

Professional Football Heading in Training Guidance

July 2021



1. Background

In 2020, The FA released guidance for youth football on heading in training. This guidance followed the release of the FIELD Study results in October 2019 which concluded that, 'mortality from neurodegenerative disease was higher and prescriptions of dementia-related medications were more common among former professional soccer players than among controls from the Scottish population. The risk of death from neurodegenerative disease varied according to disease subtype. Mortality from other common diseases was lower among former soccer players than among controls. These data need to be confirmed in prospective matched-cohort studies.' (Russell, E.R., Stewart, K., Mackay, D.F., et al, 2019).

The FA's Research Taskforce is now seeking to support further research to understand whether there are any causal links between aspects of playing football and increased risk of developing a neurodegenerative disease in later life. To date, research has focused on two areas: a) concussions caused by collisions b) whether repeated non-concussive events, in particular heading, can cause injury. The domestic football partners in England have engaged with this research to understand the issue and explore mitigating risks for today's players and future generations.

Whilst research continues, with players' welfare paramount it is right that measures are put in place that may mitigate the risk of injury if it is proven that there is a causal link between heading and neurodegenerative disease. In December 2020 the Professional Football Negotiating and Consultative Committee (PFNCC) Health and Safety Sub-Committee was tasked with developing evidence based 'Heading in Training Guidance' for the professional game. The PFNCC sub-committee has formed a Heading Working Group which incorporates medical and policy representatives from The FA, Premier League, EFL, FA Women's Super League (WSL), League Managers' Association (LMA) and Professional Footballers' Association (PFA). Working collaboratively, this group has sought to further understand heading in football with a view to creating guidance that can be implemented throughout both men's and women's professional football.

This paper provides detail of the approach that has been taken, the guidance, and perhaps most importantly areas that require further exploration. To date the studies have concentrated on establishing the frequency of and force involved in heading a football. There is not, as yet, any medical evidence that the frequency or force of heading is likely to result in neurodegenerative disease or to increase the risk. There is still much work to be done in this field.

The Professional Football Heading in Training Guidance is one component of the Premier League's Head Injuries Action Plan.

2. Objectives and Development Process

The football partners had two objectives for the initial work which was to be concluded by June 2021. These objectives were to:

- a. Use research to understand the forces involved in heading, and use this information to inform practical heading guidelines for training in adult professional football; and
- b. Collect data that quantifies heading volume in both training and match play as a primer for future work to support further research into any associations between heading activity and longer-term brain health, and to establish appropriate measures to mitigate the risk factors identified.

To ensure that these guidelines were evidence-based, the PFNCC Heading Working Group commissioned research to be carried out between March and May 2021. All commissioned work was funded by the Premier League but delivered independently by the respective organisations. This research sought to identify what evidence exists in relation to heading in football and add to this knowledge with two preliminary studies. Finally, historical data that quantified heading in matches was gathered. The details of these research components are summarised in section 3.

To complement the research studies consultation with players and managers was facilitated by the PFA and LMA to ensure that recommendations can be implemented.

3. Research

3.1. The Quantification of Heading in Football: A Systematic Review and Evidence Synthesis. University of Central Lancashire

3.1.1. Study Summary

This project encompassed a formal systematic review of existing academic publications researching the quantification of heading in football. The University of Central Lancashire's Football Performance Hub was commissioned by the Premier League to plan and operate the review. The project ran from April 2021 to June 2021, incorporating protocol development through to report submission.

The primary aim of the project was to synthesise the existing evidence on the measurement of acceleration, force, nature, and frequency of heading in adult football players during training and match-play. A secondary purpose of the study was to examine the role of moderating variables on the quantification of head acceleration during heading, including: technical categorisation (exposure type, location of contact and timing), ball design, playing position, and gender in training and competitive match play.

3.1.2. Key Findings

Following a search that identified 9,981 possible matches, a short-list of 21 peer-reviewed articles were included that met the protocol criteria. A meta-analysis was not performed due to the variability in study methodology and reporting. Several studies investigated the quantification of heading in football. It was evident, however, that the available literature reporting on acceleration, force, nature and frequency data of heading was inconsistent and severely limited by study design, standard of play, populations, technology and consideration of confounding or moderating variables which may impact vital outcome measures. No studies in the review investigated acceleration or force responses within an elite player population.

