An Investigation of the Prevalence & Reporting of Mild Traumatic Brain Injury in a Survey of British Female Basketball Players.

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Abstract

Objective: The current study sought to investigate the prevalence of reporting of mild Traumatic Brain Injury (mTBI) and its symptoms in female basketball athletes. It also sought to evaluate the attitudes and knowledge surrounding mild traumatic brain injury (mTBI) in the same sample.

Method: Participants (N = 34) from the three highest leagues in Great Britain (Women's British basketball league: 24.91±4.28 years old, National basketball league division one: 22.06±4.14 years old, National basketball league division two: 22.33±2.73 years old) were recruited. Each participant completed a novel survey assessing the prevalence of mTBI, the reporting habits of mTBI, and the educational history regarding mTBI.

Results: Within the sample 52.94% answered they had received a suspected mTBI in their careers, with 35.29% being formally diagnosed with a mTBI. The mean number diagnosed was 2.21±1.90. Athletes were more likely to report a mTBI during a training session than they were in a competition/game (t=0.07, P>0.05) also more likely (t=0.06, P>0.05) to report a mTBI during game play to a teammate than they were to a member of their coaching staff. 41.18% answered yes to if they had ever experienced any mTBI symptoms and continued to play, and 32.35% of the samples answered yes to having not reported mTBI to continue playing in a game or practice.

Conclusions: In conclusion, female basketball players within the UK are at risk of sustaining mTBI during their careers, and further to this, these athletes do not report all mTBI suffered from. This supports the current findings in previous research as to the negative culture of underreporting of mTBI in athletic populations.

Authors declaration page

I declare that the work in this thesis was carried out in accordance with the regulations of the University of Gloucestershire and is original except where indicated by specific reference in the text. No part of the thesis has been submitted as part of any other academic award. The thesis has not been presented to any other education institution in the United Kingdom or overseas. Any views expressed in the thesis are those of the author and in no way represent those of the University.

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Introduction

Basketball is a large participation sport within Britain, with approximately 186,900 adults playing at least twice per month in 2021 (Lange, 2021), whilst 46,600 females play at least twice per month (24.9% of the total basketball population), in England alone (Basketball England, 2022). Basketball England had over 33,000 members in 2018, of 6,600 of those were female (Basketball England, 2019). Basketball is a contact sport (Abdollahi and Sheikhhoseini, 2021), and contact sports are linked to increased rate of mTBI (Lanof et al, 2014).

Concussion is defined as an injury that results in the temporary loss of normal brain function, including altered mental state, or level of consciousness (American Association of neurosurgery; AANS, 2020). Concussion is a mild version of a traumatic brain injury (TBI) (Voss et al, 2015), and as such is used interchangeably within previous research, with research from Sharp and Jenkins (2015) calling for the discontinuance of the use of the word concussion, being replaced with traumatic head injury, with a classification of severity. Therefore, within this research, both research in concussion and TBI is being outlined, and putting under the heading of Mild Traumatic brain injury (mTBI). Sports related mTBIs are defined as the 'immediate and transient symptoms of a traumatic brain injury' within exercise and sport (McCrory et al, 2017). Although there is a lack of research within the field, multiple mTBI events have been linked to second impact syndrome and chronic traumatic encephalopathy. Second impact syndrome is a potentially fatal swelling around the brain (Saunders and Harbaugh, 1984; Stovitz et al, 2017) and chronic traumatic encephalopathy is a progressive neurodegenerative disease (Stein et al, 2015) both caused by repeated mTBIs (Stein et al, 2015; Stovitz et al, 2017). If athletes are underreporting concussions, they are potentially increasing their likelihood of sustaining serious fatal injuries or chronic diseases (Kimbler et al, 2011). Thus, research regarding the prevalence of mTBI and attitudes towards mTBI is vital to prevent potentially fatal conditions in the future.

Basketball is not commonly associated with mTBI however 189 'concussions' were reported within the National Basketball Association (NBA) from 1999 to 2018 (Patel et al, 2019), whilst 0.6% of total injuries sustained within a 17-year period were classed as concussion within the NBA (Drakos et al, 2010). Within women's basketball, 36 concussions were reported between 2000 and 2008 by collegiate players entering the Women's National Basketball Association (WNBA) combine (McCarthy et al, 2013), and between 2015 and 2019 20 concussion were reported, 0.10% of all injuries, leading to 58 games missed (Baker et al, 2020). There was a rate of 2.61 mTBIs per 1000 athletic exposures in female basketball players during one school year (Kerr et al, 2017). Basketball is an increasingly physical sport, and although once deemed 'non-contact' (Drakos et al, 2010), it is deemed a contact sport by Basketball England (2021). Basketball is also often played on hardwood, with athletes jumping putting them at risk of injury (Yengo-Kahn et al, 2016).

There is importance in this research, due to the lack of research within the field of female sport, let alone female basketball players and their reporting of mTBI within Britain. Furthermore, mTBI has shown to be a serious consequence of sport, with novel research still being needed to fill in the gaps. The current research could be used to better inform not only athletes, but officials, medical staff, and coaches of the prevalence and reporting habits of their athletes regarding mTBI. The current research could also be in conjunction with prior research to influence education, rulemaking and court side decisions regarding players and suspected cases of mTBI.

There has been the suggestion in research that females are more likely to receive mTBI (Gessel et al, 2007) and may have more substantial long-term consequences of this trauma (Covassin et al, 2018; Snook et al, 2017). Dick (2009) systematically reviewed 10 articles, finding higher incidence rates of concussion in female athletes than male athletes, and some difference in outcomes but that was less well documented within the research used. Dick. (2009) also concluded that although female participation in sport is increasing, most existing research within mTBI is completed within a male population. For example, a systematic review of 38 studies (date range: 2000 to 2018) reported there was a higher incidence rate of concussion in females compared to males ($P < 0.01$) within football (soccer) (RR [95% CI], 1.76 [1.43-2.16]; $P < 0.01$) and basketball (RR [95% CI], 1.99 [1.56-2.54]; $P < 0.01$) (Cheng et al, 2019). However, they did not find any difference in incidence rates within other sports, such as baseball/softball, ice hockey, lacrosse, track and field, and swimming and diving. This may have been due to the difference in sports, and the number of people who compete in those sports in both male and female aspects.

Female football and basketball athletes were significantly more likely to receive a mTBI than males (football: *P*=0.05; basketball: *P*=0.05) (Covassin et al, 2003). Female basketball players in the National collegiate athletic association (NCAA) have a reported higher overall concussion number rate (3.94/10,000 AE, 95% CI 3.58-4.31) than their male counterparts (3.23/10,000 AE (Athletic Exposures) (95% CI 2.93-3.54) per 10,000 athlete exposures (Zuckerman et al, 2015). Furthermore, research has found that more females than males sought help for mild traumatic brain injury in sports medicine, primary care providers and speciality care departments (Martini et al, 2022).

There have been many theories as to why females are seemingly more likely to receive a mTBI than males. One of these is the muscular and skeletal structure of females compared to males. Females have been found to have significantly smaller vertebrae between cervical three and cervical seven than in a sample of height matched males, in the anterior posterior dimension ($P < 0.012$) and have less strength than male necks (Vasavada et al, 2008). Furthermore, within a sample of young adults, females were shown to have less neck strength than males (Catenaccio et al, 2017). Poorer and weaker isometric neck extension strength has recently been found to be a risk factor in mTBI in professional male rugby union athletes, with a 10% increase in extension strength being associated with a 13% reduction in mTBI rate (Farley et al, 2022). Biomechanically, females are proposed to have an increased susceptibility for mTBI due to a lower ‘biomechanical threshold (the amount of force/acceleration needed to cause a mTBI (Guskiewicz and Mihalik, 2011)’ (Mollayeva et al, 2018), and female athletes could cause injury with lesser magnitude (Wilcox et al, 2014). Biologically, the endocrine system in females, most notably the menstrual cycle, oestrogen, and progesterone, is proposed to also influence the recovery and symptoms (Mollayeva et al, 2018). Brown, et al (2015), using a meta-analysis and a systematic review method, concluded that the menstrual cycle could be an explanation for the higher symptom scores females seemingly report in research. However, this is not a definitive cause for symptom reporting. Moreover, Wunderle, et al (2014) used a sample of 144 female participants (aged between 16-60 years), who presented to emergency departments within four hours of a mTBI and were given a neurological and quality of life outcomes assessment one month after. The results found that females injured during the luteal phase of their menstrual cycle, had lower scores than women during the follicular phase or women taking oral contraceptives. They concluded that the hormonal levels of females during a mTBI can influence quality of life and neurological outcomes one month after the incident. This research was not completed on a sample of athletes, rather a group of female participants that had presented to emergency departments for any mTBI injury. However, alternatively Mihalik, et al (2009) concluded that there was no link between the two.

Female athletes also have been found to have poorer rehabilitation outcomes after mTBI incidences. Chiang Colvin, et al (2009) found that in a sample of soccer players female athletes performed poorer on cognitive testing ($F=2.72$, $P=0.05$) after concussion, and displayed more symptoms ($F=20.1$, $P=0.00001$) than their male counterparts. Furthermore, Kostyun and Hafeez (2014) concluded that female athletes (266 athletes, 102 female (14.9 ± 3.4 years), 164 males (14.3 ± 2.3 years)) had a longer recovery course ($P=0.002$) and required more treatment ($P<0.001$) for their symptoms than their male counterparts. They also were more likely to need medication ($P<0.001$) and vestibular therapy ($P<0.001$). This is supported by Broshek, et al (2005) who found that females athletes had significantly greater declined in simple and complex reaction times and reported more symptoms compared to males. However, Ling, et al (2020) found that within a comprehensive meta-analysis, female athletes in basketball were less likely than their male counterparts to receive concussions through player contact ($P=0.01$). Furthermore, Master, et al (2021) found that there were no significant differences between female and male recovery times. There has been a range of research with varying conclusions, and therefore more research should be done to add to the breadth and depth of research already available.

Literature review

mTBI research is a growing and complex field, with new literature being published ever presently (Master et al, 2022; Walshe et al, 2022; Aghakhani, 2022). Headway reported an increase in all head injury hospital admissions by 23.00% since 2006, with 39.41% of all head injury admissions being in females (Headway, 2018). Sports related mTBI is an ‘increasingly common’ occurrence within the United Kingdom (Phillips et al, 2017). With an ever-increasing number of women and girls becoming involved in basketball (Basketball England, 2022), it is more important than ever that we accurately report and treat mTBI in female athletes.

