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„Vergleich kognitiver Leistungsfähigkeit von Leistungssportler*innen aus American Football und kontaktlosen Sportarten"

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Abstract Deutsch

Einleitung. Die bisherige Literatur ist sich über die möglichen Auswirkungen von Gehirnerschütterungen auf die kognitiven Funktionen nicht einig. Studien legen kurzzeitige, langandauernde oder auch gar keine Folgen nahe. Diese Studie untersuchte mögliche Unterschiede in den kognitiven Funktionen zwischen Leistungssportler*innen aus American Football und kontaktlosen Sportarten, sowie Nicht-Sportler*innen. Basierend auf der vorangehenden Literatur wurde erwartet, dass American Football Spieler*innen niedrigere Werte bei Tests zu kognitiven Fähigkeiten als Athlet*innen aus kontaktlosen Sportarten und Nicht-Sportler*innen erreichen würden und, dass American Football Spieler*innen mit vergangenen Gehirnerschütterungen niedrigere Werte als solche ohne aufweisen würden. **Methoden.** Die Stichprobe bestand aus 118 Teilnehmenden (48 American Football Spieler*innen, 32 Sportler*innen aus kontaktlosen Sportarten, 38 Nicht-Sportler*innen). Sie wurden zu ihrer Gesundheit und ihrer Vergangenheit mit Gehirnerschütterungen befragt, sowie einem kognitiven Screening unterzogen. Anschließend wurden ihre kognitiven Funktionen, anhand der Dimensionen Lernen und Gedächtnis, Sprache, Komplexe Aufmerksamkeit, Exekutivfunktionen und Soziale Kognition erhoben. **Ergebnisse.** Die statistische Analyse durch einfaktorielle Varianz- und Kovarianz-Analysen zeigte keine signifikanten Unterschiede zwischen den Sport- und Gehirnerschütterungsgruppen. **Konklusion.** American Football Spieler*innen schnitten nicht schlechter in kognitiven Tests als Sportler*innen aus kontaktlosen Sportarten oder Nicht-Sportler*innen ab, auch die Vergangenheit mit Gehirnerschütterungen zeigte keinen Zusammenhang mit Ergebnissen der kognitiven Tests. Dies deutet darauf hin, dass die Ausübung von American Football keine negativen Folgen für die kognitiven Funktionen bei aktiven Spieler*innen mit sich führt. Allerdings müssen die Ergebnisse durch Limitationen wie eine kleine Stichprobe und unklare Gütekriterien der benutzen Tests hinterfragt werden. Es ist notwendig weitere Studien durchzuführen, um eindeutige Aussagen über Zusammenhänge zwischen Kontaktsportarten, Gehirnerschütterungen und kognitiven Funktionen fertigen zu können.

Abstract English

Introduction. The body of literature is indifferent about possible consequences regarding cognitive function following concussion. Different studies suggest short-term, long-term, or even no impairment. This study investigated possible differences in cognitive function between high-performance athletes of American Football and non-contact sports, as well as non-athletes. Regarding previous literature, it was expected for American Football players to score lower on assessment of cognitive function than non-contact athletes and non-athletes, and for American Football players with history of concussion to score lower than those without. **Methods.** The sample consisted of 118 participants (48 American Football players, 32 non-contact athletes, 38 non-athletes), which went through a cognitive screening, an assessment of general health and concussion history, followed by an assessment of cognitive function, evaluated through the dimensions of memory and learning, language, complex attention, executive functions, and social cognition. **Results.** Statistical analysis through one-way analyses of variance and covariance did not find any significant differences between sport and concussion groups. **Conclusion.** American Football players did not score lower on tests of cognitive function than non-athletes and non-contact athletes. Concussion history did not have a significant effect on scores of American Football players. This suggests that playing American Football does not impair cognitive function in active players. However, due to limitations regarding the low sample size and uncertain psychometric criteria of the measures used, the possibility that the hypotheses have been falsely rejected remains. It is mandatory to further study links between contact sports, concussions, and cognitive functions to make substantiated statements about their possible connections.

1. Introduction

Over recent decades, knowledge of possible implications of head trauma and concussion has grown immensely. This research has also impacted the world of sports through recent talks of rule changes in youth football, such as reducing air pressure in balls and possibly even banning headers (Gobmeier et al., 2021). Another sport that is heavily impacted by concussion research is American Football. To prevent concussion related problems as effective as possible, the National Football League (NFL) in the United States of America has implemented a so-called concussion diagnosis and management protocol into their medical procedures (NFL, 2017). Goal of this protocol is to diagnose concussion and to ensure that players currently suffering from concussion do not start practicing or playing too early in the recovery process. During the protocol, players are examined repeatedly by medical professionals, starting on the sideline directly after a possible concussion and continuing the days after concussion until it is ensured a player can safely return. In addition to the medical examination, an assessment of cognitive function, based on the Standardized Concussion Assessment Tool (SCAT5; McCrory et al., 2017), is conducted. The results of this assessment are compared to baseline scores, measured prior to a season, to identify possible loss of cognitive function from concussion (NFL, 2017).

American Football leagues in Austria and other European countries currently do not have similar concussion protocols active. The responsibilities lie with the players and teams themselves. With growing popularity of American Football in Europe also comes a rise in quality and competition in European leagues. Therefore, it might be time to establish a more professional care for concussion in European leagues as well. This study will help lay a foundation for this cause. To do so, it is planned to assess cognitive function of high-performance athletes from American Football and compare them with non-contact sports athletes and non-athletes. The study will try to answer the question whether there are differences in cognitive function between American Football players, non-contact sport athletes, and non-athletes. Additionally, differences in cognitive function among American Football players with and without concussion history will be investigated.

1.1 American Football

The first game of American Football was played on November 6th, 1869, in New Brunswick (New Jersey) between the universities of Rutgers and Princeton. The first official rulebook was written in 1880 describing first clear differentiations from its origin sports rugby and soccer (Nauright, 1996). American Football is a ball game played by two opposing teams on a rectangular field. It is played for four quarters each lasting 12 to 15 minutes depending on the ruleset. Each game consists of multiple phases for each team, the most important ones being offense and defense changing alternatively. While a team is in possession of the ball the unit on the field is called “offense”, their goal being the advancement of the ball as far down the field as possible with the final task to score points. The unit without possession of the ball is called the “defense”, their task is to stop the opposing offense from advancing the ball and scoring points. Different to the fluent game state of the origin sports soccer and rugby American Football is played in “plays”. Each play starts with the ball in possession of the offense and stops when the ball either leaves the field or the player holding onto the ball touches the ground with a body part other than his hands or feet after being in contact with a defensive player. The offense has four tries, known as downs, to advance the ball 10 yards (9.14 m) towards the opposing end zone. Reaching the marker of 10 yards is rewarded with a new set of tries for the offense to continue moving the ball down the field. This process is repeated until the offense scores points by advancing the ball into the end zone through a “touchdown”, or alternatively, by kicking the ball through the goalposts to score a “field goal”. Should the offense fail to gain 10 yards within their four tries, possession of the ball is exchanged, and the other team gets to try to advance the ball. This also happens after scores (IFAF, 2023).

The most typical type of offensive plays are running or passing plays. For a running play, the ball is handed to a runner who tries to run the ball as far as possible while his teammates try to create a path through the defensive players trying to stop him. For a passing play, the ball is thrown to one of several possible pass catchers running routes. The most common type of defensive plays are man and zone coverage. In man coverage, defensive players are responsible for guarding a single offensive player following their movements and trying to prevent them from catching the ball. In zone coverage, defensive players are covering an area of the field trying to prevent offensive players in those areas from catching the ball. The game is played with 11 players on the field for both teams. While the personnel changes according to the needs of different play calls, the following is the most basic setup of positions: A typical offense fields a Quarterback whose job it is to distribute the ball through hand-offs or throwing the ball, five Offensive Linemen trying to protect their Quarterback from the defense, four Wide Receivers trying to catch the ball when thrown towards them, and a Running Back trying to run the ball if it’s handed off to him. A typical defense consists of four Defensive Linemen trying to pressure the Quarterback and stop possible running plays, three Linebackers with flexible roles in primarily stopping running plays but also being involved in stoppage of passing plays, and four Defensive Backs primarily trying to stop passing plays.