The review found that there is a need for implementation of valid and reliable technology to accurately measure the kinematics of heading in applied football environments. This in turn will help inform future studies to better understand the potential relationships that exist between force transmission, injury, and causation.

The review highlighted specific areas that require further research and investigation:

- a) There is a lack of force transmission data from competitive matches, particularly at an elite level. This is compounded by the observation that laboratory-based studies tend to underestimate the forces transmitted by heading when compared to training data. It is reasonable to postulate that the heading forces transmitted during games are higher than in training, therefore there may be a significant disparity between the forces reported in the literature and the true values transmitted in elite football;
- b) A proportion of studies that compared heading acceleration forces between genders reported lower values for males than females. One contributing factor to this may be the influence of neck musculature on force transmission during heading. Exploratory research suggests that increased neck muscle strength may act to reduce the magnitude of head acceleration measured when heading a ball. Hence it could be hypothesised that groups of players with a lower neck muscle

strength, which may include young and women footballers, may experience higher acceleration forces when heading a ball; and

- c) Whilst it is evident that the head acceleration imparted by heading is lower when balls travel at a lower velocity, the effect of ball inflation pressure and the mechanical properties of the ball is unclear. These influences require further research and evaluation.

3.2. Heading in Matches Data: Opta data from Stats Perform

Opta data was interrogated to quantify heading in matches across the Premier League, EFL and WSL. The average number of headers by position were recorded for each competition across multiple seasons. Where possible data from season 2013/14 to 2020/21 was used, however, in the case of EFL League One, EFL League Two, Premier League Under 18s and Under 23s only more recent data sets were available.

Table 1 shows the average number of headers by position and league. The data suggests that the number of headers per match increases from the Premier League through to EFL League Two. Under 23s, Under 18s and WSL matches have fewer headers per match than the Premier League. Across the Premier League and EFL competitions defenders carry out more headers on average than forwards, who in turn carry out more headers than midfielders. In contrast, midfielders complete more headers than forwards in the WSL.

Table 1 – Average number of headers per match by position and competition

	Premier League 2013/14 - 2020/21	EFL Champ. 2013/14 - 2020/21	EFL League One 2019/20 - 2020/21	EFL League Two 2019/20 - 2020/21	Premier League U23s 2016/17 - 2020/21	Premier League U18s 2019/20 - 2020/21	WSL 2013/14 - 2020/21
Defenders	7.02	9.28	9.08	10.10	5.3	4.16	5.74
Midfielders	3.65	4.35	4.39	5.13	2.56	2.50	4.20
Forwards	4.93	6.17	6.06	6.04	2.90	2.73	3.22

3.3. Headed Ball Analysis: Second Spectrum

3.3.1. Study Summary

Second Spectrum’s optical tracking systems are installed at all 20 Premier League grounds and provide the precise location of every player and the ball 25 times per second during matches. This movement data served as the foundation for analysing the velocity of the ball and the force transferred for each headed ball.

Force was calculated through an algorithmic process with estimative assumptions on ball mass and duration of time over which force is applied (Iga et al, 2013).

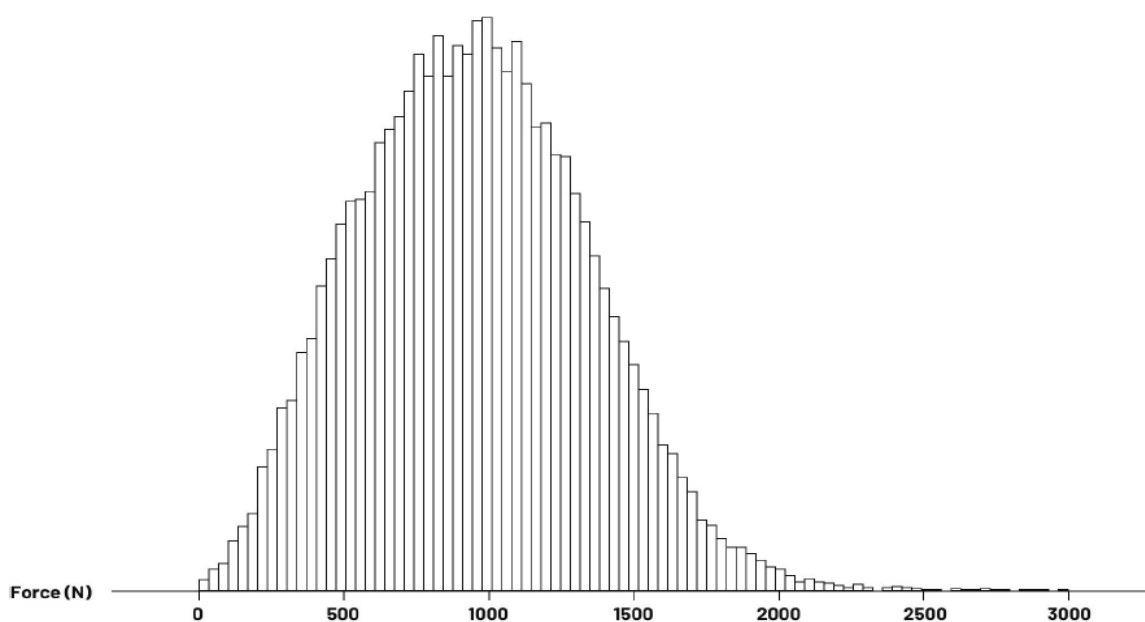
Second Spectrum also connected the headed ball force data to relevant tactical information from game play, such as the identity and position of each player, and the events occurring prior to a headed ball.