Mild traumatic brain injuries (mTBI)

Concussion, a mild form of traumatic brain injury (Voss et al, 2015), is defined as an injury resulting in temporary loss of brain function, changes in the level of consciousness and altered mental state (AANS, 2020). Moreover, the signs tend to spontaneously resolve and have functional disturbances rather than structural injuries seen on neuroimaging (Herring et al, 2021). Within this research concussion and mild traumatic brain injuries are being put into the heading mTBI. Sports related mTBIs are defined as the 'immediate and transient symptoms of a traumatic brain injury' within exercise and sport (McCrory et al, 2017). There is a high prevalence of mTBI within sport with an estimated 3.8 million sports related mTBIs occur yearly within the United States of America (USA) (Langlois et al, 2006). Collision sports (namely American football and rugby union) have the highest incidence rates of mTBI with 0.53 and 4.18 per 1000 athletic encounters respectively (Pfister et al, 2016) alongside combat sports (such as boxing) (Brown et al, 2021) having 73.7% of respondents having at least one symptom of a mTBI in the week before surveying and Lystad and Strotmeyer. (2018) with 58% of respondents within a Thai Boxing association sanctioning authority database within the USA, having a suspected mTBI in their careers. Furthermore, mTBIs are more common in females than males (Dick, 2009; Kutcher and Eckner, 2010, Gessel et al, 2007), with females reporting more signs and symptoms than their male counterparts (Colvin et al, 2009). Gessel, et al (2007) completed a surveillance study over nine US high school sports, in over 100 high schools, and found females had a higher rate of mTBI (0.36/1000 A-Es) than males (0.22/1000 A-Es) (RR 1.68, 95% CI 1.08, 2.60, P=0.03), and mTBI represented a larger proportion of total injuries among females (15.1%, of 29 167) than males (PR= 1.61, 95% CI 1.59, 1.64, P<0.01). Within basketball Gessel, et al. (2007) found females had a higher rate of mTBI than males (RR 2.93, 95% CI 1.64, 5.24, P<0.01). A limitation of this study is that only injuries that athletes reported to their athletic trainers, and those that had missed over one day of play were reported. This may be due to biomechanical forces at play during sport. Females exhibited greater peak angular acceleration about the head, and increased displacement compared to males (Tierney et al, 2005). Females have been found to have a

smaller head mass, less isometric strength, a smaller neck girth, lower levels of head-neck stiffness (Tierney et al, 2005) and weaker less defined musculature within the neck (Vasavada et al, 2008). Females also have a longer recovery time than their male counterparts (Colvin et al, 2009). However, other research has found that in a group of 1005 participants aged 12 to 17 years, males were 10.0% ($\chi 2$ (1) = 7.01, p = 0.008) more likely to report they had received a mTBI than females (Donnell et al, 2018).
There are multiple different explanations for the mechanics and physiology of mTBI in research. Biomechanically, a mTBI is often the result of a sudden deceleration or acceleration of the head or body (Shaw, 2002), that may be caused by a blow to the head, face, neck, or body, with impulsive forces transmitting to the head (McCrory et al, 2017). For example, during car accidents, whiplash type injuries can cause mTBI and/or mTBI symptoms (Hynes and Dickey, 2005; Elkin et al, 2016), without any impact to the head. Furthermore, Guskiewicz and Mihalik (2011) outline that 'direct and inertial loading of the head may result in linear and rotational head acceleration', which induces strain within brain tissue resulting in injury. There is not a specified threshold of force after which mBTI occurs (Guskiewicz and Mihalik, 2011), however, forces are higher in impacts that result in mTBI than in impacts that do not cause mTBI (Pellman et al, 2003). McIntosh, et al (2014) found that angular acceleration in coronal plane has the strongest association with mTBI ($P<0.001$). This mechanism of injury then causes metabolic and electrophysical changes (Henry et al, 2011). MTBI and head injury is most found during contact plays within basketball, (91.7% of injuries reported) (Achenbach et al, 2021). Players are most likely to be injured during contact plays with contact from other players, contact with the floor and contact with the ball (Dick et al, 2007). MTBI has been linked to physiological changes within the brain (Werner and Engelhard, 2007), notably a deformation of tissue within the brain, such as the corpus collosum (McAllister et al, 2012). Furthermore, abnormalities have been identified with white matter fractional anisotropy and mean diffusivity in mTBI patients (Churchill et al, 2020). Symptoms of mTBI include, but are not limited to headaches, altered consciousness, dizziness, visual disturbances, memory loss, tinnitus, nausea or vomiting, difficulty concentrating, sensitivity to lights, loss or change to the senses, feeling dazed or confused, and sleep disturbances (AANS, 2020; NHS, 2020). Fatigue is the most reported symptom within both males and females (30.4% and 48.6% respectively) in

sample of 1209 NCAA division one collegiate athletes within North-eastern universities in the USA (Covassin et al, 2006). This is followed by difficulty concentrating for females (31.7%) and sleeping less than usual in males (27.8%). The clinical criteria for defining and diagnosing a mTBI is not always fully defined, and this can result in patients not seeking medical attention and therefore experiencing chronic, or longer term, side effects (Kimbler et al, 2011). Within the UK, the diagnosis criteria for mTBI are not outlined as per the NHS, but there is a symptoms list (NHS, 2021).

Complications of mTBI

Chronic Traumatic encephalopathy

Chronic traumatic encephalopathy (CTE) is a progressive neurodegenerative syndrome (Stein et al, 2015), which is caused by multiple mTBIs (Stein et al, 2015; Stovitz et al, 2017) and repetitive blows which lead to acceleration-deceleration forces in the brain (Saulle and Greenwald, 2012). These blows lead to tauopathy and is characterised by ‘deposition of hyperphosphorylated tau (p-tau) protein as neurofibrillary tangles, astrocytic tangles and neurites in striking clusters around small blood vessels of the cortex’ (McKee et al, 2015). Furthermore, it is characterised by atrophy in the medial and cerebral temporal lobes, ventriculomegaly and an enlarged cavum septum pellucidum (McKee et al, 2009). It can be attributed to declines in memory and cognition, and further can be linked to depression, suicidal tendencies, poor impulse control, aggressiveness, Parkinsonism and finally Alzheimers and dementia (Stern et al, 2011). As a condition, it can only truly be diagnosed posthumously (Mckee et al, 2015), and therefore this makes it difficult to treat and manage. CTE has been found in athletic samples. In a convenience sample of 202 deceased American football players, from a brain program, CTE was diagnosed in 177 of subjects (Mez et al, 2017) which included 110 former NFL players. However, this study did acknowledge that although the percentages are high, they cannot directly link all cases to American football itself, due to brain degeneration being linked to age, not just repeated head trauma. CTE has been found posthumously in other athletes within American football (Omalu et al, 2005; Olamu et al, 2006), wrestling (Omalu et al, 2010), football/soccer (Ling et al, 2017) and rugby (Buckland et al, 2019).

Furthermore, case studies in retired or active contact sport athletes have found the real-life consequences of CTE and traumatic head injury. Aaron Hernandez, who played in the NFL for three years, was found dead in 2017 of suicide, with his brain being donated to the Boston university, who diagnosed him with stage three to four CTE (McKee, 2017) with further players having committed suicide (Azad et al, 2016; Malcolm and Scott, 2012). Repetitive mTBI injury can lead to the development of CTE (Stein et al, 2015) however it has not been clinically linked as to CTE causing depression and suicidal ideations (Iverson et al, 2013). As with any disease, correlating sport with CTE can be difficult, as not all athletes who compete athletically, and not all who suffer from mTBI, develop CTE (Hazrati et al, 2013). These serious and life limiting or threatening conditions are a potential chronic effect of repeated mTBI, therefore research into reporting habits of athletes is important to prevent these from developing, however more research should be done to solidify the links between mTBI and CTE.

Second impact syndrome

Second impact syndrome is a potentially devastating, yet rare condition. First described by Schneider (1974) and outlined by Saunders and Harbaugh (1984), it is characterised by a swelling and oedema around and in the brain (Stovitz et al, 2017). It involves two separate events, one TBI, followed by a second TBI within weeks, without proper recovery from the first (Bey and Ostick, 2009). Physiologically, during a single brain impact cerebral blood volume increase, leading to cerebral swelling (Reilly, 2001). This cerebral swelling can lead to pressure increase in the cranium and furthermore catastrophic head injury (Treggiari et al, 2007). Case studies have found catastrophic outcomes, with often young (adolescent) athletes suffering from chronic severe cognitive, motor, and sensory deficit, or even death (Cantu and Gean, 2010; Weinstein et al, 2013; McLendon et al, 2016, Sarcar, 2022, Tator et al, 2019). However, second impact syndrome seemingly is steeped in controversy, with some researchers believing scientific evidence being ‘non-existent’, preferring the terms cerebral swelling (McCrory et al, 2011) and it is disputed that two consecutive mTBIs can cause the extremely rapid swelling that has been linked to catastrophic intercranial pressure (McCrory et al, 2012). Whilst further research may be warranted, the potential severity of second impact syndrome means it is essential that athletes suffering from mTBI are protected and full recovery is achieved prior to returning to sport.

Dementia and mTBI

Dementia, a group of neurodegenerative brain disorders associated with a continued decline of brain functioning (NHS, 2020) including memory loss, and problems with: thinking speed, mental sharpness, understanding, judgment, mood, movement, and language (NHS, 2020). Alzheimer's disease is a type of dementia, and the most common type within the UK (NHS, 2018). Alongside Dementia, Dementia Pugilistica, formally known as 'punch drunk', was first outlined in 1928 as a condition that affected boxers after head injury (Martland, 1928; Changa et al, 2017; Castelli and Perry, 2017). It was characterised as neurological deficits such as memory impairment and personality changes. Therefore, mTBI and dementia has been linked to boxing for nearly 100 years (Castelli and Perry, 2017), and it has only further defined in more recent years.

Fann et al. (2018) completed a large scale follow up based research including over 2.7 million people in Denmark using the Danish civil registration systems, and used the Danish national patient register to obtain the TBI information, and the Danish national patient register combined with the Danish Psychiatric Central Register, and the Danish National Prescription Registry. Different models were used to adjust for different time periods since the TBI, multiple TBIs, and sex. They found that 4.7% of the population had had at least one TBI between 1977 and 2013, and 4.5% had dementia between 1977 and 2013. The adjusted risk of all-cause dementia in people with a history of TBI was higher (hazard ratio=1.24, 95% CI 1.21–1.27) than in those without any history of TBI, as was the risk of Alzheimer's disease (hazard ratio=1.16, 95% CI 1.12–1.22). It further increased with the number of TBI events, and the younger the age of the person who received their first TBI. Förstl, et al (2010) systematically reviewed a range of boxing related literature, concluded that the risk of chronic brain injury, is associated with the duration of boxer's career, and there are links to Alzheimer's disease in the biochemistry of the brain.

There are neuropathic changes linking TBI and dementia including inflammation and white matter degeneration, amyloid β and tau concentration and accumulation within the brain and the white matter (Barnes, 2018). There have been often controversial and varying links between mTBIs and dementia, most notably within case reports. Yuan and Wang (2018) reported the case of a 54-year-old former professional football player, who first developed memory problems at the age of 46. Gradually, over the coming eight years his memory problems gradually increased, before becoming more intense, as he could no longer remember conversations or questions asked just minutes before, accompanying this was cognitive deficit and significant MRI changes. He was ultimately diagnosed with Alzheimer's disease as a secondary to CTE, that was related back to his repetitive mild head trauma throughout his career. There are research problems with the generalisability of case studies. Due to them being within a singular person or group, they often lack the ability to generalise to the whole population and therefore can be seen as lacking in external validity, objectivity, and rigour (Rowley, 2002). Although they do have place in research, they are lower levels of evidence.

Outside of sport, dementia and TBI has also been linked to other groups, most notably the armed forces and those with acquired brain injury. Barnes, et al (2018) examined the association between TBI severity and dementia diagnosis in 178,779 American combat veterans (49.0±18.4 years of age) who had been diagnosed with one or more TBI's and 178,779 combat veterans (49.95±18.00 years of age) who had not had not been previously diagnosed. They found that in the cohort study a total of 2.6% of veterans without a diagnosed TBI developed dementia, whereas 6.1% of those with a diagnosed TBI developed dementia. The data was adjusted for demographics and medical and psychiatric comorbidities, and the hazard ratios for dementia were 2.36 (95% CI 2.10-2.66) for mTBI without loss of consciousness, 2.51 (95% CI, 2.29-2.76) for mTBI with loss of consciousness, 3.19 (95% CI, 3.05-3.33) for mTBI with loss of consciousness status unknown, and 3.77 (95% CI, 3.63-3.91) for moderate to severe TBI. The authors of this paper did highlight study limitations, including the use of medical record databases based on clinical diagnoses, which may not always be accurate (Barnes et al. 2018) in both the dementia and the TBI. The number of people who were diagnosed with a mTBI at the time may have increased in later years, underreporting or over reporting may have had an effect. This could lead to the underdiagnosis of dementia, especially within the early stages of the disease, and therefore the reliability of the results may be in question. There could also be the effect of better diagnosis of mTBI, as over the years the threshold for diagnosing a mTBI has drastically changed, from facial injury being useful in the diagnosis of 'punch drunk' (Parker, 1934) to a three-step diagnosis pathway including signs and symptoms at the game/practice, post-game/practice and within the 48 hours post game/practice (Raftery et al, 2016). Yaffe, et al (2018) included dementia, TBI, post-traumatic stress disorder and other medical conditions data from 109,140 female veterans over the age of 55 years who were also receiving care from the veteran's health administration medical centres in the USA. On follow up, 4% of the veterans had developed dementia. They found that women with past TBI's were significantly more likely to receive a dementia diagnosis than those without (TBI-adjusted sub distribution hazard ratio: 1.49, 95% CI 1.01–2.20). Gardner, et al (2014) found that traumatic brain injury led to an increased risk of dementia ($P<0.001$). Across all age groups and mild traumatic brain injury was more prevalent as age increased (age 55-64: P = 0.55; vs age 65-74; P = 0.02; age interaction $P<0.001$). Furthermore, Lee, et al (2013) identified 28,551 patients with mTBI, and after controls for age, gender, urbanization level, socioeconomic status, diabetes, hypertension, coronary artery disease, hyperlipidaemia, history of alcohol intoxication, history of ischemic stroke, history of intracranial haemorrhage and Charlson Comorbidity Index Score, the adjusted hazard ratio was 3.26 (95% Confidence interval, 2.69–3.94). They concluded that mTBI was a significant risk factor for dementia.