The nicknames “chess on lawn” or “contact-chess” for American Football emphasize the distinct tactical aspect of the game, which is easily overlooked viewing the sport without prior knowledge. While the game can look confusing and arbitrary for the untrained eye, each players movements are designed by the coaching staff, trying to find the best plays for their players to advance the ball or stop the opposing team from doing so. These designs include the type of routes offensive players run in order to possibly catch the ball, the way the whole offense tries to create space for their Running Back to run down the field, the way the Offensive Linemen defend their Quarterback, and many more. The whole game consists of a “cat and mouse game” between the coaches of each team anticipating the way the opposing offense or defense will line up or move their players and trying to counter these systems in the best way possible, further resulting in tactics changing multiple times throughout one game of American Football.

While tactics are a big aspect of American Football, so are heavy impacts and collisions among the players. Due to this, all players must wear protective gear while being on the field. This consists of a helmet including a facemask, a mouthguard, shoulder pads protecting the upper body, including shoulders, chest, and the upper parts of the arm, and further protective pads on the tailbone, hips, thighs, and knees (IFAF, 2023). While not mandatory, a lot of players wear further protective gear for their neck, the lower back, and their elbows. This protective gear is necessary as almost every player is in contact with an opposing player during each play. The most usual contacts are defined as blocks and tackles. Blocking is defined as obstructing an opponent by engaging in intentional contact with any part of the blocker’s body, the most common example for a block is pushing an opponent (IFAF, 2023). During running plays, blocks are used by the players of the offense to create space for their ball carrier. During passing plays, blocks are used by the Offensive Line to prevent the pressuring Defensive Line from reaching and bringing the Quarterback to the ground before the ball is thrown. By contrast a tackle is defined as any attempt by a defensive player to grasp or encircle a ball carrying opponent to halt their advance or bring them to the ground (IFAF, 2023). To gain a better understanding of extent of these collisions, what actions are allowed and what are not, some fouls and illegal actions relevant to player contact and possible injuries will be discussed. Players are not allowed to grasp and twist, turn, or pull an opponent’s face mask, chin strap, or any helmet openings. It is not allowed to target an opponent with the crown of their helmet with the intention of making forcible contact, players doing so will be disqualified from the game. Players must not grab the inside back collar of an opponent’s jersey or shoulder pads and abruptly pull that player to the ground. It is not allowed for a defensive player to unnecessarily tackle a passer when it is obvious that the ball has been thrown. Players must not target and make forcible contact to the head or neck area of a defenseless opponent. Examples for defenseless players are players in the act of throwing a pass, attempting to catch a forward pass, players on the ground, or players obviously out of the play (IFAF, 2023). Almost any other contacts or collisions are endorsed in order to stop a ball carrier. As it is the goal of the offense to gain as much ground as possible with each play, players usually move at full speed. To stop their opponents as early as possible, also defensive players maintain high speeds during tackles or pass breakups. This results in high speed and heavy impact collisions, which regularly lead to injuries and relatively high rate of injuries in American Football players (Mueller et al., 1996).

1.2 Sports and Cognitive Function

Evidence from past research suggests that physical activity offers cognitive benefits (McMorris, 2016), especially regular participation in physical activity has shown associations with improved cognitive functions (Etnier & Chang, 2009). This research can be further supported through research finding positive associations between physiological effects of chronic physical activity, such as high cardiovascular fitness, coordinative ability, motor fitness, and structural as well as functional changes in brain anatomy (Chaddock et al., 2011; Voelcker-Rehage & Niemann, 2013). As studies have shown that athletes score higher than population norms on cognitive tests including executive functions, in addition to regular participation, also long-lasting participation in physical activity and sports supports theories of their positive impact on cognitive functions (Lundgren et al., 2016; Moratal et al., 2020; Vestberg et al., 2012). Reported benefits to cognitive function of physical activity have been most visible when executive functions were assessed (Chaddock et al., 2011; Khan & Hillman, 2014; Scharfen & Memmert, 2019). Executive functions refer to the mental processes in action when we have to concentrate and pay attention; the literature agrees on three core executive functions: cognitive fluency, inhibition, and working memory (Diamond, 2013). Supporting these results, a meta-analysis observed that elite athletes outperform control groups on cognitive tasks of attentional allocation and cognitive flexibility, with team-based sports, relying on high-intensity interval training, being one of the disciplines most responsible for this effect (Logan, 2023). It has been further reported that physical activity with low cognitive demand offers only little or no improvement in cognitive abilities (Diamond & Ling, 2016), whereas cognitively demanding physical activities show the strongest effects (Diamond & Ling, 2016; Gu et al., 2019). These findings have been supported when considering past involvement in open and closed-skill sports, showing that past experiences in cognitively demanding sports may aid in the development of executive functions (Koch & Krenn, 2021).

Previous research has highlighted the significance of executive functions in sports (Lundgren et al., 2016; Vestberg et al., 2012). Following the importance of executive functions in sports, studies revealed that high-performance athletes showed better executive functions performance compared to lower-level athletes and non-sports experts (Huijgen et al., 2015; Moratal et al., 2020; Vestberg et al., 2012). These studies indicate that an athletes' executive functions may have an impact on their performance, resulting in them being more likely to reach highest performance levels in their sports (Voss et al., 2010). Thus, performance levels could register as an interference variable when comparing cognitive function in athletes.

1.3 Cognitive Function and American Football

Studies specific to American Football and possible benefits on cognitive function are limited. When investigating performance in a variant of the Eriksen flanker task, that relates to executing motor responses in the face of distraction, it has been reported that American Football players show a clear cognitive advantage (Wylie et al., 2018). This was especially true for defensive players, explainable by the reactive nature of defense in American Football. However, a study done on rugby players has shown contrary effects, reporting that elite rugby players performed worse on tests of complex attention, processing speed, executive functions, and cognitive flexibility than a non-contact sports group (Hume et al., 2017). Since rugby has a similar physicality to American Football, this insight should be comparable to American Football players. Another point of research regarding American Football, is the age of first exposure to tackle football. First exposure, especially before the age of twelve, was associated with increased odds for impairment in self-reported neuropsychiatric and executive functions in former American Football players (Alosco et al., 2017). A different study however reported no association between early age of first exposure and worse behavioral, cognitive, psychological, and physical outcomes, but instead suggested it might even contribute to resilience (Brett et al., 2019). Indifferent research on this topic confirms the need of further study.

Due to the violent nature of American Football and the players engaging in regular collisions with each other, associations with concussion and possible harm for the brain come to mind easily. Dompier et al. (2015) have confirmed that concussions take up a serious amount of injuries in several levels of play (youth = 9.6%, high school = 4.0%, collegiate 8.0%). In addition, it was also shown that both American Football matches as well as practices were a major source of concussion at all levels of play (Dompier et al., 2015). Analysis of fMRI data of American Football players from the Israeli National American Football team showed morphological changes in the parietal and frontal regions of the brain (Roee et al., 2023), further suggesting possible cognitive consequences of participation in American Football. The repeated collisions amongst players and resulting head injuries are likely to play a part in the interplay between American Football, as exercise, and cognitive function.

1.4 Cognitive Function and Concussion

Overall research on the implications of concussion on cognitive function has shown incongruent findings over the last decades. There are studies proposing no cognitive consequences (Collie et al., 2006; Maillard-Wermelinger et al., 2009; Karr et al., 2014). Studies proposing only short-term consequences, resulting in cognitive impairment of up to seven days, but no long-term implications (Belanger & Vanderploeg, 2005; Bleiberg et al., 2004). Studies reporting consequences up to two months (Howell et al., 2013) and others proposing even longer lasting consequences (Bernstein, 2000; Guskiewicz et al., 2005; Ellemberg et al., 2007; Hume et al., 2017; McInnes et al., 2017, Tapper et al., 2016; Taylor et al., 2018). Studies researching this topic in samples of active athletes regularly propose at least some form of impairment following concussion. Criticizing early studies suggesting that sport concussion leads to permanent cognitive impairment for methodological limitations, a study on 729 athletes involving baseline and interval testing stated that cognitive impairment occurs from the day of the injury until about 2 days afterwards, while recovery of cognitive performance transpires during the third to seventh day postinjury (Bleiberg et al., 2004). This progression was further supported in a meta-analysis on 790 cases of sports-related concussion, detecting an overall effect of concussion of $d = .49$ across cognitive domains with the largest acute (within 24 hours) effects for delayed memory, memory acquisition, and global cognitive functioning, however no effects beyond seven days postinjury (Belanger & Vanderploeg, 2005).

