Providing a clearer insight into how concussion and pain impact mental health, cognition, and quality of life

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Abstract

Much of the present literature suggests that sport-related concussion (SRC) can lead to poor mental health, impaired cognition, and reduced quality of life. However, physical pain has also been reported to have the same influence on these three outcomes, and while SRC and pain often accompany each other, it is surprising that little research assesses the two simultaneously. Therefore, the present study aimed to further investigate the relationship the two factors have on the three outcomes. Depression was measured using the Center for Epidemiological Studies, anxiety was assessed using the State-Trait Anxiety Inventory while the SF-12 recorded quality of life. A trail-making test assessed cognitive flexibility of participants. Data analysis of 84 participants (Concussed 45 vs. 39 Non-concussed) revealed that (i) SRC history was related to reduced accuracy in the cognitive flexibility task but had no bearing on mental health symptoms and quality of life scores, and (ii) physical pain was not related to cognitive flexibility but was responsible for poorer mental health and lower quality of life. This study, like no other to our knowledge, highlights the different influence that SRC and pain have on mental health, cognition, and quality of life. With the knowledge that concussion appears to be more responsible for impaired cognition whereas physical pain is associated with poorer mental health and reduced quality of life, we are better placed to predict the outcome of these events and support athletes that have sustained SRC, are experiencing physical pain, or both.

Introduction

Sport-related concussion (SRC) has become a widely investigated area in recent years, with many sport-related activities involving high energy events that can expose athletes to direct and indirect traumas and increase their risk of injury (Chambers et al., 2015; Póvoas et al., 2014). Particular consequences of SRC have been identified, with poorer mental health (Hoyle, 2020; Mrazik, 2021), impaired cognition (Gonzalez et al., 2021; Kodali & Fisqua 2021), and reduced quality of life (Doroszkiewicz et al., 2021; Walton et al., 2021), among the most prevalent outcomes. Although physical pain often accompanies SRC (Provance et al., 2020), surprisingly few studies incorporate this factor into SRC research. Therefore, the relationship between SRC and pain and these three broad outcomes warrants investigation. By better understanding how SRC and physical pain relate to mental health, cognition, and quality of life, we are better able to support athletes that have sustained SRC, experiencing physical pain, or both.

Depression and anxiety are the most researched mental health disorders, likely due to their high prevalence, with 3.4% of the general population suffering from depression (WHO, 2022). However, higher rates are reported in athletes that have (Walker et al., under review) and have not sustained concussion (Walker & Marchant, 2020; Yang et al., 2007). Given the high comorbidity between depression and anxiety, it is unsurprising that higher scores of anxiety are often found in those that have sustained concussion (Yang et al., 2015). Moreover, those who report experiencing higher levels of physical pain also score higher on depressive symptomology questionnaires (Walker et al., under review). As SRC and physical pain are often
experienced together (Provance et al, 2020), this raises the question as to which contributes more to elevated depressive and anxiety symptoms.

Cognitive flexibility involves the ability to adjust to changed demands or priorities (Diamond, 2013) and is therefore important for athletes with evidence showing that cognitive flexibility levels of team athletes are higher than those of individual athletes (Aslan, 2018). Aslan (2018) suggests this could be due to individual sports requiring less cognitive function than team sports. There is also evidence of SRC negatively impacting cognitive flexibility in athletes (Hume et al., 2017; Wilmoth et al., 2019). With SRCs much more likely to occur in team contact sports such as rugby, football, and hockey (Harmon et al., 2019), and flexibility important for optimal performance (Aslan, 2018), it is necessary to protect athletes from sustaining SRC and the impact this can have on areas of cognition such as cognitive flexibility. The role of physical pain on cognitive flexibility is still unclear with many animal studies including rats (Cowen et al., 2018), and chronic pain (Hageman et al., 2014; Moriarty et al., 2016) composing much of the literature.

With concussion linked with poorer mental health (Walker et al., under review; Yang et al., 2015) and impaired cognition (Aslan, 2018), evidence of a link with reduced quality of life (Gard et al., 2020) is unsurprising. It is possible that the two broad outcomes could impact quality of life. For example, impaired cognition leading to individuals struggling to complete daily tasks could negatively impact quality of life. Likewise, not being able to compete at a sporting level that one once could, could lead to poorer mental health and quality of life. However, even if these examples did explain reduced quality of life in athletes, it is still unclear whether this is due to SRC or physical pain, with evidence that both negatively impact quality of life (Ponsford et al., 2019; Samadi et al., 2021; Vaegter et al., 2021; Voormolen et al., 2019), and therefore this warrants further exploration.