Second Spectrum’s investigation examined every contact between ball and head whether or not it was an intentional action. In contrast, Opta data uses a methodology which only includes intentional actions.

3.3.2. Headed Ball Force Distribution

The total number of headed balls that could be evaluated was 35,590 across 380 matches. The average force per headed ball was 950 Newtons (N), with the highest force recorded as 2,992 N. Figure 1 shows the force distribution curve.

Figure 1 – Distribution of headed balls by force.



3.3.3. Headed Ball Force by Player and Position

By identifying the identity of each player heading a ball, Second Spectrum were able to evaluate force per player and force per position. On average central defenders carried out more headers per match and accumulated the highest force loading. Quantification and force data by position can be seen in table 2.

Table 2 – A comparison of the quantity of headers and heading forces by position

Headed Ball Force by Player and Position				
Position	Total headed balls	Average force (N) per headed ball	Average headed balls (#) per player per 90	Average total force (N) per player per 90
Central Defenders	13450	1060	7.5	7928
Full-backs	5633	963	4.5	4290
Forwards	5493	816	4.5	3657
Midfielders	10950	870	3.6	3172
Goalkeepers	64	932	0.2	142

Whilst the average number of headers can be seen in table 2, on five occasions during season 2019/20 players recorded between 20 and 28 headers within a Premier League match.

3.3.4. Headed Ball Force by Preceding Event

In addition to evaluating the force on each headed ball, Second Spectrum included additional information in the analysis with the aim of providing context of the tactical game situations when high and low force headed balls tend to occur. Table 3 shows the quantity of headers based on the preceding event, and which actions frequently preceded high force headers.

Table 3 – A comparison of the quantity of headers and heading forces by preceding event

Preceding Event	Total headed balls	Average force (N) per headed ball
Corner	2256	1146
Cross	3105	1118
Goal kick	2421	1077
Free kick	2554	1045
Pass	19124	919
Throw in	2248	822
Shot	69	812
Clearance	2088	812
Deflection	1725	720

3.4. A Description of Head Impact Accelerations in Elite Football Training: Sport and Wellbeing Analytics Limited (SWA)

3.4.1. Study Summary

This project involved the capture and quantification of impact exposure attributable to heading activities in training sessions within a cohort of elite male and female footballers. The 'PROTECHT' mouthguard system operated by Sport and Wellbeing Analytics Limited (SWA) was utilised for the study which was conducted at Liverpool FC and Manchester City FC, with Under 23 and Under 18 players. The study also incorporated players from Manchester City Women's FC.

The major objectives of this study were to:

- a) Assess the heading exposure observed in training by quantifying both the kinematics of impacts attributable to heading, and the total number of headers completed by each player in each training session;
- b) Assess any differences in trends of heading impact with variations of gender, age, playing position and impact type; and
- c) Assess the effect of the differing technical and tactical aspects of football training on the kinematic pattern and number of headers observed during training sessions.

