Abstract

Objectives. The link between football (soccer) headings and dementia risk is a concern given the popularity of this sport worldwide. To assess this link, the cognitive ability of former professional players was tested and self-reported estimates on heading frequency were collected.

Methods. A survey was co-designed with former players to gather demographics data; information on playing career, including playing position; estimates of total head injuries sustained in training and match play; and estimates of heading frequency during training and match play. Data then were collected by post from 60 males (mean age = 67.5; SD = 9.5), who had played professionally for teams in England. In addition to the survey, each individual also completed the Test Your Memory (TYM) self-administered cognitive test to evaluate overall ability.

Results. Bayesian and traditional linear regression analyses were carried out using the TYM score as outcome. Predictors were estimated career head injuries and estimated career headers, while we controlled for age and reported non-football head injuries. The results of our analyses showed that estimated career headers, but not estimated career head injuries, predicted TYM scores.

Conclusion. To our knowledge, this is the first study to provide direct evidence supporting a link between heading the ball and cognitive impairment in retired professional football players.

Keywords: Association football; Soccer; Heading; Cognitive impairment

Introduction

The study of the link between association football (i.e., soccer; henceforth, football) headings, head injury and neurodegenerative diseases leading to dementia has generated much media attention in recent years, leading to the (English) Football Association (FA) and the (English) Premier League issuing guidelines, to be introduced in the 2021/2022 Season, limiting the number of higher force training headers to ten per week. This guidance also has been agreed by the FA, the Premier League, the English Football League, the Professional Footballers Association (PFA) and the League Managers Association (LMA), and applies to all levels of English football, including grassroots and amateur levels [1, 2]. New guidance also has been adopted by the Scottish [3], English [4] and (Northern) Irish Football Associations [5], aimed at protecting children. Nevertheless, the view that football heading *per se* has pathological long-term neuropsychological consequences is based on research that is limited in scope [6-8], focusing primarily on active younger players and ignoring longer term effects [9]. Therefore, still missing is strong evidence that football play, and football heading in particular, are risk factors for dementia [10].

The most convincing reports linking football play with risk of dementia to date were published by Mackay et al. [11] and Russell et al. [12]. Mackay et al. [11] examined the death certificates of 7676 Scottish male former professional footballers (FPFs) and compared their death certificate information with similar information obtained from 23,028 general population controls matched with the players on the basis of sex, age, and degree of social deprivation. They found that FPFs aged 70 years and over were nearly 3.5 times more likely to die from dementia than similarly aged male members of the general population. Russell et al. [12] reanalysed the same data, but with greater focus on records that could reveal incidence of neurogenerative disease as a function of field (i.e., playing) position. They observed that defenders ran the highest risk of neurogenerative disease (HR = 4.98), closely

followed by FPFs who played in a variety of positions (labelled multi position, HR = 4.94) and midfielders (HR = 4.59), while forwards exhibited the second lowest risk of neurogenerative disease (HR = 2.79) across playing positions (only goalkeepers had a lower neurogenerative disease risk; HR = 1.83). Russell et al. [12] also examined neurogenerative disease risk as a function of the FPF's career length, noting that those with the longest playing careers, i.e., greater than 15 years, revealed greatest risk of neurogenerative disease (HR = 5.20). Although no direct evidence was available, the strong suggestion by Russell et al. [12] was that these findings could be attributed to the relative number and severity of head impacts sustained by the FPFs when they headed the ball.

One of the ways to move past circumstantial evidence is to examine dementia-related outcomes (e.g., memory and cognitive ability) in individuals who are at an age where symptoms of dementia are most likely to begin to manifest (i.e., ~ 60 years of age), and who played professionally when younger. FPFs are more likely to have played at a higher intensity level than amateur footballers, therefore having the potential to have accrued the most football-related damage [9]. A study approximating these criteria was published by Vann-Jones, Breakey and Evans [13], who collected remote data on the memory ability of FPFs in Scotland and England. Vann-Jones et al. measured memory with the Test Your Memory (TYM) questionnaire, a self-administered cognitive test proven to be effective for screening individuals with memory problems and dementia [14-17]. Vann-Jones et al. [13] compared TYM scores in their cohort (n=92) to the general population finding no significant difference, therefore concluding that participation in professional football did not confer higher risk of dementia.

In the present study, we set out to expand on the work by Vann-Jones et al. [13] by adding information on heading frequency and football-related head injuries. This was done by carrying out a postal survey directed to FPFs, and asking them to estimate the average

number of match and training headers; and the number of football-related head injuries sustained. A novel and very important feature of our study was that training activity was included [cf. 18-21]. Additionally, participants were asked to complete the TYM test. The objective was to determine whether the heading and football-related head-injury measures predicted the FPFs' TYM-assessed cognitive ability.