Studies on retired athletes, however, do regularly find longer-lasting consequences. In a sample of retired professional American Football players observations of a fivefold prevalence of mild cognitive impairment and a threefold prevalence of reported memory impairments were made in players with three or more reported concussions, suggesting a long-term impact of concussion on cognitive function. Additionally, while no connections between repeated concussion and Alzheimer’s disease were made, an earlier onset of dementia-related syndromes was observed in the retired American Football players (Guskiewicz et al., 2005). This was further supported by a systematic review of sports related concussion and cognitive health outcomes in retired athletes of American and Australian football, boxing, field and ice hockey, rugby, and soccer, suggesting long-term impairment in memory, executive function, and psychomotor function (Cunningham et al., 2020). Comparison of cognitive function in former elite rugby players with non-contact sport athletes further supports these indications, as history of concussion was associated with small to moderate cognitive deficits in former rugby players (Hume et al., 2017). In contrast to these findings a sample of Australian rules football players showed no associations between the number of previous self-reported concussions and current cognitive state (Collie et al., 2006).

Thus, the main two results from literature are short-term consequences during a seven-day period for active athletes and longer-lasting consequences in retired athletes. However, a study analyzing the impact of first concussions on cognitive impairments in female soccer players found lower scores in the domains of decision making, inhibition and fluidity, and planning six to eight months after injury (Ellemberg et al., 2007), showing consequences outside of the commonly found 7-day window as well as prior to retirement, therefore opposing studies suggesting only short-term consequences. Research done on adolescent active athletes has found that concussions had a more persistent effect on cognitive function than previously thought, with lower scores being observed longer than up to two years after concussion. While the effects did not amount to big differences in the assessments, the authors warned about underestimating the effects on individuals (Taylor et al., 2018). Possible long-term consequences in active athletes were further supported by Tapper et al. (2016) showing deficits in executive functions in tasks requiring simultaneous processing of visual and auditory information for ice hockey players with concussion history, with the time since last concussion ranging from two to 98 months. This leaves the research field in disunity, demonstrating the need for further study.

1.5 Current Study

This study aspired to give further insight into the impact of participation in American Football and resulting concussions on cognitive function by answering the question whether there are differences in cognitive function between high-performance American Football players, high-performance athletes from non-contact sports, and a comparison sample of non-athletes, and whether American Football related concussion history can be associated with differences in cognitive function. Regarding findings of previous studies, it was predicted that the group of American Football players would show lower scores in tasks measuring cognitive function than athletes from non-contact sports and the group of non-athletes (hypothesis 1). It was further hypothesized that American Football players with concussion history would show lower scores in tasks measuring cognitive function than those without concussion history (hypothesis 2). Due to injuries being an incremental part of high-performance sports, previous studies tried to find possible differences in motivational climate or goal orientation between athletes by their history with sports injuries (Bashan et al., 2018). As an athlete's orientation possibly affects the way they act on the field, variables such as motivation and goal orientation could be influential on their willingness to risk injuries and thus concussions. Therefore competitiveness, win and goal orientation were assessed to control for possible interference variables.

2. Methods

2.1 Participants

For this study 118 participants (39.0% female, 59.3% male, 1.7% diverse) were recruited from three groups: American Football players (48), non-contact sports athletes (32), and non-athletes (38). Their age ranged from 18 to 62 years (M = 26.6, SD = 7.7). Highest education from participants ranged from vocational training (3.4%), over high school graduation (47.5%), to university degrees (45.8%). In addition to participants which already graduated from university, 33.9% were currently attending a university education, demonstrating a high education level in the sample. 91.5% of participants reported Austrian citizenship, while the remaining participants reported German (5.9%), Luxembourgish (0.8%), Italian (0.8%) and Croatian (0.8%) citizenships. All participants had to be above the age of 18 and be free of medical conditions resulting in severe cognitive impairment. Participants of the American Football group were recruited from local American Football teams. The group of non-contact athletes was primarily recruited through Austrian orienteering, triathlon, and tennis organizations, as well as notices at local physiotherapist offices, universities, and social media. The comparison group was primarily recruited through notices at universities and social media. Additional participants of all groups were gathered through a snowball system and referrals. Each participant was offered a compensation of 20 Euros for their time. Sensitivity analysis with the G*Power software determined that effect sizes f of 0.29 and higher could be reliably detected with a sample size of 118 by the alpha level of 0.05 and power of 0.80. Following transformation rules according to Lenhard & Lenhard (2022) this results in partial eta squared effect sizes of .078 or higher being reliably detected within this study.

2.2 Measures

2.2.1 Demographics and Relevant Athletic Information

At the beginning of testing participants demographics were assessed. This included date of birth, gender, highest education, and years in education. Additionally, participants were questioned on health problems, such as neurological disorders, mental disorders, or any other causes for severe cognitive impairment. Afterwards information on the athlete's sports career was collected, including sport practiced, years active in the sport, major competitions participated in, and, if applicable, position played (see Appendix A).

2.2.2 Screening

2.2.2.1 Concussion Interview. Concussion history was assessed by interviewing participants about their past experiences of concussion. Participants first were briefed on the study's definition of concussion being a blow to the head followed by variety of symptoms (e.g. loss of consciousness, headache, dizziness, loss of balance, blurred vision, "seeing stars", feeling in a fog or slowed down, memory problems, poor concentration, nausea, or throwing up). Afterwards participants were asked five questions: Have you ever sustained a concussion? How many times have you sustained a concussion while playing or training American Football? Have you ever been evaluated by a medical professional for concussion? Did you ever lose consciousness or sustained other symptoms of concussion? If you ever had a concussion, when did you endure your last one? Depending on their answers participants were grouped into one of two groups by the amount of notable concussion experiences (no concussions, one or more concussions). Any recalled cases of concussions with symptoms of the beforementioned list noted were counted as concussions, it was not necessary for these incidents to be investigated by medical professionals. This approach was adapted from previous studies on concussion and cognitive function (Hume et al., 2017), only adding a question about the time elapsed since the participant's last concussion.

2.2.2.2 Vienna Visuo-Constructive Test 3.0 (VVT 3.0). Prior to the main assessment of cognitive function participants were asked to complete the VVT 3.0 (Valencia & Lehrner, 2018) as a cognitive screening process. During this paper-pencil task participants were asked to copy three figures as closely as possible, these figures being a clock, two overlapping pentagons and a see-through cube. The results depended on several mandatory aspects of the figures being copied, with each aspect giving a point up to a maximum of ten possible points.

2.2.2.3 Wortschatz-Test (WST). The WST (Schmidt & Metzler, 1992) was used to assess verbal intelligence. In this test participants completed 40 trials, during each trial six words were presented on the screen with only one of them being an existing word in German. Participants had to confirm whether they are familiar with one of the six words and if so which one. The tests duration is approximately ten minutes. The resulting WST scores can be converted into a verbal IQ score. Internal consistency has been shown as excellent (α = .94; Schmidt & Metzler, 1992).

2.2.3 The International Neurocognitive Test Profile (INCP)

The INCP (Lehrner, 2021) is a self-administered neurocognitive test battery conducted on tablet computers or online, it is currently in its third version and under constant evaluation. The INCP consists of 18 subtests aiming to assess cognitive impairment regarding the six neurocognitive domains proposed in the DSM-V (American Psychiatric Association, 2013). The future goal for this test is to be used autonomously in private settings as a self-monitoring instrument observing the cognitive status. Thus, the target group are cognitively healthy individuals interested in monitoring their cognitive functions. So far, no studies regarding the reliability and validity of the INCP have been conducted. Content and construct validity however are given, as the test is modeled after similar assessments and the subtests follow the neurocognitive domains of the DMS-V. Convergence validity can be assumed, since the subtests use adapted paradigms of known paper-pencil tests used to assess cognition (Lehrner, 2021). While originally planned to conduct all 18 subtests of the INCP, due to issues in programming only 8 subtests were available to be used in this study[1]. However, it was possible to administer at least one subtest per cognitive domain. The conducted tests are listed in the following paragraphs.