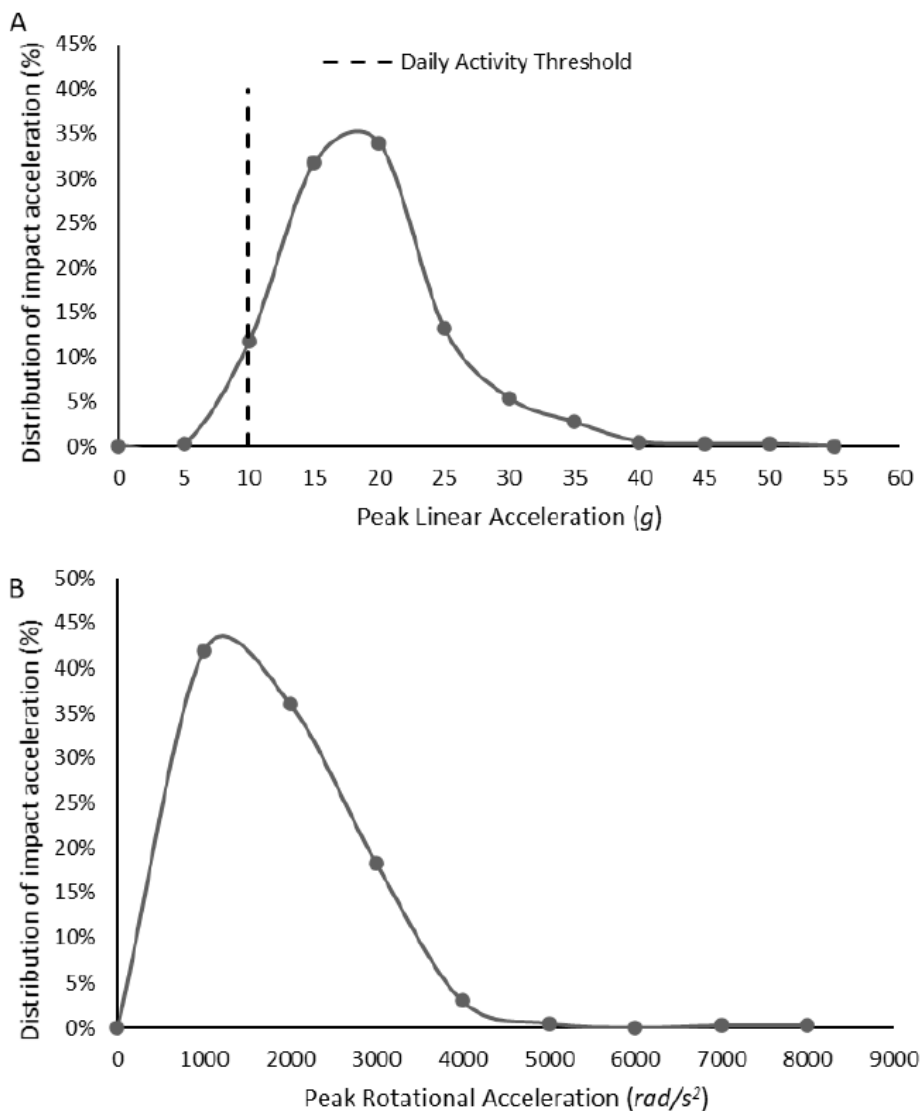
3.4.2. Key Findings

The key observations generated by this study were:

- a) Generally, the loads experienced by players heading the ball were lower than typical contact events reported in other sports using the same wearable technology such as rugby union or boxing;
- b) Different types of header lead to varying patterns of head acceleration during training. In simple terms, not all headers transmit equal force so that quantifying heading purely by recording the number of headers per session will not result in an accurate and reproducible assessment of activity;
- c) Headers completed following a long ball and cross (~35-45m distance) resulted in the highest loads on a player's head, which were of a similar magnitude to the average values reported for other sports such as rugby union and boxing;
- d) The highest linear acceleration forces from heading were produced by the U18 male age groups;

- e) The impact distribution recorded in the study show that 96% of impacts occurred within 0-40 g range for linear acceleration and up to 4,000 rad/s² for rotational acceleration respectively;
- f) Overall mean values for linear and rotational acceleration were 16.8 ± 6.6 g and 1,373 ± 856 rad/s² respectively. Daily activity (running, walking and jumping) values are outlined in the literature to occur below 10 g (Ng et al, 2006). The distribution curves for both linear and rotational acceleration can be seen in figure 2. In comparison to these figures, linear and rotational mean values of 26.6 g and 2,000 rad/s² have been observed in other sports; and
- g) Though a header has the potential of exposing a player to a 70 g and 8,000 rad/s² impact, the probability of these events is extremely low (0.2%). In other sports, linear and rotational peak values reaching 150 to 200 g and 15,000 rad/s² have been reported.