Methods

Participants. A total of 208 male FPFs, from two former professional footballer associations, were sent copies of the survey. From this initial cohort, 60 FPFs completed the whole survey and the TYM test. All participants had played professionally for teams in England. The average age of the sample was 67.5 years (SD = 9.5), ranging from 39 to 87 years. On average, participants started their career at 16.8 years old (1.4), played professionally for 15.7 (4.4) years, before retiring aged 32.5 (4.5). The average time between end of career and survey completion in this sample was 35.0 years (9.7). Seven participants had played primarily as goalkeepers, 13 at full-back, eight as centre-halves, three in wide-midfield positions, 11 in central-midfield, 13 at centre-forward, and two at inside-forward. The mean TYM score was 46.4 (5.0), ranging from 21 to 50. Participants provided implied consent to use of data for research by returning the survey and/or the TYM materials. The study was approved by the Faculty of Natural Sciences Psychology Research Ethics Committee.

Materials. A retrospective survey was co-designed *ad hoc* for this study, incorporating input and feedback from FPFs via their professional footballer association committees, as arranged by the association secretaries. The survey consisted of 18 items, each with an aim of obtaining information relating to the FPF's career. The questions asked about career length, main playing positions, the number of training sessions and matches in a season, how often multiple training sessions took place, the estimated number of headers made per match and per training session, as well as reporting how many head injuries had been sustained (see

Supplemental Material). Additionally, the TYM test was used to measure cognitive ability. This test takes approximately five minutes to complete. The TYM test, despite its name, includes a series of (self-administrable) cognitive tasks, aimed at measuring more than just memory. In fact, it includes: general knowledge questions, a calculation task, a word fluency task, a reasoning task, a naming task, a visuospatial task, and finally a delayed recall task. Each of these tasks are scored individually, with the maximum overall score of 50 points. To note, assistance with completing the TYM test is accounted for by adding five points to the total score if no assistance is received; four points for trivial assistance; three for minor assistance; two for moderate assistance; and finally one point for major assistance. As both the survey and TYM were completed entirely remotely, it was not possible to verify the TYM scores with independent clinician evaluations.

Procedure. The secretaries of seven former professional footballer associations located near the authors were contacted by email and invited to participate in the research. It was explained that participation would involve meeting with the researchers to provide feedback on a draft *Career Football Heading Survey*, as well as assisting with the eventual distribution of the completed version of the survey to members. Three associations agreed to take part in survey development. We then emailed a survey draft to them asking for suggestions on how to improve it, and met in person with some members. At the end of this process, we had a relatively short co-designed document aimed at capturing information about the FPFs' careers.

Prospective participants were approached via their former professional footballer associations for data collection. All participants received a package through the post containing a cover letter, the football heading and head injury survey, the TYM test and an addressed and franked envelope to be used to return the materials free of charge (see *Materials*). The cover letter addressed to participants explained who we (the researchers)

were and their Former Professional Footballer Association's full support for our research. (One Former Professional Footballer Association provided a separate letter to be included in the pack received by their members that expressed the extent of their support for this research.) After explaining how participant anonymity would be maintained, the letter also explained how participants should return the completed survey and TYM using the addressed and franked (i.e. prepaid) envelope provided. Additionally, participants were encouraged to take their time completing the football heading survey, so as to provide a full and accurate account. Participants were informed that the TYM test should take approximately five minutes to complete, and that it should be self-administered, although the test does allow external help to be recorded. Participants were made aware that returning the materials would be interpreted as informed consent, but that they had the option of withdrawing their data by contacting the researcher at any subsequent time.

Design and analysis. A cross-sectional design was applied. The data were analysed in two steps. First, Bayesian linear regression hypotheses were tested, and second, further confirmation of supported hypotheses was provided by traditional (frequentist) linear and logistic regressions. Analyses were carried out using JASP (0.13.1; https://jasp-stats.org/). These two analytical techniques were applied to provide converging evidence in support of our hypotheses.

Before describing the Bayesian and traditional approaches applied, the predictor variables will be defined: total estimated number of career headers (henceforth, headers) and the total estimated number of career football head injuries (henceforth, injuries). The number of headers was determined by adding the total number of estimated career *match* headers (estimated headers per match multiplied by estimated matches per season, and career length) to total estimated career *training* headers (estimated headers per training session multiplied by the number of training sessions per week, the number of training weeks per season, and

the length (in years) of the FPFs' careers). Analogously, the number of estimated head injuries per season (match and training sessions) were multiplied by career length.