However, within all dementia research, age is identified as the biggest risk factor, and this can cause difficulties with understanding if mTBI is risk factor, or if it is exasperating already known risk factors. Furthermore, there are often limitations of dementia and mTBI research, often mTBIs are self-reported, and under reported within medical records, especially within athletic groups of past generations due to the poorer reporting standards. There has been varying research within the field of dementia and mTBI. Carson (2017) outlines the lack of research that supports case studies, and states that governing bodies of sports may be better served addressing other risk factors into dementia rather than just CTE and TBI.

A survey of 45 retired (45.6 ± 8.9 years of age) NFL players reported an average of 6.9 mTBIs (±6.2) during their NFL careers despite having moderate length careers (6.8 ± 3.2 years). Whilst most participants had normal brain function, central nervous system function, and clinical mental status, four players did have microbleeds in the brain parenchyma, and 7% had a cavum septum pellucidum with associated brain atrophy. Further, 20% also showed signs of moderate to severe depression, but none showed signs of dementia, dysarthria, cerebellar dysfunction, or Parkinsonism. They also found that 13% of players did have signs of probable chronic brain injury. Casson, et al. (2014) concluded that in comparison to other research, they found little evidence to show that the majority of retired NFL player have a chronic brain injury. More than 5000 retired NFL players were contacted to participate in the survey. These results may be unreliable, due to players who have experienced more severe symptoms later in life may not have decided to be part of the study, or didn't want to take part in the study.

Willer, et al (2019) found that there were no marked increases in dementia associated with CTE in a sample of 22 retired professional hockey or American football athletes, compared to 21 age matched non-contact sport athletes. All athletes were assessed on a range of neuropsychological measures that were used to assess cognitive impairment and executive function, and self-reported executive function and personality. Advanced structural and functional imaging techniques were utilized as well. There were no significant changes found in any of the controls, however contact sport athletes did report having impaired executive function, but this was not confirmed through neurocognitive assessment. The difference in research may be due to the number of participants and type of participants used. This study used retired NFL and NHL players from unions, however, they did not use any players that had developed health conditions before the start of the research; for example, players who had suffered from a stroke or heart disease. These athletes may have come back with different results.

Dementia is also a relatively common disease, affecting approximately one in 14 people over the age of 65, and one in six people over the age of 80 (NHS, 2020). Therefore, with Dementia being a common disease affecting mostly the elderly, there is no guarantee that mTBI affected any of these cases, or if the athletes who have developed dementia would not have already developed it due to older age.

mTBI has been found to lead to complex and life limiting and altering diseases of the brain, and the quick and efficient removal of athletes with suspected mTBI could be a step in reducing these diseases in the athlete's future. Therefore, the current research looks to identify the underreporting of female athletes in basketball, a group that has not been studied in its long term.

Psychiatric conditions and mTBI

Within a sample of 70 children (9.8±3.3 years of age) who had suffered a TBI ,Max, et al (2013) found that, 36% were found to have a novel psychiatric condition within a six month follow up. A further study found that after a 24-month long assessment period, 31% of the children (10.02±2.99 years of age) had developed a novel psychiatric disorder at some point within the 24 months (Max et al, 2015). They found that the more severe the injury, and especially the incidence of frontal white matter lesions, the more likely the development of novel psychiatric disorders. However, within young samples, especially children, they may have developed these psychiatric conditions anyway, without the mTBI being a named factor. There is more than one factor that contributes to mental illness, for example the nature nurture debate (Stoewen, 2022), genetic components (Phelan, 2002), and biological reasons (Bradshaw and Korth, 2019). These factors have all been hypothesised as being part of mental illness, that may be separate or contributing to mTBI and mental illness.

Although there has not been a huge range of research done within psychiatric illness, mTBI and sport, there have been links. Roberts, et al (2019) sampled 3,506 NFL players who had played within the league since 1960, the year where hard plastic shell helmets were introduced, and were surveyed with demographic and a range of mTBI related questions. They also used the cognition related quality of life surveys, and indicators of depression and anxiety (PHQ-9) questionnaire. 25.9% of the sample indicated anxiety, and 23.9% indicated depression, with 18.3% overlapping and admitting to both. Further to this, there was 19% greater risk of poor cognition quality of life per five seasons of professional play. Running backs and linemen were more likely to report these symptoms, these positions are also classed as high risk for mTBI. Further, loss of consciousness was associated with increased likelihood of psychiatric disorders. Further, offensive, and defensive linemen, and running backs were at an elevated risk of poor cognition, in comparison to the other positions. Within other research, depression was found to have a 9% prevalence in the general population in the USA (Lepine and Briley, 2011).

In other contact collision sports, Esopenko, et al (2017) sampled using emails, media, presentations at tournaments and word of mouth through snowball sampling, 33 former ice hockey players (54.3 years old ±10.4) compared to an age match comparison sample, there were no significant group differences within neuropsychological measures of speeded attention, verbal memory, or visuospatial functions, nor were there any significant differences within response speed, inhibitory control and visuospatial problem solving. Kerr, et al (2012) surveyed 1044 former NFL players in 2001, and then again in 2010 using a general health survey. 10.2% of respondents were diagnosed with depression between the initial and follow up surveys, and 65% self-reported at least one mTBI. The risk of developing depression increased with the number of reported mTBIs, from 3.0% risk in the no reported mTBI group, compared to 26.8% risk in the 10 plus reported mTBIs (P<0.001). However, a critique of these studies and many pieces of research that include retrospective surveys is that there may be validity issues, as recall accuracy has been found to decrease over time (Hipp et al, 2020).

Further research from Decq, et al (2016) used a survey and a telephone interview (including: questionnaires for the detection of major depressive disorder (PHQ-9), mild cognitive disorders (F-TICS-m) and headache (HIT-6)) on 239 retired male rugby players, and 138 retired other male athletes. The retired rugby players reported a higher number of mTBIs that the other athletes (P<0.001), they also reported a higher rate of major depressive disorder (P=0.04) compared to the other retired athletes, and this number increased with the more mTBIs the players reported (P=0.026) irrespective of the type of sport. Further, the rate of mild cognitive disorders was observed in the rugby players compared to the other athletes (P=0.005), but this was not associated with an increase in the number of mTBIs sustained. The HIT-6 score also increased with the number of mTBIs sustained (P=0.019). However, within a sample of retired international rugby players McMillan, et al (2017) found that the general and the mental health of the retired players was not significant different to the control groups, and cognitive testing found that all the players were within the normal thresholds. There may be differences in results due to the unknown factor of prior mental health issues. If an athlete already has a history of mental health problem, the impact of multiple mTBI may be different to those athletes who did not have a history of mental illness. Other factors also impact mental illness, for example alcohol intake, or drug intake. Research has found that although rugby players have lower prevalence’s of depression compared to the average general population, (12.6% depression in preseason, and 10.1% depression in season), but 68.6% of players had hazardous levels of alcohol use in preseason, and 62.8% in season (Preez et al, 2017). Within those with mental illness, over 20% also suffer with alcohol misuse (Westreich, 2005).

Recently mTBI has been at the forefront of the media, in a way that it has not been before. In 2020 several British rugby players launched legal action against the rugby football union, the Welsh rugby union and world rugby, for injuries sustained that have led to permanent brain injury, and the failure to protect them against long term damage, including early onset dementia (BBC sport, 2020; Sky Sports, 2020). In football, only in 2020 did the international football association approve the use of permanent mTBI substitutions (BBC sport, 2020), and in 2020 a ban on heading the ball was introduced in under 12s football training (FA, 2021).

Many sports and national governing bodies have separate and individual return to play guidelines for athletes with, or suspected, mTBI (IAFA, 2020; World rugby, 2016; CUHC, 2018). These tend to be rest, followed by staged return to exercise over a period, outlined as graduated return to play (GRTP) (May et al, 2014). The amount of time return to play takes, fluctuate between governing bodies and sports. However, return to play guidelines can only be followed if players report symptoms of mTBI, or if signs are observed such as being knocked unconscious, or if a trained professional, such as a physiotherapist, can identify the mechanism for a mTBI during play, and can remove the player from play. There are sports that use mTBI spotters, who are trained in identifying any suspicious head injury events (Davis et al, 2019). Therefore, reporting and observation and identification is an important part in safe return to play. Being knocked unconscious is an important sign of mTBI, however not all players who experience a mTBI are knocked unconscious (Wilk et al, 2010), with approximately 10% of all mTBI causing loss of consciousness (Harmon et al, 2013). Without following proper return to play guidance, the long term, and permanent effects of SRC can be life threatening. Furthermore, graduated return to play is not always followed correctly (Yard and Comstock, 2009; Kraak et al, 2021), and researchers have also outlined that GRTP are not the only solution to mTBI within sport, regarding reform (such as rule changes, e.g. eliminating tackling from youth football) within sport as a more important factor (Johnson, 2012). Within basketball in the United Kingdom (England Basketball, 2016), the consensus is that most mTBI resolve within 7-10 days, which follows the global consensus (Doolan et al, 2012). After an athlete is symptom free and rested for a period which is dependent on their age (stage 1; Figure 1, Figure 2), they can start progressing through the GRTP. The athlete can then start the first of the four stages of physical activity, which increase in difficulty and workload over a period. If any symptoms are experienced, the athlete would then return to the previous stage, until symptoms decline.

Figure one

The standard care return to play protocol for under 19-year-old players: Basketball England, 2016

STANDARD CARE RETURN TO PLAY PROTOCOL FOR PLAYERS UNDER 19 YEARS

Earliest Return to Play Day 23 Post Concussion

Stage	MINIMUM Time Between Levels	Example	Objective
1 No activity Rest period	*14 days	Physical and cognitive rest	Recovery
2 Light aerobic exercise **medical clearance recommended by a doctor	48 hours	Exercise bike 15 mins	Increase heart rate
3 Light impact and sport specific exercise	48 hours	Light jog, 20 lengths of court / 10 mins on treadmill Shooting drills such as spot shooting, cone shooting	Add sport specific impact
4 Non contact basketball	48 hours	Finishing drills, ball handling, 5 on 0	Add coordination
5 Full training **required medical clearance by a doctor	48 hours	Full contact training drills, 5 on 5, 1 on 1, transitions	Restore confidence
6 Match	24 hours	Competitive match	Return to play

Figure two

The standard care return to play protocol for over 19-year-old players: Basketball England, 2016

GRADED RETURN TO PLAY FOR THOSE PLAYERS AGE 19 YEARS OR OLDER IN AN ENHANCED CARE SETTING

Earliest Return to Play Day 6 Post Concussion

Stage	MINIMUM Time Between Levels	Example	Objective
1 No activity Rest period	*24 hours	Physical and cognitive rest	Recovery
2 Light aerobic exercise	24 hours	Exercise bike 15 mins	Increase heart rate
3 Light impact and sport specific exercise	24 hours	Light jog, 20 lengths of court / 10 mins on treadmill Shooting drills such as spot shooting, cone shooting	Add sport specific impact
4 Non contact basketball	24 hours	Finishing drills, ball handling, 5 on 0	Add coordination
5 Full training	24 hours	Full contact training drills, 5 on 5, 1 on 1, transitions	Restore confidence
6 Match	24 hours	Competitive match	Return to play

Knowledge and Education

A 2011 study from Bramley, et al (2011) sent a questionnaire to 183 high school (14 to 18 years of age) soccer players, with a 32.8% response rate. They found a statistically significant association (P=0.01) between indicating mTBI education (found by asking 'have you ever been taught about concussion?') and telling a coach about a mTBI type injury. Critically, this study needed parental permission for each questionnaire returned, and this could have affected the answers from the athletes. Parental permission can skew results and cause a smaller sample size (Harris and Porcellato, 2018).