2.2.3.1 Learning and Memory.

2.2.3.1.1 Faces-Pairs-Test (FPT). This task measured episodic memory of visual input at two stages (immediate recognition and delayed recognition). During the task, pictures of faces had to be matched with the picture of another face previously presented as a pair. A total score was obtained by adding the sub-scores of the three trials as a percentage. The three trials were conducted as follows: In the immediate recognition trial, the face of a woman and the face of a man, as a pair, were presented. Participants were asked to memorize the paired faces in two

[1] The parties in charge of the INCP repeatedly could not meet the dates previously agreed on for initialization of data collection. After adapting the study design to fit the new timeframe, they, and later I, were informed that the anticipated progress of the INCP was not met due to previously undisclosed personal and health issues of the responsible programmer. Therefore, data collection started with the tests available at this point.

rounds for about 4 minutes, afterwards the faces were shown one after another with participants having to complete the pairs, choosing out of two presented options. The tasks duration was approximately three minutes with the score being the sum of correctly chosen couples. After a delay of about 20 minutes, participants were asked to correctly match one face to the previously memorized partner out of six possible faces. The score was the sum of all correctly matched couples. After this delayed recognition, participants were shown the previously presented faces alongside new faces and were asked to confirm whether they had previously seen the face or not. The score was the sum of hits minus the sum of false hits.

2.2.3.1.2 City Identification Test (CITY). This task measured semantic memory. During the task 16 names of capitals were presented, participants had to match the capital names to the correct country out of four proposed answers. The tests duration was approximately one minute, the score was the sum of correct answers.

2.2.3.1.3 Face Identification Test (FACE). This task measured semantic memory. During the task, 16 faces of well-known actors had to be identified out of four proposed answers. The tests duration was approximately one minute, the score was the sum of correct answers.

2.2.3.2 Language.

2.2.3.2.1 Auditory Vocabulary Test (AVT). This task measured language skills in the form of auditory perception and understanding. During the task, participants listened to spoken words, which are either real German words out of the Duden dictionary or invented but similar in terms of word-sound and pronunciation, mimicking possible German words. Participants were asked to identify existing words by indicating either “yes” or “no”. The tests duration was approximately three minutes, the score was the sum of correct answers as a percentage. Prior to data analysis an item-difficulty-analysis was conducted following the procedure described by Moosbrugger & Kelava (2020) reducing the items from 110 to 100, during this process the 10 items with the lowest item discrimination were cut.

2.2.3.2.2 Image Naming Test (INT). This task measured language as well as semantic memory skills. During the task, participants were shown two words and a picture of an object, participants had to match the correct word to the picture. The tests duration was approximately three minutes, the score was the sum of correct answers as a percentage. Prior to data analysis an item-difficulty-analysis was conducted following the procedure described by Moosbrugger

& Kelava (2020) reducing the items from 110 to 100, during this process the 10 items with the lowest item discrimination were cut.

2.2.3.3 Complex attention.

2.2.3.3.1 Digit Symbol-Test (DST). This task measured attention and information processing. During the task, participants had to pair symbols and digits according to a given template. Participants were instructed to match as many symbols as possible in 60 seconds over three rounds. The tests duration was approximately three minutes, the score was the sum of correct pairings over the three trails as a percentage.

2.2.3.4 Executive Function.

2.2.3.4.1 Traffic-Light-Test Short (TLT-S). This task measured the executive functions inhibition and cognitive flexibility. During the task, participants were shown a traffic light with either a shining green or red light. In the first trial participants had to press a "go"-button when the green light is shown and a "stop"-button when the red light is shown as quickly as possible. In the second trial the button to press was switched. The tests duration was approximately 90 seconds, the score was the sum of all correct pressed buttons minus incorrect pressed buttons as a percentage.

2.2.3.5 Social Cognition.

2.2.3.5.1 Emotion Face Test Short (EFT-S). This task measured emotional ability as well as the executive functions inhibition and cognitive flexibility. During the task, participants were shown schematic faces of either a happy or a sad face. In the first trial participants had to press a "happy"-button when the happy face was shown and a "sad"-button when the sad face was shown as quickly as possible. In the second trial the button to press was switched. The buttons showed the verbal terms "happy" and "sad" as written here. The tests duration was approximately three minutes, the score was the sum of all correct pressed buttons minus incorrect pressed buttons as a percentage.

2.2.4 Sport Orientation Questionnaire (SOQ).

The SOQ (Elbe et al., 2008) was used to measure the points of reference an athlete uses to assess their sports performance. It consisted of a total of 25 items measuring three subscales: competitiveness (13 items), win orientation (6 items), and goal orientation (6 items). Each item was answered on a 5-point Likert scale ranging from *1 = completely disagree* to *5 = completely agree*. Maximum scores were 65 for competitiveness, 30 for win orientation, and 30 for goal orientation. Internal consistency has been shown as excellent for competitiveness (α = .94) and good for win orientation (α = .82) and goal orientation (α = .81). Validity has been confirmed (Elbe, 2001).

2.3 Procedure

The research questions were examined through a cross-sectional study of high-performance American Football players, athletes from non-contact sports, and a non-athlete comparison group. Prior to the assessments, participants were contacted through E-Mail, SMS, or WhatsApp and asked about their concussion history and the amount of exercise they engage in weekly, to check early for possible exclusion criteria. Participants that were included through this step were sent a link to the screening questionnaire, which consisted of a short assessment of demographics, education, health, and relevant athletic information followed by a screening including the concussion interview, VVT 3.0, and WST. After completion, participants were sent a link to the assessment of cognitive function (INCP), which participants were asked to complete in a quiet environment, on their personal computers, wearing headphones and using a mouse. Afterwards, participants were able to ask any remaining questions through their initial means of contact (see Appendix B).

2.4 Inclusion and Exclusion Criteria

It was necessary for inclusion that participants were healthy adults without any health problems that could cause severe cognitive impairment, such as neurological disorders or mental disorders, among others. American Football players were included if they participated regularly in practice and competition of American Football. Participants of the group of non-contact athletes were included if they participated regularly in training and competitions of non-contact sports. Regular practice for the athlete groups being defined as at least 4 units of engagement per week e.g. sport specific practice, strength training, conditioning, or similar. Regular competition for the athlete groups being defined as multiple contests per season, the common number of contests varied by athletic discipline. Participants of the non-athlete group were excluded if they engaged regularly in exercise or sports as part of any clubs or other organized exercise. Non-athletes were included if they stated an occasional run, but any further commitment to an exercise regime led to exclusion. For non-contact athletes and non-athletes any mention of a concussion observed and diagnosed by medical experts was a reason for exclusion, for American Football players only concussions that happened outside of any American Football related behavior led to exclusion. Additionally, participants must have reached a score of 9 or 10 on the VVT, as scores of 8 or below are conspicuous, indicating cognitive impairment and therefore resulted in them being excluded from the study. Verbal IQ scores lower than 85 were also excluded indicating limited verbal intelligence.

2.5 Statistical Analysis

Data was analyzed using the psimistri software and customized Microsoft Excel spreadsheets. The statistical analysis was conducted with IBM SPSS Statistics 29. The study's hypotheses were measured through one-way analyses of variance as well as one-way analyses of covariance for subtests affected by interference variables. To evaluate the influence of interference variables on the assessment of cognitive function, chi-squared tests were conducted for gender and education, while the impact of age, along with exploratory measures of competitiveness, win orientation, and goal orientation was investigated using one-way ANOVAs. Prerequisites in the data for analyses of variance were met, as investigated through observation of the distribution of scores, Q-Q plots, and Levene tests. For exploratory analyses regarding possible effects of multiple concussions, time since the last concussion, years played in the sport, and the level of competition onto scores of cognitive function, correlations with the different subtests were calculated.

3. Results

3.1 Demographics and Covariates

Table 1 displays demographics, relevant athletic information, and concussion history in detail. Relevant differences between the groups laid in age and gender distribution, as well as the highest achieved education of participants at the time of the study. The sample of non-athletes was significantly older and better educated than the athlete groups, and the group of American Football players contained more males than the other two groups. Table 2 displays the distribution of gender, age, and education within the American Football players group, separated by their concussion history. It is shown that the two groups differ significantly in age, with the players without concussion history being significantly older than the players with concussion history.