Although there is good evidence of SRC negatively impacting mental health such as depression (Walker et al., under review) and anxiety (Yang et al., 2015), areas of cognition such as cognitive flexibility (Aslan, 2018), and quality of life (Gard et al., 2020; Ponsford et al., 2019; Voormolen et al., 2019), the role that physical pain has on these outcomes is still ambiguous. This is due to evidence that physical pain can also lead to poorer mental health (Walker & Marchant, 2020), impaired cognition (Hageman et al., 2014; Moriarty et al., 2016), and reduced quality of life (Samadi et al., 2021; Vaegter et al., 2021). As SRC and pain are often experienced simultaneously (Provance et al., 2020), and athletes are among the most at-risk of sustaining both, the two contributing factors are rarely examined in conjunction in the literature. Therefore, the present study aims to address this gap in the literature, as learning which factor affects each outcome allows us to better support athletes that have sustained SRC, is experiencing physical pain, or both.

Method

Participants

Eighty-four participants completed questionnaires measuring depression and anxiety symptoms as well as quality of life, and a trail making task designed to measure cognitive flexibility. Information of participants is presented in Table 1. The post-concussion symptom scale (PCSS; Lovell, 2006) was also used to record severity of symptoms ($M = 63.71, SD = 25.35, Range = 9-105$). Post-concussed participants reported having sustained SRC between 1 and 120 months ($M = 32.18, SD = 32.17$) prior to participation in this study with incidences ranging between 1 and 12 ($M = 3.58, SD = 3.01$). Recovery period ranged from 1 week to 12 months (Months, $M = 2.03, SD = 2.38$). Fifty-one per cent ($n = 43$) of the total sample displayed depressive symptoms. Fifty-five per cent ($n = 25$) of the post-concussed sample and 46% ($n = 18$) of non-concussed participants displayed depressive symptoms.

Table 1. Participant characteristics

<table>
<thead>
<tr>
<th>Sex</th>
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<tbody>
<tr>
<td>Male</td>
<td>52</td>
<td>24.08</td>
<td>4.68</td>
</tr>
<tr>
<td>Female</td>
<td>32</td>
<td>23.72</td>
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<table>
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<th>Age</th>
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<tbody>
<tr>
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<td>M</td>
<td>SD</td>
<td>Range</td>
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<td>-----</td>
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</tr>
<tr>
<td>84</td>
<td>24.08</td>
<td>4.68</td>
<td>9-105</td>
</tr>
</tbody>
</table>

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Student Status

Athlete status

SRC History

Depressed Categorisation (Total)

Depressed Categorisation (Athletes)

- Athletes were defined as those that had competed in sport once a week for the past three months or would usually do so without COVID-19 disruptions. That is the three months preceding March 2020.

Measures

General Information Questionnaire (GIQ): included data on sex, age, student status, athlete status, concussion history, and level of physical pain experienced in the past week. Pain was measured using NRS-11 (Downie et al., 1978)) providing a score ranging 0-10.

Post-Concussion Symptom Scale (PCSS; Lovell, 2006): The PCSS was used to corroborate whether those that had reported sustaining SRC had done so. The questionnaire contains 22 items, that are all symptoms of SRC. Participants were required to report to what extent they experienced each symptom following the concussive event on a seven-point Likert scale (0-6), with ‘0’ indicating participants did not experience said symptom while ‘1-6’ indicated increasing severity. The sum of scores could therefore be between 0-132, with a cut-off of [?]7 indicative of an individual that had experienced SRC (Iverson et al., 2003; Lau et al., 2011; Sicard et al., 2018).

Center for Epidemiological Studies Depression Scale (CESD; Radloff, 1977): The CESD is a 20-item questionnaire that measures the depressive symptoms that participants have experienced in the past week. A four-point scale was used to rank the responses: 0 to 3. Zero indicated that participants had experienced that symptom ‘rarely or none of the time’ (less than once a week), 1 ‘some or a little of the time’ (1-2 days a week), 2 ‘occasionally or a moderate amount of time’ (3-4 days a week) and 3 ‘most or all of the time’ (5-7 days a week). Four items were reverse coded due to the nature of the question. A total score [?]16 of 60 highlights an individual may be experiencing some form of depression (Husaini et al., 1980). A higher total score reflected more severe depressive symptoms.