Furthermore, 382 division one collegiate athletes (228 women, 19.57 ± 1.24 years of age, 1.69 years ±1.59 years of collegiate experience) who undertook a checklist of 16 potential symptoms, found that athletes do have a limited knowledge of mTBI related symptoms (Fedor and Gunstad, 2014). Increased mTBI knowledge and education has been linked to an increase in reporting intention behaviour. Daneshvar, et al (2021) found that in a sample of 118 male football players, those who were given an educational programme of either a crash course video, a concussion in sport video or a CDC concussion fact sheet, had significant improvements in mTBI reporting intentions both immediately after, and at a one month follow up (P<0.001). This therefore means that by increasing the knowledge of athletes within mTBI, the athletes are more likely to report their mTBI.

Reporting of mTBI in sport

Underreporting of mTBI within athletic populations is seemingly rife. Williamson and Goodman (2006) researched the prevalence of mTBIs within a sample of youth ice hockey players in the British Columbia amateur hockey association. They found that the estimated number of mTBIs taken from official injury reports were between 0.25 and 0.61 mTBI per 1000 player games hours. This is significantly lower than the player estimates, who reported 6.65 and 8.32 per 1000 player game hours, within elite hockey, and 9.72 and 24.30 mTBIs per 1000 game hours in non-elite youth hockey. The results may be different due to players not reporting their mTBI to coaches/medical staff, or not knowing what mTBI symptoms and signs were at the time. A limitation of this study is, like all TBI research, there is a lack of definitive diagnosis criteria and test, rather a group of symptoms that are linked to the diagnosis.

Research from Llewellyn, et al (2014) found that in a sample of 161 collegiate student athletes (56.5% women, aged 21.5±1.3 years, 3.7±1.0 years of collegiate athletic experience) who retrospectively reported mTBI; the self-reported rate was 33.5%. However, the unreported rate was 11.8%, with the potentially unrecognized rate being 26.1%. The most commonly unrecognized symptom being ‘knocked silly’ and ‘seeing stars’. Overall, 49.1% of all respondents acknowledged a known, unreported, or potential mTBI. This shows that the rate within collegiate athletes for mTBI is nearing 50%.

Furthermore, research from McLeod, et al (2008) found that in a pre-participation screening, 55% of athletes reported having at least one mTBI symptom at one time after a head injury, and from that 86.4% did not report mTBI history in sport, and 92.7% did not report mTBI history during recreational activities. However, this study found much variation between the three PPS questions and found that asking athletes if they had received a mTBI alone was not adequate, when athletes may not know if they had received a mTBI prior. Further to this, participants may have coincidental symptoms, for example fatigue is very common among athletes.

Kerr, et al (2017) used a retrospective general health survey, in a sample of 829 former NFL players (playing from prior to World War Two to 2011). They found that 50.3% of respondents reported they had sustained a mTBI, and not reported it within their careers. Within this study however, the length of time between Pre-World War Two (1939) and 2017 (when the study was released) is substantial. This could cause invalid results within the sample due to recall bias; where participants underestimate or overestimate past experiences (Colombo et al, 2020). Athletes do not disclose for many reasons such that can be categorised as intrinsic, cultural, and environmental factors (Kneavel et al, 2019). A cultural shift must be completed to stop players from feeling the need to not report mTBI (Murray et al, 2015), including the use of education to increase knowledge (Kurowski et al, 2015) in athletes, which has also been linked to reporting patterns (Hunt, 2015).

Athletic level-based reporting patterns

There seems to be variation within groups as to mTBI reporting rates. Wallace, et al. (2020) surveyed 577 high school athletes (64.5% black, 72.3% male, 16.02±1.2 year of age) from 14 schools. Overall, 9.5% of athletes experienced a mTBI within practice, and 16.3% reported at least one mTBI within games. However, 32.5% and 35.3% of athletes reported experiencing at least one 'bell-ringer' events in practice and games, respectively. They found that black athletes were significantly less likely to report a mTBI (P=0.015) and 'bell ringer' event (P=0.003) that occurred during games, than white athletes. The most common reasons for underreporting were outlined as 'I did not think it was serious' (56.1%), 'I did not want to let my team down' (44.4%), and 'I didn't know it was a concussion' (31.4%).

Sex based reporting patterns

There also is varying research on sex in mTBI underreporting. Although females have been shown to suffer mTBI more often (Covassin et al, 2016; Covassin et al, 2003) and have worse, or longer duration of neurocognitive symptoms (Broshek et al, 2005; Chiang Colvin et al, 2009; Covassin et al, 2012), this may be also associated with increased reporting of mTBI and its symptoms by female athletes.

Research from Wallace, et al (2017) detected a gender difference within SRC symptom knowledge. In a sample of 288 high school athletes (15.6±1.2 years of age, 198 (68.8%) male, 90 (31.2%) female) who completed a Register-Mihalik, et al (2013) questionnaire on underreporting and symptoms of SRC. A sex difference in knowledge (F=4.97, *P*=0.03) was found, with females (15.06±2.63; 95% confidence interval ¼ 14.54, 15.57) having a higher total symptom knowledge score than male athletes (14.36±2.76; 95% confidence interval ¼ 13.97, 14.74). Furthermore, male athletes were found to be significantly less likely to report SRC symptoms than female athletes. Reasons indicated were coaches being upset, teammates and coaches thinking they are weak, losing playing time, missing games, or missing playoff games. Male athletes also were less likely to report than females due to not wanting to let their team down (χ^2=7.10, *P*=0.01). For both males and females, the three most likely reasons to not report were: not wanting to let their team down, not thinking it was a big deal and not wanting to lose playing time. Further to this, athletes from the United States and Ireland stated that reasons to not disclose their potential mTBIs, included: Not wanting to miss a game (20.0% and 14.6% respectively), not wanting to lose playing time (19.7% and 13.9% respectively) and not thinking it was a mTBI at the time (15.7% and 19.9% respectively) (Beidler et al, 2021). This is important due to explaining why athletes choose to disclose suspected mTBI, and therefore why athletes may choose to not disclose.

Furthermore, research from Kroshus, et al (2016) assessed sex differences in concussion reporting and intentions and behaviour using a study in a collegiate group. They found that females reported greater intention of reporting mTBI, but no differences in the likelihood to continue to play with mTBI symptoms. Gender conformity, rather that sex, appeared to show greater difference and should be a consideration for mTBI safety. However, O'Connor, et al. (2020) completed a cross sectional study over 268 Irish collegiate student athletes from sports at a higher risk of mTBI, and they found that one in four student-athletes reported a non-disclosure of a mTBI, (*P*=0.004), with no significant differences within gender, mTBI knowledge and the pressure athletes felt to play. It is vitally important that athletes report their mTBI, to prevent further injury, that could be catastrophic, to the brain of the athlete.

Consequences of mTBI

The failure to diagnose a mTBI can also lead to some longer-term consequences. Meeham, et al (2013) found that in a sample of 486 patients seen at two mTBI clinics for SRC, who completed a post- mTBI symptom scale, a total of 148 patients (30.5%) reported they had sustained a blow to the head, that resulted in one or more symptoms of mTBI but were not diagnosed with mTBI. Furthermore, athletes who suffered a previous undiagnosed mTBI were more likely to lose consciousness (P=0.038) and have a higher post- mTBI symptom scale (P=0.004) in their current injury than those who did not have a prior undiagnosed mTBI. They concluded that failure to diagnose the first mTBI, a second mTBI can have longer term, and more serious consequences. Research has also found that musculoskeletal injury rates are higher in players returning from a mTBI (17%) than they are in the general athletic population (9%), in the 90 days following a return to play (odds ratio, 2.48; 95% CI, 1.04-5.91; P = .04) (Brooks et al, 2016).

Overall, with much of the previous research finding that mTBI is a serious condition, with underreporting often being found in athletes; the gaps within the literature show that novel research is needed, to aid in future basketball mTBI reporting. As such, the aims of the current research were to investigate the prevalence of reporting and evaluate the knowledge and attitudes towards mTBI, and its symptoms in a sample of female basketball players within the United Kingdom, playing within England Basketball's Division One and Two leagues, and within the Women's British Basketball League (WBBL) during the 2021-2022 season.

The current study will utilise a survey to evaluate both the knowledge and attitudes towards mTBI and its reporting. A convenience sample will be used, through word of mouth and social media, to recruit participants. The survey will be adapted from surveys used in previous studies (Rosenbaum and Arnett, 2010; Torres et al., 2013; Kroshus et al, 2015). The survey will ask demographics (age, number of years playing basketball, and level of basketball played), mTBI history and knowledge and attitudes (including likelihood of reporting symptoms), further outlined within the methods section of this paper. The aims of the study are to investigate the prevalence and likelihood of female basketball athletes (18-30 years of age) to report mTBI symptoms and to evaluate the attitudes and knowledge of mild traumatic brain injury in athletes (18-30 years old).

Methodology section

Study Design

A cross sectional survey was used to collect data on the reporting of mTBI and the knowledge and education surrounding mTBI.

Participants

Female basketballer players were recruited from the three main leagues within Great Britain: Women's British Basketball League (WBBL), the Division One National Basketball League and the Division Two National Basketball League. The sample was recruited mainly by word of mouth (e.g. through teammates of those contacted) through the basketball community and social media. Every participant was required to be over the age of 18, and under the age of 30 years, and a current athlete within one of the three divisions named above. Before any participants were surveyed a full project approval form was completed and approved and ethical approval were obtained from the University of Gloucestershire (Ethics number: LHALL21-22).

Procedures and measures

A bespoke survey (Appendices one) was used to collect quantitative primary data. The survey was adapted from previous surveys conducted by Rosenbaum and Arnett (2010) (appendices three), Torres, et al (2013) (Appendices two). The survey was made up of 25 questions; three demographic questions, five yes or no questions, with expansion free text responses, 10 Likert scale questions, a scale of 1-5 (1= strongly disagree, 5= strongly agree), and one multiple choice question.

The likelihood of mTBI being reported was assessed using Likert scale questions on a scale of one to five, with one being the least likely, and five being the most likely to report mTBI symptoms. MTBI history was assessed with the number of suspected and formally diagnosed mTBI/concussions sustained ever over the participants basketball careers. This also covered any missed time during practices or games. The reporting of mTBI was assessed using questions such as 'have you ever not reported symptoms of a concussion to continue playing in practice or a game?' (Appendix one).

Analysis

A sample size calculation determined a minimum of 37 participants were needed for the study, (0.231 correlation, 0.05 significant and 0.8 statistical power) (Kroshus et al, 2015).

The results of the survey were exported from the online surveys software (JISC copyrighted 2022) provided by the University of Gloucestershire, into an excel (Office 365 version 2207, 2022) spreadsheet. From this the data was analysed. The mean, standard deviations, mode, 95% confidence intervals (95% CI) and ranges were calculated where necessary. Furthermore, for two sets of questions a dependent paired two tailed t-tests were used to calculate the difference and its significance between answers. Only two sets of questions were analysed in this way, because they were directly comparable against each other. These questions were comparing: 'If you had a suspected concussion, how likely would you be to report symptoms to your coach during a game' to 'If you had a suspected concussion, how likely would you be to report symptoms to your coach during a training session'; and 'If you had a suspected concussion, how likely would you be to report symptoms to your coach during a game' to 'If you had a suspected concussion, how likely would you be to report symptoms to a teammate during a game?' Percentages of the sample who answered yes or no to questions also was calculated; this was to analyse descriptive data.

Results

Demographics of the athletes who completed the survey can be found in table one; 97 people started the survey, 34 completed it with a 35% response rate.