Table 1

Demographics, Athletic Information, and Concussion History for Sport Groups

	American Football [*n* = 48]	Non-contact [*n* = 32]	Non-athletes [*n* = 38]
Age, years [*M* ± *SD*]	24.9 ± 3.3	25.8 ± 10.0	29.5 ± 8.7
Gender			
Female	5 (10.4)	20 (62.5)	21 (55.3)
Male	41 (85.4)	12 (37.5)	17 (44.7)
Divers	2 (4.2)	0 (0.0)	0 (0.0)
Education level			
Vocational	0 (0.0)	1 (3.1)	3 (7.9)
High school	29 (60.4)	17 (53.1)	10 (26.3)
Tertiary	16 (33.3)	13 (40.6)	25 (65.8)
Unknown/missing	3 (6.3)	1 (3.1)	0 (0.0)
Years in education [*M* ± *SD*]	16.4 ± 3.0	16.0 ± 2.9	17.0 ± 3.3
Years played sport [*M* ± *SD*]	8.1 ± 3.9	10.4 ± 5.2	
Sport level			
National competition	35 (72.9)	14 (43.8)	
International competition	13 (27.1)	15 (46.9)	
Unknown/missing	0 (0.0)	3 (9.4)	
Number of concussions [*M* ± *SD*]	1.9 ± 1.9	0.0 ± 0.0	0.0 ± 0.0
None	14 (29.2)	32 (100.0)	38 (100.0)
One or more	31 (64.6)	0 (0.0)	0 (0.0)
Unknown/missing	3 (6.3)	0 (0.0)	0 (0.0)
Months since last concussion [*M* ± *SD*]	27.5 ± 26.8	0.0 ± 0.0	0.0 ± 0.0

Data are presented as *n* (%) unless specified differently.

Table 2

Demographics, Athletic Information, and Concussion History for Concussion Groups

	No concussion [*n* = 14]	One or more concussions [*n* = 31]
Age, years [*M* ± *SD*]	26.6 ± 3.2	24.1 ± 3.0
Gender		
Female	2 (14.3)	2 (6.5)
Male	12 (85.7)	27 (87.1)
Divers	0 (0.0)	2 (6.5)
Education level		
High school	8 (57.1)	21 (67.7)
Tertiary	6 (42.9)	10 (32.3)
Years in education [*M* ± *SD*]	18.4 ± 3.7	15.5 ± 2.1
Years played sport [*M* ± *SD*]	6.9 ± 3.6	8.7 ± 3.9
Sport level		
National	11 (78.6)	21 (67.7)
International	3 (21.4)	10 (32.3)
Concussion History [*M* ± *SD*]	0.0 ± 0.0	2.7 ± 1.7

Data are presented as *n* (%) unless specified differently.

As the distribution of gender varied among sport groups, and gender impacted the performance in the cognitive assessment (subtests: FPT, CITY) as well as the expression of competitiveness and win orientation differently, gender was added as a covariate for the affected analyses. Regarding observable differences in the distribution of age among sport and concussion groups, and age impacting the performance in the cognitive assessment (subtests: CITY, FACE, AVT) as well as the expression of competitiveness and win orientation differently, also age was added as a covariate for the affected analyses. Although there were significant differences in education between the sport groups, education was not added as a covariate, since these differences could be traced back to the difference in age. This was confirmed by the amount of respectively younger participants from the athletic groups currently enrolled in tertiary education. Due to their age at the time of assessment, their education had not yet been completed.

Table 3 shows the scores on the SOQ scales by group. Exploratory analyses on competitiveness, goal orientation, win orientation show that the group of non-athletes has a significantly lower expression of competitiveness and goal orientation than the athlete groups, while the group of American Football players has a higher win orientation than the other groups. The data showed that the subscales of the SOQ only impacted scores on cognitive function through the variable of age, thus they were not added as covariates for the main analyses.

Table 3
SOQ Scores for Sport Groups

	American Football [*n* = 45] *M* ± *SD;* adjusted *M* ± *SD* for analyses of covariance	Non-contact [*n* = 30] *M* ± *SD*; adjusted *M* ± *SD* for analyses of covariance	Non-athletes [*n* = 38] *M* ± *SD*; adjusted *M* ± *SD* for analyses of covariance
Competitiveness*	49.16 ± 8.86	47.47 ± 6.45	**30.37 ± 9.53**
	47.89 ± 1.42	48.26 ± 1.63	**31.23 ± 1.44**
Win orientation*	**23.58 ± 4.58**	19.23 ± 4.84	17.89 ± 5.79
	22.67 ± 0.82	19.61 ± 0.95	18.68 ± 0.84
Goal orientation	25.91 ± 3.96	26.50 ± 3.55	**22.71 ± 4.24**

* One-way analyses of covariance were conducted for the marked scales.
Groups differing significantly (p < .05) are marked as bold.

3.2 Sport Group Differences in Cognitive Function

Table 4 shows cognitive function scores for each cognitive domain for the three sport groups. One-way analyses of variance (ANOVAs) have been conducted for INT, DST, TLT-s, and EFT-s. One-way analyses of covariance (ANCOVAs) have been conducted for FPT, CITY, FACE, and AVT, with gender and age being added as covariates. Statistical analysis concluded that there are no significant differences between the sport groups for any of the cognitive domains: Learning and memory has been assessed through the FPT (η_p^2 = .002, $F(2, 109)$ = 0.129, p = .879), the CITY (η_p^2 = .023, $F(2, 111)$ = 1.290, p = .279), and the FACE (η_p^2 = .022, $F(2, 110)$ = 1.217, p = .300). Language has been assessed through the AVT (η_p^2 = .010, $F(2, 108)$ = 0.557, p = .575) and the INT (η_p^2 = .014, $F(2, 114)$ = 0.818, p = .444). Complex attention has been assessed through the DST (η_p^2 = .026, $F(2, 114)$ = 1.546, p = .218). Executive function has been assessed through the TLT-s (η_p^2 = .008, $F(2, 108)$ = 0.462, p = .631). Social cognition has been assessed through the EFT-s (η_p^2 = .001, $F(2, 103)$ = .060, p = .942).

Table 4
Cognitive Function Scores (as percentages) for Sport Groups

Cognitive domains and the respective tests used	American Football [*n* = 48] *M* ± *SD;* adjusted *M* ± *SD* for analyses of covariance	Non-contact [*n* = 32] *M* ± *SD*; adjusted *M* ± *SD* for analyses of covariance	Non-athletes [*n* = 38] *M* ± *SD*; adjusted *M* ± *SD* for analyses of covariance
Memory and learning			
FPT*	72.57 ± 10.03	74.72 ± 10.92	75.97 ± 8.53
	74.14 ± 1.56	73.69 ± 1.82	74.89 ± 1.6
CITY*	77.34 ± 16.69	76.37 ± 16.17	75.00 ± 17.38
	76.01 ± 2.47	79.10 ± 2.86	74.38 ± 2.65
FACE*	56.79 ± 13.87	55.44 ± 17.95	63.98 ± 15.41
	59.97 ± 2.05	55.64 ± 2.36	59.98 ± 2.15
Language			
AVT*	83.76 ± 6.90	82.20 ± 9.23	84.97 ± 5.37
	84.03 ± 1.09	82.62 ± 1.28	84.30 ± 1.16
INT	89.83 ± 3.19	89.23 ± 5.90	90.55 ± 4.02
Complex attention			
DST	97.67 ± 2.98	98.51 ± 1.03	97.51 ± 2.68
Executive functions			
TLT-s	95.12 ± 5.12	94.35 ± 8.54	95.88 ± 6.02
Social cognition			
EFT-s	94.29 ± 6.54	93.79 ± 6.70	94.03 ± 4.94

* One-way analyses of covariance were conducted for the marked tests.

3.3 Concussion History Group Differences in Cognitive Function

Out of the 45 American Football players that completed the interview on concussion history 64.6% of players reported that they endured at least one concussion during their career. Out of these players 17.8% recalled one concussion, 20.0% two, 13.3% three, 6.7% four, and 10.0% five or more concussions. The average number of concussions declared was 1.9 with a standard deviation of 1.9 over all players. The time since the last concussion ranged from 2 to

109 months, with a mean of 27.5 months (2.3 years) and a standard deviation of 26.8. Table 5 shows cognitive function scores for each domain compared between the concussion history groups. One-way analyses of variance (ANOVAs) have been conducted for FACE, AVT, INT, DST, TLT-s, and EFT-s. One-way analyses of covariance (ANCOVAs) have been conducted for FPT and CITY, with age being added as a covariate. These analyses showed significant differences between concussion groups for one subtest of the language domain (INT: $\eta_p^2 = .097$, $F(1, 43) = 4.626$, $p = .037$). Other tests showed no significant differences between concussion groups: Learning and memory (FPT: $\eta_p^2 = .076$, $F(1, 40) = 3.270$, $p = .078$; CITY: $\eta_p^2 = .045$, $F(1, 42) = 1.999$, $p = .165$; FACE: $\eta_p^2 = .055$, $F(1, 41) = 2.376$, $p = .131$), language (AVT: $\eta_p^2 = .069$, $F(1, 41) = 3.054$, $p = .088$), complex attention (DST: $\eta_p^2 = .006$, $F(1, 43) = 0.280$, $p = .599$), executive function (TLT-s: $\eta_p^2 = .000$, $F(1, 39) = 0.018$, $p = .893$), and social cognition (EFT-s: $\eta_p^2 = .004$, $F(1, 35) = 0.123$, $p = .728$).