Figure 2 – Distribution of impact accelerations from heading for peak linear acceleration (graph A) and peak rotational acceleration (graph B)



4. Professional Football Heading in Training Guidelines

Based on the evidence to date, these guidelines have been produced for use in the men's and women's professional game. It is acknowledged there is a significant amount of further research required which will inform further iterations of this guidance. It should be noted that of the headers measured by SWA the mean peak linear acceleration was 16.8 ± 6.6 g, with 96% of headers falling in the 0-40 g range. This compares to daily activities such as walking, running and jumping which record accelerations of up to 10 g. These guidelines therefore focus on managing cumulative loading and reducing single heading events that produce outlier results for peak linear and/or rotational acceleration.

4.1. Risk Factors

Research has identified that the following factors may influence the force and nature of heading in the professional game.

4.1.1. Age and gender

There is a lack of definitive evidence to quantify the influence of age and gender on the transmission of forces attributable to heading in professional football. However, there is early but limited evidence to suggest that poor neck muscle strength may be one contributing factor to a higher force transmission when heading a ball, and younger players are likely to have a lower level of muscle strength than adult players. This rationale may also apply when comparing adult female players to male players of comparable age and professional standard.

4.1.2. Position

The Opta data demonstrates that central defenders have on average a higher number of headers per match compared to other positions. This is supported by the Second Spectrum analysis which showed that the players with the greatest number of headers in individual matches were defenders. On average central defenders carried out 7.5 headers per match compared to full backs and forwards, both 4.5 headers per match and midfielders, 3.6 headers per match.

4.1.3. Quantity of headers based on playing competition

Opta data from 2013 to 2021 suggests that the average number of headers per match for players in EFL League Two is higher than those playing in the Premier League. In contrast WSL, Premier League Under 18 and Under 23 matches recorded less headers per game.

4.1.4. Type of header by preceding event

Both the SWA and Second Spectrum preliminary studies indicated that headers that occurred immediately following a cross or long-ball had greater acceleration/force than headers occurring after chipped or thrown passes. In addition, headers occurring when a player had taken more than three steps or had dived resulted in higher acceleration than when taking fewer than three steps, standing, jumping or moving backwards.

4.2. A Player Centric Approach

Given the factors listed above it is clear that all headers are not equal. Further research is required to increase understanding and inform future iterations of this guidance so that it reflects differences in position, age and sex. To aid the development of player centric guidance it is recommended that clubs develop player profiles that consider the following:

- Gender
- Age
- Playing position
- The number of headers per match
- The nature of these headers

Club staff should work with players following each match to ensure that they have adequate time to recover from their heading exposure after a competitive match. It is advised that a heading recovery element is factored into the structured post-match recovery that professional teams observe following matches.

During the training week, clubs are encouraged to prepare players for the match demands of heading, more specifically optimising training practice to encourage good heading technique alongside formal conditioning work to develop neck and torso strength. Early but limited research suggests that there may be a relationship between neck strength and head acceleration, and this will be investigated further during season 2021/22. A strength and conditioning expert panel has been convened in order to produce a heading strength guidance document for professional clubs to be published no later than 1 September 2021.

Training should be planned to mitigate the quantity and nature of heading practice during the training week. Whilst research is in its infancy there is some limited evidence to suggest the following may be considered:

Wherever possible limit the number of headers carried out when a player takes more than three steps and runs onto a ball or dives for a ball.

Practice technique using thrown passes as this leads to lower peak accelerations.

4.3. Limiting Heading in Training

Based on the findings of preliminary studies a recommended maximum number of 10 higher force headers per training week has been calculated. This recommendation applies to headers categorised as resulting in the highest forces, namely:

- a) Headers following a long pass (those in excess of 35m), for example, returning a goal kick.
- b) Headers from crosses, corners and free kicks.

The recommended limit has been calculated using the maximum mean number of headers occurring for any position group across competitions as set out in table one. The recommendation follows the principle of preparing players adequately for match-play. This is an initial recommendation designed to protect player welfare and will be reviewed regularly.

Preliminary data recorded mean linear acceleration as 16.8 g, compared to daily activities such as running and jumping that produce linear acceleration of around 10 g. As such the focus of this guidance is on higher force headers. However, it is important that coaching staff and players consider whether lower force headers are required in training to suitably prepare a player for match play. Moderation of such headers is recommended.