Table one

The demographics of the sample

	Women's British Basketball League (WBBL) players	National Basketball league Division one	National Basketball League Division Two
Number of participants	11 (32.35%)	17 (50.00%)	5 (14.71%)

(Percentage of overall sample size)			
Mean age in years (±1SD) in years	24.91±4.28	22.06±4.14	22.33±2.73
Mean playing time (±1SD (in years)	16.00±3.35	11.94±3.86	10.17±3.97

Table one: the demographics of the sample

NOTE: SD = Standard deviation.

Within the sample 52.94% answered that they suspect they have sustained an mTBI during their athletic careers and 35.29% responded they had been formally diagnosed with an mTBI within their athletic career. The mean number of mTBI formally diagnosed by the sample was M±SD= 2.21±1.90. Further, 66.67% of the sample reported they had never missed any time in game or practice due to a mTBI. This means that 2.94% of the sample stated that they had never missed any game time due to a mTBI but had been formally diagnosed with one during their athletic careers. This, however, does not consider if that mTBI was done at the end of the season, or before a break where no games would be played. Full statistical analysis of the Likert scale questions can be found in table two.

Athletes were more likely to report a mTBI during a training session (mean (M) ± Standard deviation (SD) answer= 4.00±0.92) than they were in a game (M±SD= 3.71±1.09). However, this was not statistically different (t=0.07, P>0.05)

The sample was also more likely (t=0.06, P>0.05) to report a mTBI during game play to a teammate (M±SD= 3.97±0.92) than they were to a member of their coaching staff (M±SD= 3.71±1.09). Within the sample 41.18% answered yes to if they had ever experienced any mTBI symptoms and continued to play, and 32.35% of the samples answered yes to having not reported mTBI to continue playing in a game or practice.

Within the sample, 1.76% answered that they would continue to play while suffering from a headache resulting from a mTBI. The sample agreed that coaches need to be extremely cautious when determining whether an athlete should return to play after a mTBI (M±SD= 4.53±0.61). The sample disagreed with the statements 'I think that concussions are less important than other injuries' (M±SD= 1.65±1.01) and I feel that an athlete has a responsibility to return to a game even if it means playing while still experiencing symptoms of a concussion (M±SD= 1.47±0.86). The sample agreed with the statement 'I feel that an athlete who is knocked unconscious (knocked out) should be taken to hospital' (M±SD= 4.64±0.90).

Furthermore, 20.59% agreed that headaches are less significant than being knocked unconscious, and 20.59% agreed that feeling nauseous is less significant than being knocked unconscious. When asked who was responsible for determining when a player return to play after a suspected mTBI all 33 participants (100%) answering with medical personnel being who they thought is responsible for determining a player returns to play after a suspected mTBI. Moreover, 29.41% of the sample thought coaches were responsible, 17.00% thought that the players teammates were also responsible, and 38.24% thought that the player themselves were also responsible for the players return to play. 17.00% of the sample answered that all four (coaches, players themselves, teammates, and medical personnel) were responsible for a players return to player after a suspected mTBI.

64.71% of the sample reported they had never received any formal training about the risks of mTBI. Those who had reported formal training received it via the following means: presentations from physiotherapists, doctors, sports therapists, and from preseason mTBI testing. Furthermore, they reported they received mTBI education from educational sessions within a regional training setting, from NCAA mTBI testing and workshop.

Table two

The full statistical analysis of the Likert scale questions (1=Disagree, 5=agree). The full questionnaire can be found in appendices one.

	Mean ± standard deviation	Range	1 = strongly disagree	2 = disagree	3 =Neutral	4 = Agree	5 =Strongly agree
If you had a suspected concussion, how likely would you be to report symptoms to your coach during a game?	3.71±1.09	2-5	0 (0.00%)	6 (17.65%)	8 (23.53%)	10 (29.41%)	10 (29.41%)
If you had a suspected concussion, how likely would you be to report symptoms to your coach during a training session?	4.00±0.92	1-5	1 (2.94%)	1 (2.94%)	5 (14.71%)	17 (50.00%)	10 (29.41%)
If you had a suspected concussion, how likely would you be to report symptoms to a teammate during a game?	3.97±0.94	2-5	0 (0.00%)	2 (5.88%)	9 (26.47%)	11 (32.35%)	12 (35.29%)

I would continue playing basketball while also having a headache that resulted from a head injury	2.85±1.25	1-5	6 (17.65%)	7 (20.59%)	12 (35.29%)	5 (14.71%)	4 (11.76%)
I think that concussions are less important than other injuries	1.65±1.01	1-5	19 (55.88%)	12 (35.29%)	1 (2.94%)	2 (5.88%)	0 (0.00%)
I feel that an athlete has a responsibility to return to a game even if it means playing while still experiencing symptoms of a concussion	1.47±0.86	1-4	24 (70.59%)	6 (17.65%)	2 (5.88%)	2 (5.88%)	0 (0.00%)
I feel that an athlete who is knocked unconscious (knocked out) should be taken to hospital	4.64±0.90	1-5	1 (2.94%)	1 (2.94%)	0 (0.00%)	5 (14.71%)	26 (76.47%)
I feel that having a headache is less significant than being	2.82±1.14	1-5	6 (17.65%)	5 (14.71%)	14 (41.18%)	7 (20.59%)	2 (5.88%)

knocked unconscious (knocked out)							
I feel that feeling nauseous is less significant than being knocked unconscious (knocked out)	2.85±1.08	1-5	4 (11.76%)	8 (23.53%)	13 (38.24%)	7 (20.59%)	2 (5.88%)
I feel that coaches need to be extremely cautious when determining whether an athlete should return to play after a concussion	4.53±0.61	3-5	0 (0.00%)	0 (0.00%)	2 (5.88%)	12 (35.29%)	20 (58.82%)

Figure three

The likelihood of reporting symptoms of a mTBI to a coach in a game compared to the likelihood of reporting symptoms of a mTBI to a coach in a training session

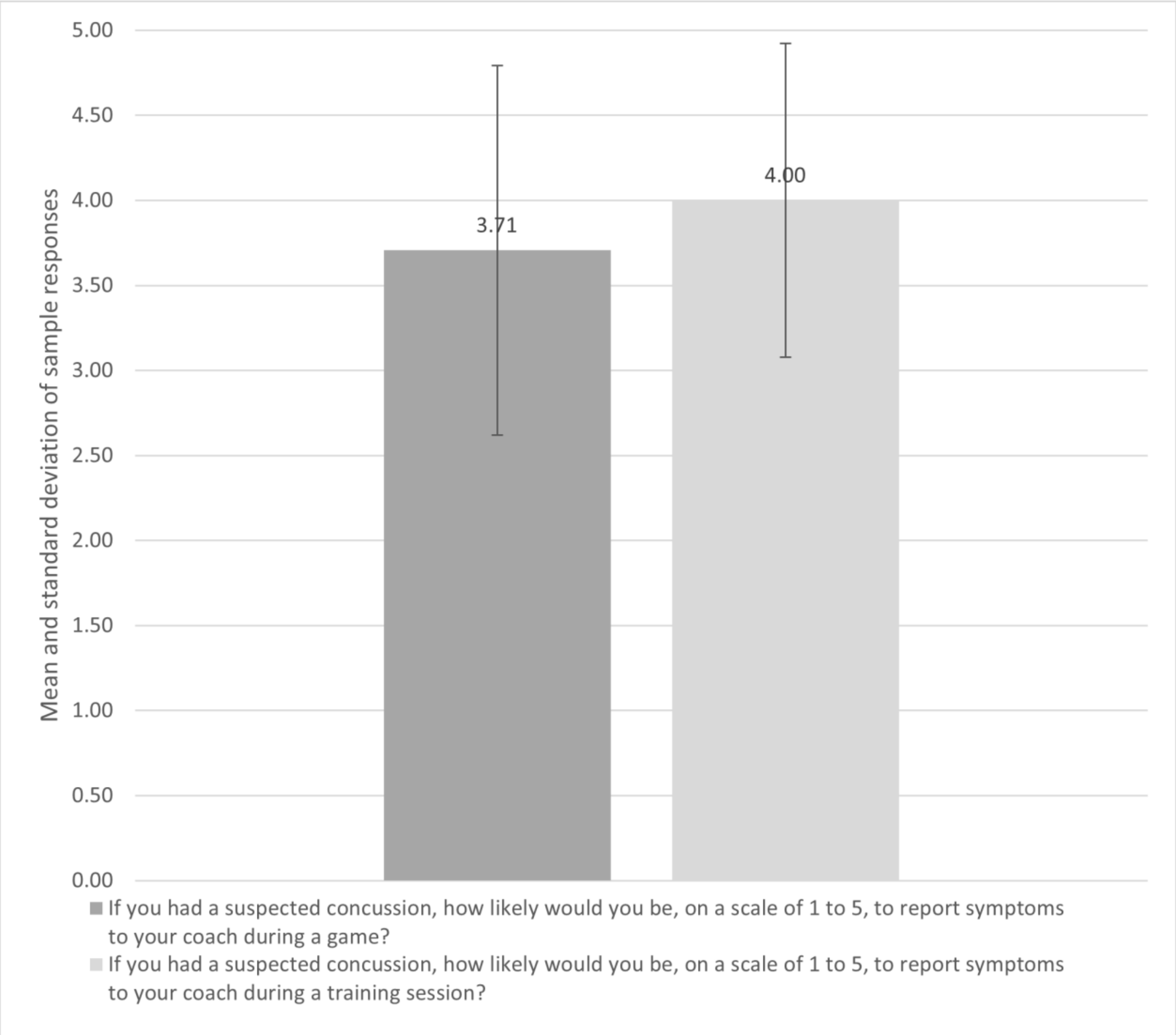
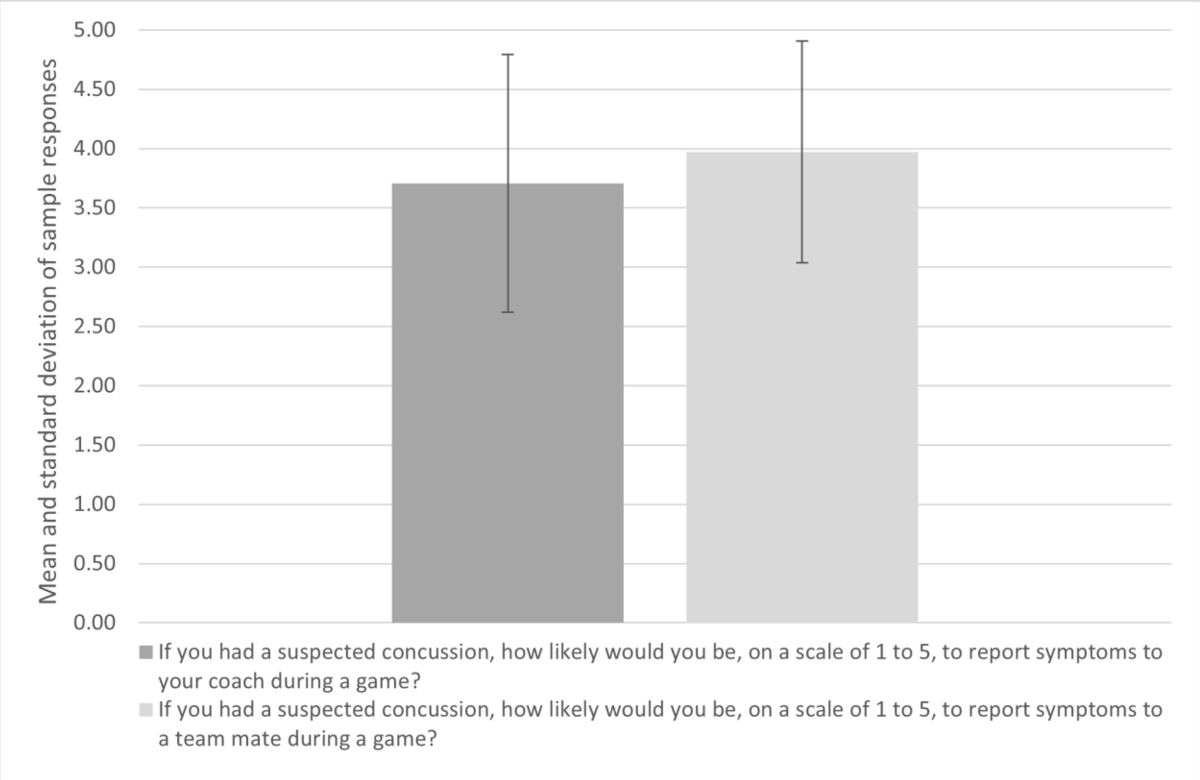


Figure four

The likelihood of reporting mTBI symptoms to a coach in a game compared to the reporting mTBI symptoms to a teammate in a game



Discussion

The current study sought to investigate the prevalence of reporting of mTBI and its symptoms in female basketball athletes. It also sought to evaluate the attitudes and knowledge surrounding mTBI in the same sample. Within the current study 51.52% answered that they had suspected they have sustained a mTBI, and 33.33% had been formally diagnosed with a mTBI within their athletic career. Further to this, 39.39% of the sample had experienced mTBI symptoms and continued to play, and 30.3% had not reported their mTBI to continue playing in a game or practice.

