	58.6%	0.66	0.65	0.68	65.4%
Social Determinants of Health	70.0%	56.7%	0.65	0.64	0.68	64.5%
Final Model	70.8%	57.5%	0.64	0.64	0.69	63.8%

Note: Model fit results from all logistic regression models in the study are included in this table. Final model = personality and social determinants of health final model.
Sensitivity = percentage of those predicted to have one diagnosed SRC who were diagnosed with SRC; Specificity = percentage of those predicted to have zero diagnosed SRC who were not diagnosed with an SRC; NPV = negative predictive value, ratio of true negative predictions taking into account all negative predictions; PPV = positive predictive value, ratio of true positive

predictions considering all positive predictions; AUC = area under the ROC curve, compares the relation between true positive rate and false positive rate; Accuracy = the percentage of true predictions, both positive and negative.