State-Trait Anxiety Inventory (STAI, Speilberger et al., 1970): The STAI was used to assess state and trait-anxiety in participants. The 40-item questionnaire was presented as two surveys, Y-1 and Y-2 which measured state-anxiety and trait-anxiety, respectively. The Y-1 form evaluated how participants felt at present whereas the Y-2 form recorded how participants feel generally. The four responses for both forms were ranked 1 to 4. For the Y-1 form, 1 suggested ‘not at all’, 2 indicated ‘somewhat’, 3 indicated ‘moderately so’ and 4 indicated ‘very much so’. For the Y-2 form, 1 suggested ‘almost never’, 2 indicated ‘sometimes’, 3 indicated ‘often’ and 4 indicated ‘almost always.’ This resulted in a scoring range of 20-80 for both State-Anxiety and Trait-Anxiety with greater scores indicating higher anxiety levels.

Health Related Quality of Life: SF-12 (SF-12, Ware et al., 1996): The SF-12 was used to investigate quality of life containing 12 items which had a two, three, five and six-point Likert scale depending on the nature of the question. The sum of scores was calculated between 0 and 36, with greater scores indicating better quality of life.

Pavlovia: Trail Making Task: The Trail Making Task (TMT; Reitan, 1955): TMT is a popular switching task that can assess cognitive flexibility. TMT consists of two parts in which the participant connects 25 dots as quickly as possible while maintaining accuracy (Arnett & Labovitz, 1995). The first part of the task, TMT-A, participants connect dots 1-25 to provide a baseline score whereas the second part, TMT-B, acts as the switching task with participants connecting a series of numbers and letters. That is, the number “1”...
connects to letter “A” which connects to number “2” and so on until number “13” concludes the test as the twenty-fifth target. Accuracy scores and reaction times were recorded for both TMT-A and TMT-B.

Reliability Statistics

Reliability statistics was calculated by conducting a Cronbach’s Alpha. Analyses revealed internal consistency scores of $a = .93$ for PCSS, $a = .92$ for CESD, $a = .95$ for STAI (state), $a = .94$ for STAI (trait) which are all considered excellent (Sharma, 2016) The SF-12 bore an internal consistency score of $a = .81$ which Sharma (2016) describes as a good score.

Procedure

Participants completed the questionnaires on the online survey platform Qualtrics (Qualtrics, Provo, UT) and were fully informed about the study with their consent obtained prior to participation. This was followed by the participants completing the study questionnaires (GIQ, CESD, STAI, SF-12). After completing the last questionnaire, participants were directed to the trail making task on Pavlovia.

Ethics

British Psychological Society (BPS) ethical guidelines were adhered to with data collection commencing after ethical approval was obtained from the University’s Departmental Research Ethics Committee (DREC). A participant information sheet informed participants of the nature of the study and their rights as a participant including details on the withdrawal of data if they wished to do so. All participants were 18 years or older at the time of completing the study. A debrief form was displayed reiterating the aims of the study.

Data Analysis

Two MANOVAs investigated the difference in cognitive flexibility, depressive symptoms, state-trait anxiety symptoms, and quality of life between those that have and have not sustained sport-related concussion; one with and one without controlling the effect of physical pain. It was predicted that those that have sustained sport-related concussion would produce lower accuracy scores on the cognitive flexibility task, elevated depressive and anxiety symptoms and lower scores of quality of life, as well as physical pain covarying significantly.

Results

SRC history on Cognitive Flexibility, Depression, Anxiety, and Quality of Life

The first MANOVA (that did not control for the effect of physical pain) revealed a significant effect of SRC history on accuracy scores in TMT trails (A & B). For TMT (A) it was $F (1, 82) = 4.34$, $p = .04$, $n_{p^2} = .05$ and for TMT (B), $F (1, 82) = 8.68$, $p = .004$, $n_{p^2} = .096$, whereas there were no significant effects of reaction times for TMT (A) ($p = .33$, $n_{p^2} = .012$) and TMT (B) ($p = .97$, $n_{p^2} = .000$). There was also no significant effect of SRC history on depressive symptoms ($p = .34$, $n_{p^2} = .011$), state anxiety scores ($p = .91$, $n_{p^2} = .000$), trait anxiety scores ($p = .94$, $n_{p^2} = .000$), total quality of life scores ($p = .39$, $n_{p^2} = .009$), physical quality of life scores ($p = .88$, $n_{p^2} = .000$), and mental quality of life scores ($p = .23$, $n_{p^2} = .017$). Descriptive statistics are displayed in Table 2.