Bayesian regression analyses were employed to test the following hypotheses: 1) that headers affected overall cognition, as measured by the TYM score and 2) that participants' football-related head injuries affected their TYM score. For all analyses, the model prior was set to Uniform (i.e., all models are a-priori equally likely), and the prior on parameters was set to the default Jeffreys-Zellner-Siow (JZS) prior. To address potential issues with non-normally distributed residuals in the regressions, Markov-Monte Carlo chain sampling was applied to each analysis 1,000 times. In each test, the outcome of the regression was the TYM score, and the null model included age and number of non-football-related head injuries.

The *traditional linear regression analysis* employed the TYM score as the outcome variable (or DV), while age and non-football-related head injuries were employed as covariates (cf. the null model in the Bayesian regressions above), and whichever predictor that was supported in the Bayesian tests. The same approach was applied to the logistic analysis checks (method set as Enter), but a binary TYM score classification was used as the outcome variable (DV). People were classified as not having or having cognitive problems according to the age-adjusted TYM cut-off scores: cognitive problems if scoring below 47 in people 18-69 years of age; cognitive problems if scoring below 46 in people between 70 and 79; and cognitive problems if scoring below 45 in people who are 80 or older. In these analyses, the α level was set to 0.05.

Results

Table 1 reports sample size (N), means, standard deviations (SD), median and lowest/highest score (min-max) for all variables in the sample.

Table 1: Descriptive statistics

	N	Mean	SD
TYM score	60	46.367	4.991
Age	60	67.467	9.475
Estimated career head injuries	60	63.650	146.782
Estimated career headers	60	51766.213	61290.326

Bayesian linear regression analyses. To test the hypothesis that headers affected the TYM score, the null model, including age and non-football head injuries, was compared with the model including headers. This analysis yielded substantial evidence that headers affected the TYM score, $BF_M = 114.505$. BF_M indicates how much the odds of a specific model change after observing the data. After observing the data in this case, the odds in favour of the model with headers increased by a factor of 114.505. The coefficient of the headers model had a posterior mean of -0.00003189, a SD of 0.00009375, and lower/higher 95% credible intervals of -0.00005225 and -0.00001555, respectively. These values indicate that 100,000 headers would reduce the TYM score on average by 3.2 points, with upper/lower limits of 5.3 and 1.6 point reductions, respectively. In contrast, the regression comparing the model with injuries ($BF_M = 0.464$) to the null model with age and non-football head injuries ($BF_M = 2.153$) favoured the null model.

Traditional linear regression analysis. To provide further checks of the hypothesis linking headers to a decline in TYM score, a linear regression analysis with headers as a predictor was applied. The model fit with headers was significant, $F(3,56) = 5.332$, $p = 0.003$, as was the standardized regression coefficient, $\beta = -0.469$, $p<0.001$. Figure 1 depicts the negative relationship between headers and the TYM score.

Traditional logistic regression analysis. A logistic regression analysis with headers as the predictor, and a binary TYM classification (1: absence of cognitive problems; 0: presence of cognitive problems) was carried out too. The model fit with headers was significant, p = 0.021. The Akaike information criterion (AIC) and the Bayesian information criterion (BIC) scores, reflecting model fit, were reduced from 73.9 to 70.6, and 80.2 to 79.0, respectively, indicating better fit when headers were included in the model. The Nagelkerke pseudo R^2 was 0.125 for the null model and the headers model combined, and 0.116 when the null model was removed; these results tentatively mean that about 12% of variance in the TYM binary classification was explained by headers. The standardized coefficient for headers was -0.697, with a p value of 0.035.

(Insert Figure 1 around here)

Discussion

In this study, we set out to establish whether cognitive ability in FPFs, as measured by TYM score, was affected by estimates of heading frequency and head injuries. This approach is original in that we obtained an estimate of heading frequency and then examined its association with cognitive status in FPFs, rather than evaluating this association in younger, current players, who are far less likely to present with signs of neurodegeneration [10]. Moreover, to our knowledge, we are the first also to include training data. Our findings, consistent when tested with both Bayesian and traditional statistical analyses, support a link between estimated heading frequency and overall cognitive ability in this cohort: more headers corresponded to a lower point score on the TYM test, and to increased likelihood of being classified as having cognitive problems. In contrast, our findings do not support associations between the TYM score and reported football-related head injuries. As far as we are aware, this is the first study to demonstrate a direct link between heading frequency and cognitive impairment in retired professional football players.