Table 5
Cognitive Function Scores (as percentages) for Concussion Groups

Cognitive domains and the respective tests used	No concussion [N = 14] *M ± SD;* adjusted *M ± SD* for analyses of covariance	One or more concussions [N = 31] *M ± SD;* adjusted *M ± SD* for analyses of covariance
Memory and learning		
FPT*	70.71 ± 8.74	74.02 ± 10.80
	68.85 ± 2.70	74.92 ± 1.84
CITY*	84.38 ± 13.59	76.01 ± 15.23
	83.60 ± 4.17	76.36 ± 2.73
FACE	61.61 ± 13.62	54.96 ± 13.01
Language		
AVT	86.64 ± 4.83	82.76 ± 7.58
INT	**91.21 ± 3.38**	**89.13 ± 2.84**
Complex attention		
DST	98.06 ± 1.19	97.53 ± 3.63
Executive function		
TLT-s	95.42 ± 3.51	95.17 ± 5.78
Social cognition		
EFT-s	95.56 ± 4.10	94.73 ± 6.61

* One-way analyses of covariance were conducted for the marked tests.
Significant differences (p < .05) marked as bold.

3.4 Exploratory Analyses

Exploratory analyses on the relationship between multiple concussions, the time since the last concussion, the years of the sport played, and the level of play with scores on cognitive function revealed no significant correlations.

4. Discussion

Based on findings from previous studies, it was predicted that American Football players would score lower in tasks measuring cognitive function than athletes from non-contact sports and the comparison group of non-athletes (hypothesis 1). As none of the tests of cognitive function have shown significant differences in the scores between the three sport groups this assumption could not be confirmed with the data collected for this study. The groups performed equally in all cognitive domains assessed, thus suggesting no differences in cognitive function between American Football players, non-contact sport athletes, and non-athletes. Therefore hypothesis 1 must be dismissed. It appears that neither do American Football players perform worse in tests of cognitive function than non-athletes and non-contact sport athletes, nor do athletes score higher than non-athletes in any domain of cognitive function. Prior literature has shown differences in executive functions between athletes and non-athletes, thus it was expected for non-contact athletes to score higher in this domain than non-athletes. This result not being in conformity with the body of literature might be troubling regarding the interpretive value of this study.

Additionally, it was predicted that American Football players with one or more endured concussions would score lower in tasks measuring cognitive function than those without any concussions (hypothesis 2). With lower scores produced only in the language domain, through one of its subtests, there is not enough evidence to assume that the predictions were correct. Therefore hypothesis 2 must also be dismissed. Thus, self-reported concussion history over the career of active American Football players did not show any significant association with their scores of cognitive function. As the mean time-period since the last concussion for this sample was 27.5 months (2.3 years) this study assessed the long-term impacts of concussion history on active high-performance American Football players, therefore no observation regarding short-term consequences, as commonly found in the literature, can be made. However, the results of this study suggest that a history of concussion does not have a long-term impact on cognitive function in active athletes. This finding supports previous meta-analyses, which suggested short-term consequences without long-term effects in athletes having experienced concussions (Belanger & Vanderploeg, 2005).

Since the reasoning behind the assumption that American Football players would score lower on cognitive function was grounded in prior studies on the impact of concussion and the repeated head collisions part of American Football, this lack of difference can be seen as a positive result. It suggests that regular exposure to American Football practice and competition does not impair cognitive function. This result holds several practical implications. First and foremost, it could be the first step for the dismissal of stereotypes regarding American Football and its players. The literature connects American Football with cognitive deficiencies as well as lower quality of post-career life (Guskiewicz et al., 2005; Roberts et al., 2019). While studies so far could not present a united front on the impact of American Football and concussion on cognitive function during their athletic careers, the scientific interest in the field as well as results from retired athletes paint a clear picture, expecting American Football players to perform worse on tests assessing cognitive function. This study observing no differences in cognitive function between the groups is a showing that the sport of American Football not consequentially comes with impairment of cognitive function. Should further research confirm this study's findings and add further dismissals of long-term cognitive detriments from participating in sports as physically demanding as American Football and concussions, it could reduce concerns for people participating in such sports, which could provide a feeling of safety and well-being for athletes in general and especially athletes of more violent or physically straining disciplines. This shows how psychological research can help to improve our knowledge of psychological and cognitive aspects of research fields, such as sport, and thus be beneficial for the well-being of athletes or human beings in general.

4.1 The Lack of Differences from a Cultural Point of View

A lot of studies on the impact of concussion on American Football players were conducted in the United States of America, whereas this study recruited athletes in Austria. While Austria is a successful nation regarding American Football in Europe, as can be seen by recent success in the European League of Football (Hanswillemenke, 2022), the Europe U19 Championships (Preston, 2023), and Men's European Championship (Preston, 2023), the performance and competition level of American Football in the United States is much higher. Although the athletes assessed in this study were experts in their field competing on high levels, they were also engaged in regular jobs or education, rather than pursuing their athletic career as a full-time occupation. In comparison to American Football players in the United States or the NFL, this sample did not financially depend on their sporting career, which could have an impact on any negative consequences thereof. Important factors regarding cognitive benefits from exercise are regular practice and prolonged participation (Etnier & Chang, 2009; Moratal et al., 2020), therefore this would not explain its missing positive impact on results of the sports group athletes. However, the fact that our American Football group consisted of part-time players might have been a contributing factor to the unexpectedly high scores compared to full-time players.

Successful American Football players in the USA will usually start their career in youth or high school programs, followed by a career as college athletes, with the final goal to get drafted into the NFL or other professional American Football leagues. This journey is a process requiring hard work and dedication, with only the top 7.3% of high-school athletes making the jump to collegiate levels, and an even smaller fraction, just 1.6% of college athletes, making it into the NFL. Thus, putting immense pressure on the young people pursuing such a career, as 1.006.013 high school participants face about 254 NFL draft picks yearly (NCAA, 2020). Data shows that in the 2022/23 NFL season 56.4% of players were black or African American (Gough, 2023), black athletes drafted into the NFL come from denser, more socioeconomically disadvantaged, and blacker hometowns than black athletes that do not get drafted (Allison, 2018). This possibly indicates that a big number of American Football players drafted into the NFL stem from families with lower socio-economic status, thus further indicating a pressuring environment for American Football players in the US in comparison to American Football players in Europe.

There are numerous regulations on American Football in the US regarding the number of training sessions with full-contact or the number of practices per week. In Austria there are no such regulations active at the time of the study. While the highest level of American Football teams in Austria usually practice three times a week for 1.5 hours on almost all levels, in the US teams tend to practice more than that, even at young ages. However, in the US the minutes of full-contact practices are strictly regulated. USA Football, the member of the International Federation of American Football (IFAF) of the US, has published guidelines for youth tackle football teams. These guidelines allow four practices per week, each one lasting up to two hours. Additionally, they limit the amount of full-contact drills to either 90 or 120 minutes per week, depending on the time in the season (USA Football, 2023). The amount high school teams in the US practice are different from school to school usually ranging from 10 to 20 hours per week. At high school level full-contact practice has recently been reduced to 60-90 minutes per week following the National Federation of State High School Associations Concussion Task Forces suggestion (Amaro, 2021). At collegiate level hours per week are set to about 10 to 15 hours per week (NCSA College Recruiting, 2023). During the season NFL players usually practice 4 days a week, with two daily sessions of about 2 hours, however a lot more work is done without full-contact, due to worries of injury and the physical strain NFL players underlie regardless of practice (Bowen, 2013; Football Operations, 2023). These numbers show that American Football practice is much more regulated in the US, which could indicate a better care for players with regards to their health. However, they also suggest that American Football players in the US have usually played a lot more minutes of American Football than those in Europe, which could have an impact on possible negative consequences resulting from engagement in the sport. Regarding the whole picture, it is clear that American Football in Europe is on a lower level of organization and competition, which is a likely reason for a lower level of play and possibly an overall less violent way of playing due to lower stakes. While a study from 1993 suggests that injury rates in European American Football resembles those in the United States (Karpakka, 1993), it remains possible that the lower stakes result in a lower overall impact of the sport on cognitive function, therefore the reason for missing differences might lie in the samples of American Football players when comparing our findings to similar studies.