Table 2. Descriptive statistics of cognitive flexibility, depressive symptoms, anxiety symptoms, and quality of life scores by SRC history

<table>
<thead>
<tr>
<th>SRC History</th>
<th>TMT (A) Accuracy (%)</th>
<th>TMT (A) Reaction Time (s)</th>
<th>TMT (B) Accuracy (%)</th>
<th>TMT (B) Reaction Time (s)</th>
<th>Depressive Symptoms</th>
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</thead>
<tbody>
<tr>
<td>SRC</td>
<td>M = 94.58 SD = 12.03</td>
<td>M = 48.05 SD = 29.64</td>
<td>M = 95.02 SD = 7.13</td>
<td>M = 52.72 SD = 17.70</td>
<td>M = 18.76 SD = 11.73</td>
</tr>
<tr>
<td>No SRC</td>
<td>M = 12.03 SD = 98.67</td>
<td>M = 29.64 SD = 43.05</td>
<td>M = 7.13 SD = 98.56</td>
<td>M = 17.70 SD = 52.84</td>
<td>M = 11.73 SD = 16.51</td>
</tr>
<tr>
<td>SRC</td>
<td>M = 2.49</td>
<td>M = 11.76</td>
<td>M = 9.34</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No SRC</td>
<td></td>
<td></td>
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</table>
Table 1. Summary of MANCOVA results and univariate ANCOVA results.

<table>
<thead>
<tr>
<th>Mental Health Measure</th>
<th>Mean Difference</th>
<th>p-value</th>
<th>Partial Eta Squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>State-Anxiety Symptoms</td>
<td>39.42</td>
<td>.008</td>
<td>.002</td>
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<tr>
<td>Trait Anxiety Symptoms</td>
<td>44.80</td>
<td>.001</td>
<td>.007</td>
</tr>
<tr>
<td>Total Quality of Life Scores</td>
<td>23.71</td>
<td>.000</td>
<td>.000</td>
</tr>
<tr>
<td>Physical Quality of Life Symptoms</td>
<td>8.69</td>
<td>.27</td>
<td>.109</td>
</tr>
<tr>
<td>Mental Quality of Life Symptoms</td>
<td>9.51</td>
<td>.042</td>
<td>.046</td>
</tr>
</tbody>
</table>

**SRC history on Cognitive Flexibility, Depression, Anxiety, and Quality of Life with pain as covariate**

The second MANCOVA (that controlled for the effect of physical pain) revealed a significant effect of SRC history on accuracy scores of both TMT (A), $F(1, 81) = 4.27, p = .042, \eta^2_p = .05$ and TMT (B), $F(1, 81) = 8.47, p = .005, \eta^2_p = .095$, whereas there were no significant effects of reaction times for TMT (A), $p = .29, \eta^2_p = .014$ and TMT (B), $p = .96, \eta^2_p = .000$. There was also no significant effect of SRC history on depressive symptoms ($p = .39, \eta^2_p = .009$), state anxiety scores ($p = .99, \eta^2_p = .000$), trait anxiety scores ($p = .85, \eta^2_p = .000$), total quality of life scores ($p = .46, \eta^2_p = .007$), physical quality of life scores ($p = .76, \eta^2_p = .001$), and mental quality of life scores ($p = .27, \eta^2_p = .015$). However, pain had a significant effect on depressive symptoms $F(1, 81) = 9.88, p = .002, \eta^2_p = .109$, state anxiety scores $F(1, 81) = 7.5, p = .008, \eta^2_p = .085$, trait anxiety scores $F(1, 81) = 5.6, p = .02, \eta^2_p = .065$, total quality of life scores $F(1, 81) = 12.88, p = .001, \eta^2_p = .137$, physical quality of life scores $F(1, 81) = 10.14, p = .002, \eta^2_p = .108$, and mental quality of life scores $F(1, 81) = 9.81, p = .002, \eta^2_p = .05$. Pain had no effect on accuracy of TMT (A), $p = .99, \eta^2_p = .00$ and TMT (B), $p = .75, \eta^2_p = .001$ or reaction times of TMT (A), $p = .14, \eta^2_p = .026$ or TMT (B), $p = .66, \eta^2_p = .002$.