Epidemiology of mTBI

The current study found that 52.94% of the sample suspected they had received a mTBI during their athletic careers, and 35.90% acknowledged they had been formally diagnosed with a mTBI. The mean number of mTBIs formally diagnosed by participants was 2.21 within their careers

Injuries in basketball are seemingly common. There were 1,514,957 estimated emergency room visits associated with basketball within a five-year period in the United States (Fletcher et al, 2014). MTBI has been found to be relatively high injury incidence rate (2.92 per 100 athletes) (Covassin et al, 2018). MTBI rates and amounts do however vary between pieces of research. Zuckerman et al. (2015) found a 10.92 rate of mTBI per 10,000 athlete exposures in a sample of female basketball players from the 2009-2013 seasons within the National Collegiate Athletic Association (NCAA). Additionally, studies have shown that collegiate and high school female basketball players have a rate of 0.43 and 0.21 rate of mTBI per 1000 athlete-exposures respectively (Gessel et al, 2007). Furthermore, within a sample of 15 female high school basketball players, there were eight potential mTBIs, with a rate of 53.3% (McDonald et al, 2016) over two seasons. Borowski et al. (2008) collected injury data during the 2005-2006 and 2006-2007 academic years in 100 high schools across the USA via an online injury reporting method and found that 7% of all injuries sustained were mTBI, with females having a greater proportion of mTBI than male athletes (injury proportion ratio, 2.41; 95% confidence interval, 1.49-3.91), therefore if females have a greater proportion of mTBI, more research must be done within females and their risk of mTBI. This is mTBIs accounted for 6.5% of all injuries throughout a 16-year sampling period within the female basketball NCAA league (Agel et al, 2007). 10% of all injuries within the Women's National Basketball League (WNBA) between 2015 to 2019 were classed as mTBI (Baker et al, 2020). Pierpoint et al. (2018) found a rate of 1.94 mTBIs per 10,000 athletic exposures (e.g. one practice or one game) in high school female basketball teams. There has been research in other athletic areas that further supports this. Research has found that 50.3% of retired National Football League players surveyed reported that had not disclose to medical staff a mTBI in their careers (Kerr et al, 2018). Within a sample of 161 collegiate student-athletes (56.5% female, 21.5±1.3 years of age, 3.7±1.0 years of collegiate athletic experience) there was an unreported mTBI rate of 11.8%, with 49.7% of all respondents reporting at least one acknowledged or not reported mTBI (Llewellyn et al, 2014). Rivara et al. (2014), found that among a sample of 288 female athletes playing soccer within 20 Washington state schools, there was a rate of 3.6 mTBI per 1000 athletic exposures. However, a longitudinal study within a sample of 209 retired NFL players, found that over three separate surveys completed in 2001, 2010 and 2019 respectively (Kerr et al, 2020), 45.9% recalled more mTBIs at later dates. This could affect the validity of the current study, as players may not accurately remember the total number of mTBIs they have received across their entire careers, also known as recall bias.

Reporting of mTBI

Research has identified that athletes can and do under report their mTBI and play through their symptoms and signs (McDonald et al, 2016). Within the current research, 41.18% stated that they had experienced any mTBI symptoms and continued to play, and 32.35% acknowledged that they had not reported mTBI to continue playing in a game or practice. Further to this, 1.76% of the sample stated that they would continue to play if suffering from a headache resulting from a mTBI. There is very little research regarding the reporting history and under-reporting of athletes in basketball within the UK, let alone female athletes in basketball. However there has been prior research from wheelchair basketball, where 263 players were surveyed and 6.1% reported they had experienced a mTBI during the current season (Wessels et al, 2012), 44% of these athletes did not report their symptoms to anyone and 67% admitted it was because they did not want to be removed from the game/practice. Female athletes have been found to under-report symptoms of mTBI. Within a convenience sample of 77 female athletes in multiple sports between 9th and 12 grade in High school within the USA, 16.4% indicated they had experienced symptoms of a mTBI but did not report these symptoms to a coach or guardian (McDonald et al, 2016). Furthermore, in a sample of 351 female Washington state soccer club players, aged between 11-14 years of age, 58.6% stated that they continued to play with symptoms of mTBI (O'kane et al, 2014), when asked weekly about symptoms. 69% of a sample of 54 National Women's Hockey League players in the 2018-2019 season reported that they had continued playing whilst experiencing mTBI symptoms, and 36% did not initially tell anyone about their mTBI on at least one occasion, and 7% never disclosed their mTBI symptoms at all (Bloom et al, 2021), although the authors didn't research the reasoning behind the lack of reporting, they hypothesised that this may be due to a lack of education regarding mTBI, and the desire to not be removed from play.

Within Rugby League, 17.2% of 151 Australian professional players, reported they had sustained a likely mTBI, and did not report this to medical staff over a two-year survey (Longworth et al, 2021). Furthermore, research has found that players within collision sports are more likely to under-report symptoms and potential mTBI events (Hansen et al, 2021; Chizuk et al, 2021). American Football is seemingly the most researched sport in mTBI, with 50.3% of respondents reporting that they had received a mTBI in their careers and did not inform medical staff (Kerr et al, 2017). Within elite Irish rugby union players, where 44.9% of the athletes reported they had received a mTBI in the 2010-2011 season, 46.6% of these did not report the mTBI. The main reasons for not reporting a mTBI included: not wanting to let the rest of their team down (70.1%), thinking mTBIs are 'part of the game' (70.1%) and not wanting to be removed from game play (85.4%) (Fraas et al, 2014).

There has also been research away from sporting participants that are at similarly high risk of mTBI. A sample of 706 United States Air Force Academy cadets found that those cadets with more extensive mTBI histories were less likely to report an mTBI scenario and had a higher prevalence for not seeking medical care after a mTBI, as well as having greater confidence in their own ability to recognise a mTBI. (Schmidt et al, 2021). Furthermore, Escolas et al. (2020) found that in a sample of army personnel (N=5174, 86% male, 83% on active duty, between the ages of 18 and 34 years old) 10% reported having one or more mTBIs in their careers, and from this 52% sought some form of medical care. As to their reasons for not responding, participants reported that they didn't think the injury required any care (63.5%), and that they were afraid that reporting the mTBI would be detrimental to their careers (18%). This is like what has been found in sporting research, where athletes often report not thinking the injury is serious enough and worrying about the effects of the mTBI on their careers (Sanderson et al, 2017). When researchers examined concussion disclosure among cadets from the United States Air Force Academy (n=2504) using an anonymous survey, the cadets were less likely to report the injury (Foster et al, 2019). This was due to believing it would have a negative career outcome for their future Air Force career. The current study did not seek to understand why players played through mTBI or did not report mTBI symptoms in order to continue to play, however other research has sought to understand the reasons behind reporting, or under-reporting mTBI.

Themes can range from intrinsic, cultural, and environmental factors (Kneavel et al, 2019). Kerr et al. (2013) completed a literature review of 30 studies, and split the reasons identified for non-disclosure of mTBIs into four levels: intra-personal (lack of knowledge, internal pressures, gender, mTBI history), inter-personal (other people's knowledge and attitudes, external pressures), environmental (access to mTBI prevention, the culture surrounding a sport) and policy (mTBI related legislature). According to the current research, athletes were more likely to report a mTBI during a training session (4.00±0.92) than they were in a game (3.71±1.09), however, this was not a statistically significant difference (t=0.07, P>0.05) The rates of mTBI typically are higher within games and competition, and lower within practice. Within a high school female sample the rate of mTBIs was 12.10 per 10,000 athlete exposures and 1.55 mTBIs per 10000 athlete exposures within just practice/training (Kerr et al, 2019). In other athletic areas, such as middle school, high school, and college American Football, mTBI rates were higher in competition scenarios than in practice (3.74 per 1000 exposures in collegiate games, 0.53 per 1000 exposures in college practices: 2.01 per 1000 exposures in high school games, 0.66 per 1000 exposures in high school practices, 2.38 per 1000 exposures in youth games, 0.59 per 1000 exposures in youth practices) (Dompier et al, 2015). Therefore, if players are more likely to receive mTBI in game, but they report less in game, there may need to be better mTBI detecting/testing within game/competition.

Attitudes

Research has found a negative culture surrounding the under-reporting of mTBI, and that there needs to be a cultural shift before any changes in reporting behaviour can be seen (Murray et al, 2015). Within the current study, the sample were statistically more likely (t=0.06, P>0.05) to report a mTBI during game play to a teammate than they were to a member of their coaching staff. This may be due to the pressure players feel from coaching staff. In a sample of 741 collegiate student athletes over a variety of sports and school divisions, one in five indicated that they had felt pressure from coaching staff to continue or return to play after a mTBI (Anderson et al, 2021). Furthermore, one in four Irish college student athletes reported they did not disclose a mTBI, with 50% reporting they felt pressured to return to play after a mTBI by coaching staff (O'Connor et al, 2019). NCAA student athletes reported they had received pressure from coaches in the last season to continue or return to play after a mTBI (13.68%), however they also reported that pressure from teammates, family, and fans was also high (Kroshus et al, 2015). When surveyed, 53.7% of medical staff felt pressure from coaches for players to return to play before they felt ready (Kroshus et al, 2015). This shows that the pressure from coaches and other players is a large part of why athletes do not disclose their mTBI, and that the culture of reporting mTBI needs to change before we can expect reporting to increase. There has been research to outlining that when athletes' teammates are more supportive of reporting of mTBI, the rate of reporting increases (Kroshus et al, 2015).

Questions were used to assess the attitudes of the sample when it came to mTBI events. Of the sample, 58.82% strongly agreed that coaches need to be extremely cautious when determining whether an athlete should return to play after a mTBI and 20.59% of the sample agreed that athletes who subsequently lose consciousness (knocked out) should be taken to hospital. Within the UK, the NHS states that if a person has been knocked unconscious, they should be taken to hospital (NHS, 2021), and if they do not regain consciousness after a head injury 999 should be immediately called (NHS, 2021). The sample disagreed that mTBIs were less important than other injuries (1.65±1.01) and that athletes have a responsibility to return to play even if still experiencing symptoms of a mTBI (1.47±0.86). There were varying answers as to whether nausea and headache are less significant than being knocked unconscious after a mTBI event. Research has found that most athletes consider mTBIs as serious injuries. Within a sample of 416 high school Rugby union players from New Zealand across 21 school (16.3 ± 0.9 years of age), 69% of the athletes stated they thought they had received a mTBI in the past, and 31% had received a confirmed medical diagnosis (Salmon et al, 2020). Of which, 88% considered a mTBI to be a serious injury, and 99% thought that sustaining a second mTBI before the first one properly healed could make a more serious injury more likely to occur. Furthermore, 26% felt that although an athlete who has sustained a mTBI should be assessed by a medical professional, the athlete had the ultimate responsibility for whether they can go back into play. When asked what they would do if still suffering headaches after the required sitting out period, 75% of the sample said they would contact a medical professional. Therefore, although athletes believe that mTBIs are serious injuries, they do not all believe that a medical professional is needed to assess a potential mTBI.