As this study's sample is mostly comprised of university students or university graduates, it is possible that education is a deciding factor for the scores in cognitive function. Studies show connections between education and general cognitive ability (Falch & Sandgren Massih, 2011), as well as education impacting cognitive function across the life span by contributing to individual differences emerging in early adulthood (Lövden et al., 2020). Since the sport groups were different in education levels only through age, it would be possible that the impact of their high education had a bigger influence on the cognitive function than any positive or negative bearings of their athletic careers, with differences in cognitive function being overshadowed by higher scores resulting from the participants high education levels.

4.2 The Lack of Differences from a Methodological Point of View

While the lack of differences among the study groups could be due to the described cultural or educational explanations, another reason for the unexpected results could lie in methodological limitations of the study. The most prominent limitation being the low sample size. The aspired number of participants could not be achieved, thus leaving the study with low power for the effects that were supposed to be found. Additionally, the cross-sectional design displays a limitation in finding effects that could change over time, such as the impact of concussion on cognitive function. Furthermore, the measure for the assessment of cognitive function contains some limitations, such as the omission of 10 out of 18 subtests for this study's assessment, a lack of testing for psychometric properties, and possibly low test sensitivity for a young and healthy sample. It is important to note that these are serious limitations to the study, reducing the power to find the expected effects between and within the study groups. Therefore, it is not impossible that the study groups do differ in cognitive function, but effects were overlooked in the statistical analysis. Both hypotheses had to be dismissed due to the nonsignificant results, however an exploratory look into the data might be of use for future studies and giving further insight into possible differences among the groups that this study was unable to find.

4.2.1 Sport Groups

A closer look on mean scores of the study groups reveals possibly interesting information. A distribution where non-contact athletes would score highest, followed by either American Football players or non-athletes, depending on whether the benefits of regular activity and sport or the negative consequences following head trauma were more impactful, was expected. This was not found, there was no systematic distribution in the mean scores of the cognitive assessment. Several variations can be found in the data, the most prominent being non-athletes scoring the highest, American Football players second, followed by non-contact athletes last. This order was found in five of eight subtests, the outlying subtests being from the domains of learning and memory (CITY), complex attention (DST), and social cognition (EFT-s). Interestingly the group of American Football players never obtained the lowest mean score in the assessment of cognitive function.

Furthermore, the partial eta squared effect sizes gathered from the analyses of variance and covariance show the variance in the assessment of cognitive function explained through the respective group variable by subtest. Following Richardson (2010) on benchmarking of partial eta squared against Cohen's (1969) criteria of small, medium, and large effects, effect sizes in this sample suggest no effects in subtests from the domains of social cognition (.001), memory and learning (.002), and executive function (.008) and small effects in subtests from the domains of language (.010 and .014), memory and learning (.022 and .023), and complex attention (.026). However, all these effects sizes lie below the critical effect size of .078 calculated in the sensitivity analysis. Therefore, none of these potential effects would have been reliably detected in this study. While this impedes interpretation and the formulation of statements regarding their possible effects, it is possible that in fact there are differences in the sample and the respective populations, but the study's power did not suffice to detect them.

While the distribution of means fits the result of no significant differences between American Football players, non-contact athletes, and non-athletes, the observation that all computed partial eta squared effect sizes lie below the critical effect size for this study illustrates the necessity for further research to confirm or deny possible effects within the populations.

4.2.2 Concussion Groups

Focusing on the mean score comparison for the concussion groups it is noticeable that the group with one or more concussions did score lower in all subtests but one stemming from the learning and memory domain (FPT). This could give an indication that the original hypothesis was not flawed, but the study lacked the sample size to find significant results, or the effects investigated were smaller than anticipated and thus not able to be found given the sensitivity available within the study. It can further be noted that correlation analysis showed small negative connections between the number of concussions recalled with the results of all but 2 subtests of the cognitive assessment. While not significant, these correlations might give additional insight into a possible negative impact of concussions onto cognitive function, that was missed in the study's statistical analysis.

Partial eta squared effect sizes for the concussion group comparison suggest no effects for the domains of executive function (.000), social cognition (.004), and complex attention (.006). Effect sizes in subtests of the memory and learning domain (.045 and .055) suggest small effects and medium sized effects in subtests of the domains of language (.069 and .097) and memory and learning (.076). Again, most of these effect sizes lie below the critical effect size of .078 calculated in the sensitivity analysis. The partial eta squared of .097 within the domain of language remains the only significant result as well as the only effect size reliably detectable in this study. Any other effects cannot be interpreted and need to be investigated in future studies to make reliable statements.

While the studies statistical analysis shows no significant differences between the investigated groups, the possibility of differences between the study groups remains due to the relatively high critical effect size calculated in the sensitivity analysis. Keeping further limitations in mind, it is possible that this study lacked the statistical power to discover potential differences among American Football players, non-contact athletes, and non-athletes, as well as between American Football players with and without history of concussions. Thus, it cannot be excluded that the hypotheses were falsely dismissed and there were unobserved differences in cognitive function between the groups investigated. Future research must overcome the limitations of this study, confirming, or denying this study's findings. If differences were overlooked, this would have grave implications. These would have been the first observed differences in cognitive function between non-athletes, athletes of American Football and non-contact sports in Austria. While further study would be needed, it would indicate that more care in form of protocols to regulate concussion in European American Football are necessary. It would be advised to raise awareness to the topic, implement changes towards the way the game is played on every level through regulations in practice and play, as well as further analyze this topic in youth academies, as it is being done in the US.

4.3 Strengths and Limitations

To my knowledge this is the first attempt at discovering possible differences in cognitive function between high-performance athletes of American Football and non-contact sports as well as non-athletes in Austria and Europe. Thus, the study enrichens the body of literature through multiple possible connections towards different fields of research within the realm of sports and health, and an opposing view on the topic of American Football to the US-centric literature. The sample of the study contained high-performing athletes from top leagues of the respective disciplines in Austria and Europe. Out of the 80 athletes recruited for this study, 28 (23.7%) participated in international leagues or competitions through the Austrian national team and 25 (21.2%) competed in the highest Austrian national competitions. The samples consisted of athletes of varying age and education, thus providing a complex sample fitting to test the hypotheses in question. While American Football is a male dominated discipline (Statista Research Department, 2022), it was possible to gather female athletes from the sport to further expand the sample and strengthen its representative value. Multiple variables possibly impacting performance in the cognitive assessment have been controlled for, thus limiting impact of disturbance variables, such as gender, age, education, language abilities, competitiveness, win orientation, and goal orientation. The study had a precise idea of what was expected from the data. When confronted with unexpected results the interpretation was critical, offering possible impacts of these findings, but nonetheless reflecting on limitations in the study design and diving deeper into the data to gain the most of the study's results. Due to the possibility of the observed effects underlying the error of wrongfully dismissing the hypotheses, also opposite implications were discussed. The study lays a foundation that must be confirmed or denied in future studies overcoming the deficits of this research.