As further research is undertaken this guidance will be reviewed and updated to reflect increased understanding.

4.4. Symptoms of Head Trauma

Players who develop any symptoms of head trauma during heading practice including but not limited to headache, dizziness, nausea/vomiting should be removed from training immediately. Players returning to training following a concussion should not take part in any part of training that involves heading activity until all other steps in the graded return to training in an enhanced care setting have been satisfied as per the FA Head Injury Guidelines (The FA's Concussion Guidelines | The Boot Room).

All professional clubs are mandated to record injuries as part of the injury and illness audit. It is expected that clubs will record any symptoms associated with head trauma on a player's medical record.

5. Monitoring of Guidelines

During training sessions it is essential that club staff monitor each player's heading practice in real time, ensuring that the quantity of headers resulting in higher accelerations is minimised and is commensurate with each player's individualised match play heading profile.

Players are encouraged to familiarise themselves with these guidelines and limit any heading practice taking place outside of club organised sessions.

6. Further Research and Work Required

These guidelines have been developed using a precautionary approach to protect player welfare even where scientific evidence is limited. The evidence gathering commissioned by the PFNCC Heading Working Group has increased understanding of the forces involved in heading, whilst also identifying areas that require further exploration. These areas are summarised below.

6.1. Auditing of heading practice

Anecdotal evidence from Premier League players and managers suggests that heading in training has reduced as tactics and amendments to the laws of the game have changed the way in which professional football is played. A robust audit of current heading practice in both training and match play is required across the Premier League, EFL and WSL to enable future development of these guidelines.

6.2. Player demographics

Limited data recorded to date suggests that women and younger players produce greater peak acceleration than male players. Further longitudinal research incorporating a greater sample size of women and players from age 16 to late career is essential to increase understanding of gender and age differences and enable specific guidelines to be developed.

The evidence reviewed suggested that there is a lack of studies that have examined whether a player's ethnicity has any impact on the accelerations recorded when heading. Future research should ensure that a diverse cohort of participants are included to enable exploration.

6.3. Field-based research

The systematic evidence review identified that studies carried out in laboratory conditions produced accelerations that were significantly lower than in real world scenarios. It can be hypothesised that this effect may also be seen when comparing training and match play. To understand the real-world effect of heading, research is required that measures heading during match play.

By utilising wearable technology in match-play (subject to approval), research will be able to validate the results of the preliminary Second Spectrum study and further understanding of the range of forces experienced in real-world situations.

6.4. Measurement of elite performers

The preliminary investigation carried out by SWA was one of very few studies that used elite participants and was limited to players associated with Premier League and WSL clubs. Further exploration with a greater sample size of elite players from across the Premier League, EFL and WSL is required to further understanding of heading in the professional game.

6.5. Standardisation of measurement

The preliminary studies carried out on behalf of the PFNCC produced results using different measurements. G-force and radian per second squared were used by SWA and Newtons within Second Spectrum's study. This is reflective of the broader systematic evidence review which identified that studies using different methodologies and measurements made comparisons difficult. As such future research carried out on behalf of the PFNCC should use consistent measurement to aid understanding globally.

6.6. Ball design

Whilst limited research has explored the effect of the football's properties on acceleration, the impact of a ball's inflation or mechanical properties remains unclear. Further studies need to examine these factors in more depth.

6.7. Neck and shoulder strength and conditioning

The potential relationship between neck and shoulder strength and acceleration was identified in the systematic evidence review. Whilst further research is required in this area, clubs are encouraged to ensure that conditioning overseen by suitably qualified professionals is maintained to ensure that neck and shoulder strength is optimised appropriately. To support this a working group comprising of sports science experts from football and other sports is required to develop specific advice and guidance for staff and players throughout the professional game.

6.8. Managers and coaches' consultation

These guidelines have identified heading activities that involve higher linear and rotational acceleration. Further consultation is required with managers and coaches to develop safe and effective practice that incorporate mitigations into coaching activities to be shared with club staff working across professional football.

7. Review Date

Further research summarised in section six will need to be initiated during season 2021/22. These guidelines will be kept under review to allow for immediate mitigation in the event that this research identifies risks not currently examined.

A formal review will take place by the PFNCC in June 2022 to consider any new evidence resulting from this research or that occurring globally and to incorporate best practice developed by working groups.

8. References

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