Moreover, the sample, when asked to list those who are responsible for determining when an individual returned to play after a suspected mTBI event, 100% of the participants fingered medical personnel, 29.41% thought coaches were responsible, 38.24% thought the player themselves was responsible, 17% thought teammates were responsible. 17% of the sample thought that all four (coaches, players themselves, teammates, and medical personnel) were responsible for determining whether or not an individual should return to play. Non-elite athletes may not have the same access to resources as elite professional athletes (Putamina et al, 2009). The current study surveyed a sample of WNBL division one, division two and WBBL players. Within these leagues there is varying financial circumstances and access to medical personnel. Research has found that most athletes who report their mTBI do so to athletic trainers (76.7%) (McCrea et al, 2004). In a sample of 113 adolescent athletes (30.1% female) from Gaelic sports, 97.3% thought that it was important to inform medical professionals if they suspected they had a mTBI, and 95.5% thought that coaches were important to inform (O'Connor et al, 2019). Within future research, the provision within the Female basketball leagues needs to be explored, as there is a variation in the provision within teams. Minimum standards are possibly needing to be set for the basketball leagues in the future to promote safety and reporting with mTBI. Practically, the recommendation of having a first aider, or someone trained in mTBI identifiers may be useful, and being able to identify the signs of mTBI, is at all playing sessions, to prevent athletes being able to play on with any symptoms

Knowledge

Within the current sample, 64.71% answered yes to if they had ever received any formal training associated with mTBI. Those who had received formal training did so via different means. Cournoyer et al. (2014) found that 60% of American football athletes (334 varsity Floridian players) sampled had received some form of formal mTBI education. However, this is varying between research, with 77.5% of a sample of within 22 different sports reporting never having received any mTBI education (Kanney et al, 2022). Previous mTBI education has been associated with better knowledge (Kurowski et al, 2015; Kanney et al, 2022), which in turn has been associated with better and increased reporting of mTBI signs and symptoms (Hunt, 2015).

Knowledge is a key factor in the reporting of mTBI. There was a statistically significant association (*P*=0.01) between mTBI knowledge and education, and the likelihood of telling a coach about a mTBI type injury within an important game (Bramley et al, 2012). Furthermore, 72% of players with mTBI education reported they would always inform their coaching staff of any mTBI symptoms, compared to 36% of those with no prior education. Therefore, further provision for educational materials to increase the knowledge of athletes towards mTBI should be utilised, to teach athletes the chronic severity of mTBI, and the problems with underreporting.

In a sample of 454 (212 females, mean age 15.7 ± 1.15 years) high school athletes from one school district within the USA, 30% reported they had received at least one mTBI before an education session, but after the session 64.3% reported they had received at least one mTBI (Miyashita et al, 2014).This was corroborated by research from 2015, which found that the reported rate of mTBI increased after an educational video session (Hunt, 2015). Further to this, 40% of a sample reported that they had sustained a mTBI, but this increased to 64.8% after they received the definition for mTBI (Kristjánsdóttir et al, 2020). Register-Mihalik et al. (2013) researched the knowledge, attitudes, and reporting behaviours within a sample of 167 high school athletes (55 females, 15.7 6 1.4 years of age) and found that when surveyed, 40% recalled disclosing a mTBI. Increased knowledge of mTBI topics was associated with increased prevalence of reporting of injury within practises. Athlete attitude scores were associated with decreases in the number of athletes stating that they would participate in games while still symptomatic. Additionally, an increase in knowledge predicted a significant increase (0.55) in symptom reporting intentions, however, it also led to a decrease in the odds of reporting a mTBI by 23% (Weber Rawlins et al, 2020). This shows that education and knowledge can influence the reporting rates of mTBI, and therefore practical recommendations can be made to better the education of athletes in Britain to understand their signs and symptoms, and report these to medical professionals or coaching staff.

Miyashita et al. (2016) reported that female athletes were more likely to report a mTBI after an education session than male athletes however, there is contrary research. Within a sample of 496 high school athletes, (77.4% male, mean age 15) who were surveyed, previous concussion education was associated with improved knowledge (*P*=0.03), but was not associated with improved self-reported behaviours

(*P*=0.63) when it came to mTBI (Kurowski et al, 2014). This may be different to prior research due to the age of the sample. Being of younger age, they may be more prone to underreporting than older populations. No significant differences were found within athletes' attitudes to reporting who received mTBI education and those who had never received any mTBI education (Kanney et al, 2022). Moreover, Conway et al. (2018) found that athletes with a higher knowledge of mTBI were associated with more reasons identified for non-disclosure of mTBI symptoms.

Recommendations

The current research sought to fill the gap within the study of female athletes surrounding mTBI, especially within female basketball in the UK. Practically, this research could be utilised and referenced by coaching and medical staff within female basketball to further understand and bring awareness to the reporting patterns of their athletes, as well as the importance of having trained medical staff and provision to have these staff, within teams and leagues. This research could also be used in to promote education of mTBI to increase knowledge surrounding mTBI for athletes. Greater knowledge has been shown to lead to greater reporting patterns. Culturally, mTBI underreporting may have been normalised, and this is important to combat to increase reporting, and potentially reduce the impacts of mTBI in a chronic sense.

In the future, this paper recommends that more novel research be conducted within the female basketball population to further understand reporting behaviours and attitudes around mTBI. This further research should be done is a large sample size, and can utilise interviews, or other methods of surveying to better increase the reliability of the current research.

Limitations

There are limitations to the current study. One limitation is the sample size, 37 participants were needed to survey a representative sample size (Koshas et al, 2015), yet only 33 athletes completed the study. Although the sample was distributed using social media, word of mouth and contacting individual players coaches and medical staff, the response rate for the survey remained low. This can affect the validity of the results and make is less generalisable when applied to the female basketball player population of the UK.

As with all research, there are limitations to the use of surveys. One limitation of surveys in this format is that open ended questions cannot be thoroughly explored immediately after they answer (Ball, 2019). Any ambiguity within questions, and therefore the answers, cannot be discussed to lead to a valid answer. The questions however do allow for collection of data regarding multiple variables within a short period of time and can be shared very easily. Formats such as interviews require careful selection of participants before being conducted and are very time intensive. Surveys are easy to propagate, and demographic questions easily allow for filtering of responses. Another limitation was the use of retrospective questions. Retrospective questions can cause recall bias, whereupon recollection of events can be different to the true event (Raphael, 1987). This may affect the validity of the results, as participants may recall less or more mTBIs than were had. A method that could have been utilised to combat this was interviews. Interviews can be used to immediately explore open ended questions and explore greater nuances that answers may need to be fully comprehensive. There were also limitations to questions used, and the survey length. Some of the questions were not specific enough, and this limits the scope of the survey somewhat. Likert scales were used in the current survey, these themselves have limitations. The scale was made up of five answers, this did leave participants able to answer three in ambiguity, rather than making them choose whether they agreed of disagreed. Further to this, Likert scales are more likely to have acquiescence bias, whereupon agree-disagree questions are more likely to receive agree responses (Kuru and Pasek, 2015). Novel surveys are not standardized, and this can cause issues in the validity of new surveys.

Questions on 1-5 Likert scale allow for the efficient tabulation of data, which makes spotting patterns in data much easier than if they were multiple sentences replies to questions during an interview. Furthermore, the central tendency bias states that participants completing Likert scale surveys have an inclination for responding with the midpoint or neutral answer (three in a scale of 1-5) (Douven, 2018). This may have affected the current study, as to some of the questions having a mean response of the median point.

A disadvantage to using a survey is the sometimes-low response rate to online surveys (Arafa et al, 2018). This tendency for low response rates did affect the current research, as it fell short of the threshold for representative sample size by 3 participants (8.1%). This does not however mean that the results of the survey can be disregarded as non-representative, as they do support findings within current research as to the underreporting of mTBI. Another disadvantage of the survey used, was the large varying range in the responses to each question. This may be due to the questionnaire not being easy enough to follow for the participants. This could affect the validity of the results, if some of the participants didn't understand the scale used.

Conclusion

In conclusion, the current study aimed to investigate the prevalence of reporting of mTBI and its symptoms in female British Basketball athletes and sought to evaluate the attitudes and knowledge surrounding mTBI. Female basketball players within the UK are at risk of sustaining mTBI during their careers, with 52.9% answering they had received a suspected mTBI in their careers, and further to this, these athletes do not report all mTBI suffered from, with 41.18% continuing to play after a suspected mTBI. After a suspected mTBI, 32.35% admitted they did not report a suspected mTBI so they could continue to play in a game or practice. This supports the current findings in previous research as to the culture of underreporting of mTBI in athletic populations and adds novel research to the often under researched women's Basketball players in Britain. It is recommended that further research in a larger sample size is completed, to further add reliability to the current study's findings. Practically, it is recommended that the current study's findings are referenced by coaches and medical staff to be more vigilant to the signs and symptoms of mTBI, because their players may not be disclosing all their suspected mTBIs. Furthermore, the provision for medical professionals and personnel within basketball may need to be improved, and regulated, as participants within the current study admitted they were the most likely (100%) to report their mTBI signs and symptoms to medical professionals.

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Appendices

Appendix one: the novel survey devised for the current survey

What is your age?

- Free text response

What level of basketball do you currently play?

- Women's National basketball league Division 1
- Women's National basketball league Division 2
- WBBL (women's British Basketball league)

How long have you been playing basketball for?

- Free text response

Have you ever had a suspected concussion during your athletic career?

- Yes or No

How many times have you been formally diagnosed with concussion during your athletic career?

- Free text response

How many times have you suspected that you had a concussion during your athletic career that was not formally diagnosed?

- Free text response

Have you ever had to miss practice or game time due to a concussion?

- Yes or No

Have you ever experienced symptoms of a concussion during a game or an athletic event but continued to play?

- Yes or No

Have you ever hidden a concussion or a symptom of concussion to stay in a game?

- Yes or No

Have you ever been formally educated about the risks of concussions?

- Yes or No

If you had a suspected concussion, how likely would you be, on a scale of 1 to 5, to report symptoms to your coach during a game?

- Scale of 1(Strongly disagree) - 5 (Strongly agree)

If you had a suspected concussion, how likely would you be, on a scale of 1 to 5, to report symptoms to a teammate during a game?

- Scale of 1(Strongly disagree) - 5 (Strongly agree)

Please rate on a scale of 1-5 that bests describe how you feel about each statement, with 1 being you strongly disagree, and 5 being you strongly agree.

- Scale of 1(Strongly disagree) - 5 (Strongly agree)

I would continue playing a sport while also having a headache that resulted from a head injury

- Scale of 1(Strongly disagree) - 5 (Strongly agree)

I feel that coaches need to be extremely cautious when determining whether an athlete should return to play after a concussion

- Scale of 1(Strongly disagree) - 5 (Strongly agree)

I feel that concussions are less important than other injuries

- Scale of 1(Strongly disagree) - 5 (Strongly agree)

I feel that an athlete has a responsibility to return to a game even if it means playing while still experiencing symptoms of a concussion

- Scale of 1(Strongly disagree) - 5 (Strongly agree)

I feel that an athlete who is knocked unconscious should be taken to hospital

- Scale of 1(Strongly disagree) - 5 (Strongly agree)

Appendices two: Torres, D.M., Galetta, K.M., Phillips, H.W., Dziemianowicz, E.M.S., Wilson, J.A., Dorman, E.S., Laudano, E., Galetta, S.L. and Balcer, L.J. (2013) 'Sports-related concussion: anonymous survey of a collegiate cohort', *Neurology: Clinical Practice*, *3*(4), pp.279-287. DOI: 10.1212/CPJ.0b012e3182a1ba22

Penn Athletics Survey 2012

1. What sport do you play?

2. What is your gender?

- ○ Female
- ○ Male

3. What year in college are you?

- ○ Freshman
- ○ Sophomore
- ○ Junior
- ○ Senior

4. Please list the symptoms of concussion (even if you have never had any) of which you are aware. If you do not know of any symptoms, please leave this section blank.

- ○ Headache
- ○ Confusion

- Dizziness
- Loss of consciousness
- Forgetfulness or memory loss
- Nausea or vomiting
- Blurred vision
- Flashing stars
- Excessive glare or light sensitivity

5. Have you ever had a concussion during your athletic career?

- Yes
- No

6. How many times have you been formally diagnosed with a concussion during your athletic career?

7. How many times have you suspected that you had a concussion during your athletic career that was not formally diagnosed?