**Discussion**

This study aimed to establish a better understanding of how SRC and physical pain contribute to mental health, cognition, and quality of life changes in post-concussed athletes. While previous research concludes that concussion leads to poorer mental health (Walker et al., under review; Yang et al., 2015), impaired cognition (Hume et al., 2017; Wilmoth et al., 2019), and reduced quality of life (Gard et al., 2020; Ponsford et al., 2019; Voormolen et al., 2019), this study presents a more nuanced explanation. Our analysis revealed that while physical pain may be responsible for poorer mental health and quality of life, it may not have any major influence on cognition. Conversely, concussion may contribute to impaired cognition but has lesser bearing on the athletes’ mental health and quality of life. Additionally, 48% of athletes reported experiencing depressive symptoms, which is much higher than the 3.4% reported in the general population (WHO, 2022) suggesting athletes are an at-risk demographic, which is in line with previous work in this area (Walker & Marchant, 2020).

During a concussive event, the brain undergoes significant trauma. As the brain moves rapidly within and against the skull, nerves and blood vessels are stretched and bruised which can cause chemical changes in the brain (Perrine et al., 2018). This is often referred to as diffuse axonal injury and is a well-established characteristic of concussion (Johnson et al., 2013; Smith & Meaney, 2000; Smith & Stewart, 2020) with the stretching of axons, disruption of axonal transport, and disconnection responsible for impaired cognition post-concussion (Giza & Hovda, 2014). Although axons can tolerate stretching up to twice their resting length during normal daily activities (Smith & Stewart, 2020), the rapid and/or dynamic nature of a concussive event leads to axons becoming stiffer and more brittle, which exposes them to injury (Johnson et al., 2013; Smith & Meaney, 2000). This high rate of stretching results in more complex demand during a metabolic crisis (Johnson et al., 2013; Smith & Meaney, 2000), and can lead to axonal degeneration (Tang-Schomer et al., 2012). The effects of this process can last for varying levels of time and therefore axonal damage could explain why those that had sustained SRC in this study performed worse on the accuracy measures of the trail making task than those with no history of concussion due to alterations in cognitive status (McInnes et al., 2017).

Interestingly, it was found that concussion was not responsible for poorer mental health or reduced quality of life, which opposes previous literature (Gard et al., 2020; Ponsford et al., 2019; Voormolen et al., 2019; Walker...
et al., under review; Yang et al., 2015) and therefore this must be discussed. As aforementioned, physical pain often accompanies SRC (Provance et al., 2020) and it is unexpected that the two have not been simultaneously investigated more often, especially given the likelihood of athletes experiencing physical pain regardless of SRC. In the present study, pain is responsible for mental health and quality of life decline, with no bearing on cognition, which would suggest other biological factors or social factors are liable. Regarding biological explanations, there is evidence of a shared neural pathway between pain and depression (Nekovarova et al., 2014), and with anxiety so closely related to depression, this could explain the higher scores of the two disorders in the post-concussed sample. From a social perspective, pain is likely to reduce playing time in athletes (Mortazavi et al., 2015; Mosler et al., 2018), or at least the ability to perform to optimal level (Smith & Milliner, 1994) and this reduction in game-time or performance could exacerbate mental health symptoms such as depression and anxiety and lead to reduced quality of life.

Although there was a relatively small sample size used, this was not underpowered and therefore the risk of type II error was low. There is, however, some level of risk of self-selection bias due to the voluntary nature of our recruitment. Athletes and non-athletes who have experienced different mental health symptoms or changes in executing daily tasks may be over-represented in the sample, resulting in overestimation of prevalence. Despite this, the present study, like no other to our knowledge, highlights the different influence that concussion and pain have on mental health, cognition, and quality of life. With the knowledge that concussion is more responsible for impaired cognition whereas physical pain is more responsible for poorer mental health and reduced quality of life, we are better placed to predict the outcome of these events and support athletes that have sustained SRC, are experiencing physical pain, or both.

References