Recruitment for the study fell short in all three groups, resulting in a lower sample size than aspired, too small for the effects the study tried to find, resulting in low power. A minimum of 30 participants per group were necessary to assume normal distribution in the results of cognitive assessment, following the central limit theorem (Fischer, 2011), while this number was acquired for the sport groups, the concussion groups did not reach that number with only 14 American Football players without any concussions. Even though there were no significant differences found, the cross-sectional design of the study limits the ability to infer causality between the groups and cognitive functioning. No information on temporal sequences can be gathered from this study`s results. Additionally, a potential selection bias within this sample could hinder generalizations to possibly different populations, such as American Football players in the United States. Differences in the way the sport is socially regarded, taught, and played might contribute to this challenge. Furthermore, the measurement used for assessment of cognitive function has not yet been tested for some psychometric properties, therefore reliability and validity cannot yet be confirmed in all cases. The omission of 10 subtests, due to issues with programming, further limits the informative value of the measure and therefore the study. Ceiling effects were observed by looking at the distribution of scores for some of the subtests (AVT, INT, EFT-s, TLT-s, DST) with the majority of scores lying close to a perfect 100%. They were further supported by analyzing kurtosis values for the score distribution. This possibly suggests that these subtests were not difficult enough to find subtle differences in samples without severe cognitive issues. Therefore, it is possible that the INCP needs further tuning in order to find early signs of cognitive decline or possibly small differences in cognitive function such as expected between this studies groups. While this is a possibility, there are also subtests where no ceiling effects were observed, namely the FPT, CITY, and FACE. Observations made regarding the subtest FACE are a sizable and significant correlation with age (r = .605; $p < .001$), while age has been examined as a covariate, questions regarding the usability of the FACE remain. During the FACE pictures of famous actors are presented, these actors are James Stewart, Cher, Uschi Glas, Liza Minnelli, John Travolta, Clark Gable, Dean Martin, Joan Collins, David Hasselhoff, Tom Cruise, Arnold Schwarzenegger, Dustin Hoffman, Hans Moser, Robert Redford, Mick Jagger, and Pierre Richard. Regarding that the mean year of birth of these celebrities is 1933 and their current mean age is 78.5, it is understandable that older participants scored better on this test, as it is very plausible that younger participants simply never heard of some of these celebrities. Which leaves the usability of this test without norm values for the assessment of the cognitive domain of learning and memory in younger adults up for questioning. The results leave us with the indication that there were no severe differences between the study groups, however, it also shows that more precise diagnostic tools are needed to find smaller effects in cognitive function in healthy and young subjects. Self-report of concussion could also represent a limitation, participants could falsely remember certain aspects of their experiences which cannot be controlled for in the interview process. However, it can be pointed out that Kerr et al. (2012) have shown that self-report of concussion is a viable option to assess concussion history. Nonetheless, lack of medical professionals in the diagnosis of concussion could be a limiting factor. Due to difficulties in reaching the aspired number of participants the decision was made to use the online version of the INCP instead of asking them to come into a laboratory, thus participants were conducting the assessment on their own at a place unknown to the study team, it would be possible that participants did not follow the requested circumstances for testing, limiting the value of the assessment of cognitive function.

4.4 Further Questions and Future Research

While this study does lay a foundation for the questions interested in, the low power as well as questions about the suitability of the measures can be a diminishing factor in the quality of the study and its conclusions. Hence it would be recommendable to conduct a similar study with more participants and either the complete variant of the measure used in this study or using a more renown measure of cognitive function. Further, a longitudinal study design observing effects of prolonged participation in American Football in Europe would enrich the body of literature, this is where immediate, short-term, and long-term consequences of concussion as well as the impact of multiple seasons of participation in the sport could be observed in detail. In a longitudinal study design daily assessments of cognitive function within 7 days postinjury, as well as several measurements in the months afterwards would be beneficial to get a detailed observation of the impacts of concussion. All athletes in this study were high-performance athletes defined through regular practice and regular competition, not all participants were professional athletes by the definition of them receiving payment for their efforts. The discussion raised the question whether the difference in competition and performance between American Football in the United States and in Europe could be a reason for a difference in the effects observed. Future studies could investigate whether the strength of the league, cultural, or geographical differences between American Football players influences scores of cognitive function. Additionally, studies inquiring about possible difference between amateur leagues and professional leagues could give more insight into the research field. While there are some studies on the effects of American Football and concussion in the realm of youth sports in the United States, in Europe this topic is neglected. Due to the differences regarding the organization of American Football in North America and Europe, this leaves a void in literature on youth sports. This study did not make predictions regarding the theoretical interaction of head trauma following participation in American Football lowering cognitive function scores and the beneficial factors strengthening them through the aspect of regular exercise and sports engagement. Due to the lack of differences found, this interaction might be worth exploring in the future. It was noticeable that athletes of American Football were often interested in their test scores, showing signs of worry about possible effects on their mental abilities and health.

The psychological effects of participation in more violent athletic disciplines could offer a promising field of study, researching the impact of the sport on emotions such as fear or anxiety. During the introduction, the study stated that there are no concussion protocols implemented in European leagues of American Football yet. With findings being somewhat ambiguous towards possible effects of American Football on cognitive functions, it is mandatory to further study possible effects and put more focus on how leagues can keep their players safe from concussion and possible long-term consequences. Studies on how to prevent head injuries are mandatory not only in the United States, but also for American Football leagues in Europe.

5. Conclusion

This study provides evidence contrary to the original assumptions that high-performance athletes of American Football would score lower in assessments of cognitive function than similar level athletes from non-contact sports and non-athletes, as well as that American Football players with history of concussion would score lower than those without. Statistical analysis found no significant differences between sport groups or concussion groups, suggesting no differences among cognitive functions between the groups. This result can be viewed as an optimistic outlook, rejecting stereotypical assumptions regarding American Football players and the sport. However, in view of the study’s limitations, there is a need for further research in order to gather more information on a possible impact of American Football and concussion history on cognitive function.

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Ethical approval This study was performed in accordance with the ethical standards of the Declaration of Helsinki. Ethics approval was granted from the “Ethikkomission Medizinische Universität Wien” (1095/2022). Participants provided consent to participation after reading a participant information sheet on the proceedings of the study.

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Appendix A

Questionnaire on Demographics and Relevant Athletic Information

1. Probanden-ID

Gib hier bitte die Nummer die ich dir zugeschickt habe ein.

2. Geburtsjahr

Gib bitte hier dein Geburtsjahr an.

3. Welchem Geschlecht fühlst du dich zugehörig?

- ○ weiblich
- ○ männlich
- ○ divers

4. Was ist deine höchste abgeschlossene Ausbildung?

- ○ keine abgeschlossene Ausbildung
- ○ Volksschule/Grundschule
- ○ Hauptschule
- ○ Handels- oder Fachschule/mittlere Reife
- ○ Lehre
- ○ Lehre mit Meisterprüfung
- ○ Matura/Abitur
- ○ Diplomlehrgang
- ○ Universität oder Fachhochschule: Bachelor
- ○ Universität oder Fachhochschule: Diplom/Master/Magister
- ○ Universität oder Fachhochschule: Dr./Ph.D. oder höher
- ○ anderer Abschluss, und zwar:

5. Gib bitte hier deine Ausbildungsjahre gegliedert nach Bildungseinrichtungen an.

z.B.

4 Volksschule, 8 Gymnasium, 5 Universität

4 Volksschule, 5 Hauptschule

4 Volksschule, 4 AHS, 5 HAK, 3 Universität

(jegliche Varianten sind in Ordnung, gängige Abkürzungen dürfen verwendet werden)

6. Übst du Leistungssport aus?

Leistungssport wird in dieser Studie durch regelmäßiges Training und regelmäßigen Wettkampf definiert.

- ◯ Ja
- ◯ Nein

7. Treffen einer oder mehrere der unten genannten Zustände auf dich zu?

- Vorliegen einer neurologischen Erkrankung (Schlaganfall, Multiple Sklerose, Epilepsie, M. Parkinson)
- Vorliegen einer schweren psychischen Erkrankung (Schizophrenie, Alkoholismus, etc.)
- Vorliegen einer schweren körperlichen Erkrankung (Tumore, Transplantationen, etc.)
- Vorliegen einer Demenz

- ◯ Ja
- ◯ Nein

8. Falls einer der oben genannten Zustände auf dich zutrifft, kannst du hier nähere Informationen dazu notieren:

____

9. Sportart

Gib gib die Sportart an, die du als Leistungssport ausübst.

- ◯ American Football
- ◯ Triathlon
- ◯ Bouldern
- ◯ Orientierungslauf
- ◯ Tennis
- ◯ Volleyball
- ◯ anderer Sport, und zwar: ________________

10. Position

Falls bei deinem Sport zutreffend, gib bitte deine Position an.

____

11. Dauer der Ausübung

Gib an wie lange du diesen Sport schon ausübst.

____

12. Gib an auf welchem Leistungsniveau du deinen Sport ausübst.

Hier kannst du z.B. auch angeben, ob du Nationalteamerfahrung hast.

Falls du für deinen Sport keine passende Antwort geben kannst lasse das Feld unausgefüllt.

____

Appendix B

Workflow Chart