8. Have you ever had to miss practice or game time due to a concussion?

- Yes
- No

9. Have you ever had to get extensions on papers, tests, or other schoolwork

due to a concussion?

- ○ Yes
- ○ No

10. Have you ever felt your academic achievement was less after concussion?

- ○ Yes
- ○ No

11. Have you ever experienced symptoms of a concussion during a game or an athletic event but continued to play?

- ○ Yes
- ○ No, I have always come out of the game if I experienced any of these symptoms

12. Have you ever hidden a concussion to stay in a game?

- ○ Yes
- ○ No

13. If you had a concussion, how likely would you be, on a scale of 1 to 5, to report symptoms to your trainer or coach during a game?

- 1 - Extremely unlikely
- 2 - Unlikely
- 3 - Indifferent
- 4 - Likely
- 5- Extremely likely

14. If you had a concussion, how likely would you be, on a scale of 1 to 5, to report symptoms to a teammate during a game?

- 1- Extremely unlikely
- 2- Unlikely
- 3- Indifferent
- 4- Likely
- 5- Extremely Likely

15. Have you ever been formally educated about the risks of concussions?

- Yes
- No

Appendices three: Rosenbaum, A. M., & Arnett, A. (2010). The development of a survey to examine knowledge about and attitudes toward concussion in high-school students. *Journal of clinical and experimental neuropsychology*, *32*(1), 44-55. https://doi.org/10.1080/13803390902806535

TABLE 2

Cluster structure of Concussion Knowledge Index

	Cluster		
Item	*1: Low difficulty*	*2: Moderate difficulty*	*3: High difficulty*
Cluster Item 1	There is a possible risk of death if a second concussion occurs before the first one has healed. (89.9)	People who have had one concussion are more likely to have another concussion. (46.2)	After a concussion occurs, brain imaging (e.g. CAT scan, MRI, X-ray, etc.) typically shows visible physical damage (e.g. bruise, blood clot, etc.) to the brain. (16.1)
Cluster Item 2	In order to be diagnosed with a concussion, you have to be knocked out. (93.2)	A concussion can only occur if there is a direct hit to the head. (50.5)	After a concussion, people can forget who they are and not recognize others but be perfect in every other way. (26.2)
Cluster Item 3	Being knocked unconscious always causes permanent damage to the brain. (75.4)		An athlete who gets knocked out after getting a concussion is experiencing a coma. (34.2)
Cluster Item 4	Symptoms of a concussion can last for several weeks. (91.5)		

Cluster Item 5	Sometimes a second concussion can help a person remember things that were forgotten after the first concussion (76.0)
Cluster Item 6	If you receive one concussion and you have never had a concussion before, you will become less intelligent. (95.6)
Cluster Item 7	After 10 days, symptoms of a concussion are usually completely gone. (53.3)
Cluster Item 8	Concussions can sometimes lead to emotional disruptions. (83.3)
Cluster Item 9	There is rarely a risk to long-term health and well-being from multiple concussions. (76.0)
Cluster Item 10	It is likely that Player Q's concussion will

	affect his long-term health and well-being. (78.4)
Cluster Item 11	It is likely that Player X's concussion will affect his long-term health and well-being. (85.0)
Cluster Item 12	Even though Player F is still experiencing the effects of concussion, her performance will be the same as it would be had she not suffered a concussion. (88.5)
Cluster Item 13	Headache (96.2)
Cluster Item 14	Sensitivity to light (81.4)
Cluster Item 15	Difficulty remembering (83.1)
Cluster Item 16	Feeling in a fog (79.8)
Cluster Item 17	Feeling slowed down (79.8)
Cluster Item 18	Difficulty concentrating (84.4)

Cluster Item 19	Dizziness (95.1)
Cluster Item 20	Drowsiness (73.2)

Note. The values in parentheses indicate the percentage of participants correctly answering the item.

APPENDIX A Scoring key for RoCKAS-ST

Section														
1			*2*			*3*			*4*			*5*		
Item	*Correct Response*	*Index*[a]	*Item*	*Correct Response*	*Index*	*Item*	*"Safer" Response*[b]	*Index*	*Item*	*"Safer" Response*	*Index*	*Symptom*	*Distractor/ Legitimate*[c]	*Index*
1	TRUE	CKI	1	FALSE	CKI	1	SD/D	CAI	1	SA/A	CAI	Hives	D	NI
2	FALSE	NI	2	TRUE	CKI	2	SA/A	CAI	2	SA/A	CAI	Headache	L	CKI
3	TRUE	CKI	3	FALSE	CKI	3	SA/A	NI	3	SD/D	CAI	Difficulty Speaking	D	CKI
4	TRUE	VS				4	SA/A	NI	4	SD/D	CAI	Arthritis	D	NI
5	FALSE	CKI				5	SD/D	CAI	5	SD/D	CAI	Sensitivity to Light	L	CKI
6	FALSE	CKI				6	SD/D	CAI	6	SD/D	CAI	Difficulty Remembering	L	CKI
7	FALSE	CKI				7	SA/A	CAI	7	SA/A	CAI	Panic Attacks	D	NI
8	TRUE	CKI				8	SD/D	NI	8	SA/A	CAI	Drowsiness	L	CKI
9	FALSE	CKI							9	SA/A	CAI	Feeling in a "Fog"	L	CKI

10	TRUE	VS
11	FALSE	CKI
12	FALSE	CKI
13	TRUE	CKI
14	FALSE	CKI
15	FALSE	VS
16	TRUE	CKI
17	TRUE	CKI
18	FALSE	CKI

10	SA/A	CAI

Weight Gain	D	NI
Feeling Slowed Down	L	CKI
Reduced Breathing Rate	D	NI
Excessive Studying	D	NI
Difficulty Concentrating	L	CKI
Dizziness	L	CKI
Hair Loss	D	NI

[a]CKI = Concussion Knowledge Index; CAI = Concussion Attitude Index; VS = Validity Scale; NI = no index—item not part of any index. [b]SD/D = strongly disagree/disagree; SA/A = strongly agree/agree. [c]L = legitimate symptom; D = distractor symptom.

RoCKAS-ST

NOTE: The phrase “Return to play/competition” refers to being cleared to play in both practice and games.

Section 1

DIRECTIONS: Please read the following statements and circle TRUE or FALSE for each question.

1 There is a possible risk of death if a second concussion occurs before the first one has healed.	TRUE	FALSE
2 Running everyday does little to improve cardiovascular health.	TRUE	FALSE
3 People who have had one concussion are more likely to have another concussion.	TRUE	FALSE
4 Cleats help athletes’ feet grip the playing surface.	TRUE	FALSE
5 In order to be diagnosed with a concussion, you have to be knocked out.	TRUE	FALSE
6 A concussion can only occur if there is a direct hit to the head.	TRUE	FALSE
7 Being knocked unconscious always causes permanent damage to the brain.	TRUE	FALSE
8 Symptoms of a concussion can last for several weeks.	TRUE	FALSE
9 Sometimes a second concussion can help a person remember things that were forgotten after the first concussion.	TRUE	FALSE
10 Weightlifting helps to tone and/or build muscle.	TRUE	FALSE
11 After a concussion occurs, brain imaging (e.g. CAT Scan, MRI, X-Ray, etc.) typically shows visible physical damage (e.g. bruise, blood clot) to the brain.	TRUE	FALSE
12 If you receive one concussion and you have never had a concussion before, you will become less intelligent.	TRUE	FALSE

(*Continued*)

Section 1

(*Continued*)

13 After 10 days, symptoms of a concussion are usually completely gone.	TRUE	FALSE
14 After a concussion, people can forget who they are and not recognize others but be perfect in every other way.	TRUE	FALSE
15 High-school freshmen and college freshmen tend to be the same age.	TRUE	FALSE
16 Concussions can sometimes lead to emotional disruptions.	TRUE	FALSE
17 An athlete who gets knocked out after getting a concussion is experiencing a coma.	TRUE	FALSE
18 There is rarely a risk to long-term health and well-being from multiple concussions.	TRUE	FALSE

Section 2

DIRECTIONS: Please read each of the following scenarios and circle TRUE or FALSE for each question that follows the scenarios.

Scenario 1:

While playing in a game, Player Q and Player X collide with each other and each suffers a concussion. Player Q has never had a concussion in the past. Player X has had 4 concussions in the past.

1 It is likely that Player Q's concussion will affect his long-term health and well-being. TRUE FALSE

2 It is likely that Player X's concussion will affect his long-term health and well-being. TRUE FALSE

Scenario 2:

Player F suffered a concussion in a game. She continued to play in the same game despite the fact that she continued to feel the effects of the concussion.

FALSE

3 Even though Player F is still experiencing the effects of the concussion, her performance will be the same as it would be had she not suffered a concussion. TRUE

Section 3

DIRECTIONS: For each question circle the number that best describes how you feel about each statement.

	Strongly Disagree	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*
1 I would continue playing a sport while also having a headache that resulted from a minor concussion.	1	2	3	4	5
2 I feel that coaches need to be extremely cautious when determining whether an athlete should return to play.	1	2	3	4	5
3 I feel that mouthguards protect teeth from being damaged or knocked out.	1	2	3	4	5
4 I feel that professional athletes are more skilled at their sport than high-school athletes.	1	2	3	4	5
5 I feel that concussions are less important than other injuries.	1	2	3	4	5
6 I feel that an athlete has a responsibility to return to a game even if it means playing while still experiencing symptoms of a concussion.	1	2	3	4	5
7 I feel that an athlete who is knocked unconscious should be taken to the emergency room.	1	2	3	4	5
8 I feel that most high-school athletes will play professional sports in the future.	1	2	3	4	5

Section 4

DIRECTIONS: For each question read the scenarios and circle the number that best describes your view. (For the questions that ask you what *most athletes* feel, base your answers on how you think MOST athletes would feel.)

	Strongly Disagree	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*
Scenario 1: *Player R suffers a concussion during a game. Coach A decides to keep Player R out of the game. Player R's team loses the game.*					
1 I feel that Coach A made the right decision to keep Player R out of the game.	1	2	3	4	5
2 Most athletes would feel that Coach A made the right decision to keep Player R out of the game.	1	2	3	4	5
Scenario 2: *Athlete M suffered a concussion during the first game of the season. Athlete O suffered a concussion of the same severity during the semifinal playoff game. Both athletes had persisting symptoms.*					

(*Continued*)

Section 4

(*Continued*)

	Strongly Disagree	*Disagree*	*Neutral*	*Agree*	*Strongly Agree*
3 I feel that Athlete M should have returned to play during the first game of the season.	1	2	3	4	5

4 Most athletes would feel that Athlete M should have returned to play during the first game of the season.	1	2	3	4	5
5 I feel that Athlete O should have returned to play during the semifinal playoff game.	1	2	3	4	5
6 Most athletes feel that Athlete O should have returned to play during the semifinal playoff game.	1	2	3	4	5
Scenario 3:					
Athlete R suffered a concussion. Athlete R's team has an athletic trainer on the staff.					
7 I feel that the athletic trainer, rather than Athlete R, should make the decision about returning Athlete R to play.	1	2	3	4	5
8 Most athletes would feel that the athletic trainer, rather than Athlete R, should make the decision about returning Athlete R to play.	1	2	3	4	5
Scenario 4:					
Athlete H suffered a concussion and he has a game in two hours. He is still experiencing symptoms of concussion. However, Athlete H knows that if he tells his coach about the symptoms, his coach will keep him out of the game.					
9 I feel that Athlete H should tell his coach about the symptoms.	1	2	3	4	5
10 Most athletes would feel that Athlete H should tell his coach about the symptoms.	1	2	3	4	5

Section 5

DIRECTIONS: Think about someone who has had a concussion. Check off the following signs and symptoms that you believe someone may be likely to experience AFTER a concussion.

3	3
Hives	Feeling in a "Fog"
Headache	Weight Gain
Difficulty Speaking	Feeling Slowed Down
Arthritis	Reduced Breathing Rate
Sensitivity to Light	Excessive Studying
Difficulty Remembering	Difficulty Concentrating
Panic Attacks	Dizziness
Drowsiness	Hair Loss