The Bayesian analysis estimated that 100,000 career headers would correspond to a mean reduction in TYM score of 3.2 points on average, with 95% credible intervals between 1.6 and 5.3 points. As per Table 1, the average number of estimated career headers of the sample was *circa* 52,000, but there was high variability (SD = 61,290), presumably due to the varying demands of playing positions, e.g., goalkeepers will head the ball exceptionally rarely, whereas centre-forwards and centre-backs will head the ball much more often. These data help in quantifying the impact that frequent ball heading in football play might have on overall cognitive health, but further estimates, especially taken in countries where heading rates might be different due to the predominance of different styles of play, as well as weather, which would have affected weight of the ball due to water absorption, are needed. In our sample, 16 of 60 participants (27%; 10 of 33 in the 18-69 age range: 30%; 3 of 21 in the 70-79 age range: 14%; and 3/6 in the 70+ age range: 50%) scored below the age-adjusted TYM cut-off scores, suggesting possible mild cognitive impairment (MCI) in these individuals. This percentage is roughly 2.5 times as high as that reported by Vann-Jones et al. (11%), who concluded their cohort of FPFs did not significantly differ from the general population [13]. It is worth noting that the mean age in our study was the same as reported by Vann-Jones et al. [13] (67.5), although we had more age variability (SD: 9.5 > 7.0), and on average our players had longer careers (16.8 > 13.8). It may be that the reported association between estimated career heading frequency and overall cognition observed here would be less pronounced in a cohort with fewer possible MCI cases. As a counterpoint, our study also provides circumstantial evidence that FPFs may be at higher overall risk of MCI compared with the general population. Both of these points require further investigation.

Rather than interpreting our findings as evidence of a link between heading the ball and cognitive impairment, it is possible to imagine that heading frequency correlates with TYM score because people with cognitive problems overestimate their heading frequency. While

this is a possibility, we also examined whether main career playing position was associated with estimated career total in headers. We subdivided participants in goalkeepers (n=7; i.e., least likely to head the ball), wide players (e.g., wide midfielders; n=19; medium likelihood to head the ball), and central players (e.g., centre-forwards, centre-midfielders; n=34; i.e., most likely to head the ball), and calculated mean career headers frequencies. Indeed, goalkeepers reported the least career headers of all (4935.6, SD=8430.9 – N.B. some goalkeepers reported heading in training), wide players reported the second highest value for career headers (45201.3, SD=50914.2), and central players reported the highest value overall (65076.5, SD=67946.6). As main career playing position is less likely to be misremembered than heading frequency, these results provide some corroboration to the idea that the estimates of heading frequency obtained from the players were, at least in part, an adequate reflection of actual heading rates.

Limitations. An obvious limitation of our study is that all measures, particularly heading frequencies, were self-reported. Subjective measures are susceptible to bias and distortions, which may become more pronounced in the case of reduced intellectual capacity. However, two points ought to be made here. First, it has been reported [22] that, while self-reported headers (in younger, active players) tend to be overestimated, there is a linear relationship between estimates and actual observations. Second, and most importantly, obtaining career-long objective measurements of heading frequency is practically impossible, as it would require each header performed by each player during each match and training session to be recorded for the duration of the player's entire football career. In addition, these measurements would need to be obtained across many players. Therefore, while we acknowledge this limitation, we believe that our approach maintains validity.

Another limitation to note is that we did not capture good estimates of the number of headers performed during pre-season training and matches (due to the inconsistent variety of

response types and measures provided), but obtained only reliable in-season estimates. While we presume there may be a positive correlation between these, future research should add this further dimension.

Finally, it is possible that there was a self-selection bias according to which mainly/only FPFs with perceived cognitive problems took part in the study out of concern for their own ability. While this is possible, two points ought to be made: 1) In our recruitment drive, we emphasised the survey on football heading and not the cognitive screening; this choice was motivated, amongst other things, by observing a certain reluctance in the FPFs we had contacted initially in engaging in research that was overtly about dementia and football (anecdotally, one FPF chose not to participate in our study, but received a dementia diagnosis around the same time); 2) and second, even if some self-selection bias had occurred, we hold that our data still are valuable as they track the relationship between football heading and cognitive impairment across a range of cognitive abilities.

Conclusions. With a postal survey and analysis of data from sixty FPFs who played in England over their careers, we have provided evidence, to our best knowledge for the first time, with retired professional players, of a link between heading the ball and cognition. FPFs who reported more headers tended to score more poorly in the TYM test, which measures overall cognitive ability. These results add to a growing literature [11, 12] suggesting headers may lead to long term consequences for cognitive health, and thus may contribute to influencing future policies restricting headers in training beyond the United Kingdom. Future research should also confirm these findings with a case-control study of older, FPFs, which, in addition to heading estimates, also obtained complete neuropsychological assessments alongside biomarker data.

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Figure 1

Plot of the TYM score (Y-axis) and the estimated total career headers (X-axis).