HEADERS AND CONCUSSIONS IN ELITE FOOTBALL

A Pilot Project

AUGUST 31, 2022

Executive summary

The purposes of this project were (1) to determine the exposure to headers in elite men's and women's football, and to describe the effects of the headers on ocular markers, (2) to observe the occurrence of concussions in elite men's and women's football training and matches, and to describe the effects of concussion on ocular markers, and (3) to determine the reliability of players' self-reporting the number of headers they make during a session.

We observed the exposure to headers over three days of women's and men's elite football training. Sixteen elite academy female and 15 professional male footballers took part in the training sessions, which consisted of 4 training sessions, 2 per day, followed by a match. To determine the heading exposure, each session was filmed, and the number of headers each player made was noted, retrospectively. The players also wore an impact tracker, during all training and match sessions, to measure the G-force of the headers. Any suspected concussions were identified by a side-line spotter and assessed by medical staff, present at every training and match session. Ocular-markers were assessed via the BioEye EyeCon device (Bioeye.com) at the start and end of the three days, and the results were compared to determine if there were any changes. After each session the players were asked to recall how many headers they executed during the session, and this number was compared to the number of headers observed in the video footage, to assess the reliability of players' self-reporting.

Female players made an average of 11 headers per player per session. Ninety percent of the headers were below 10G, and none were above 80G. Male players made an average of 3 headers per player per session, with 74% of the headers recording a G-force above 10G and 3% above 80G. There were no significant changes observed post-session in the ocular markers of the players, and no concussions were observed. Neither the women's nor men's football cohort were able to accurately self-report the number of headers they made in every session.

Observational longitudinal (over at least one season) studies should be designed and conducted across different levels of play, in both women and men's football. These studies are a prerequisite before the development of any evidence-based measures aiming to prevent or mitigate the potential risks associated with headers and concussions in elite football.

1. BACKGROUND

Research has indicated a potential causal link between repetitive head impacts and chronic traumatic encephalopathy, a neurodegenerative disease.[1] As such, there are concerns over the risk of cognitive decline and neurodegenerative diseases associated with heading and concussion in professional footballers. In elite men's and women's football, not enough is known regarding the exposure to repetitive head impacts (i.e., headers, concussion) or their effect on cognitive function. This information is crucial to allow stakeholders to make informed decisions, and intervene where necessary (e.g., prevention, risk mitigation), in order to improve players' safety.

Research across 5 top men's European leagues has found that defenders made approximately 6 headers per match, and midfielders and forwards 4 per match.[2] In elite women's football, across positions, players make an average of 4 headers per player per match.[3 4] In both women's and men's elite football, little is known about the exposure to headers in training.[5] It is important to quantify the exposure to headers in matches and training, to allow coaches to simultaneously prepare players for match demands, while limiting their exposure to injury in training. It may also be necessary to quantify the exposure to headers objectively, through for example video analysis, as subjective self-reported measures have been shown to be unreliable.[6 7]

Along with quantifying the exposure to heading in training and matches, it is also important to identify the force associated with heading in football. The force gives an indication of the impact a header had on a player's brain. Studies in youth football, and in the laboratory, found the force of headers ranged between 4 and 50G,[5] well below the threshold of 80G associated with a concussive event.[8] It may, therefore, seem that the force associated with a header is not large enough to impair cognitive functioning. However, little is known about the cumulative effect of heading on the brain. In other words, would the 6 headers of 50G a defender may make in a match (a cumulative force of 300G) affect their cognitive functioning.

Measuring markers in the eye as a window to identifying changes in the brain is an emerging area of research.[9 10] The eye can be considered an anatomical extension of the brain, with similarities in their neural and vascular structures, and immune response.[11] Assessing the health and functioning of the eye, and any changes in these assessments that may occur, can, therefore, provide insight into the health and functioning of the brain, and detect whether a person may be suffering from a concussion.[12 13]

2. OBJECTIVES

The primary objective of this project was twofold, namely, to assess the exposure (i.e., number, force) to headers during training and/or matches among elite footballers and to explore the effect of headers on their ocular-markers. A secondary objective of this project was to observe the occurrence of concussions during training and/or matches among elite footballers and to explore the effect of concussions on the players' ocular-markers. A tertiary objective was to determine the reliability of self-reported exposure to heading, compared to video analysis.

3. METHODS

3.1 DESIGN

An observational descriptive study design was used to observe the exposure to headers over three days of women's and men's elite football. The days consisted of 4 sessions over 2 days (2 per day), and 1 match (day 3). Ethical approval was provided by the Medical Ethics Review Committee of the Amsterdam University Medical Centers (W22_016#22.045; Amsterdam, The Netherlands), and the study was conducted in accordance with the Declaration of Helsinki (2013).

3.2 SETTING

In March 2022, Jalkapallon Pelaajayhdistys Ry (JPY; Finland) organised a 3-week training camp in Eerikkilä (Finland) for professional footballers out of contract. The men's section of this project took place in the 2nd week of the training camp. Each training week consisted of 4 training sessions over 2 days (2 per day), and 1 match (figure below). In June 2022, the Israeli Football Players Organisation (IFPO, Israel) replicated such an exercise in collaboration with the Women's Israel Football Association's academy. The women's section took place during the final training week of the season. The training sessions were designed and executed by experienced coaches and no instruction was given to the coaches on the prescription of training. The players were free to warm up individually before each session, and practice after the session.

3.3 POPULATION

The participants consisted of two separate groups, namely female and male elite footballers. Convenience sampling was used to recruit the participants; namely, the female group from players at the Women's Israel Football Association's Academy and the male group from players present at the Jalkapallon Pelaajayhdistys Ry (JPY; Finland) training camp. Only participants who were members of the Israeli Football Players Organisation (IFPO, Israel) or Jalkapallon Pelaajayhdistys ry (JPY, Finland) were included in the study. As the project was a pilot study, a sample size calculation was not performed.

3.4 MEASUREMENTS

3.4.1 Exposure to headers

Each session was filmed by an experienced professional. The footage of the training and match sessions was analysed retrospectively, by an experienced video analyst. The footage was analysed using VLC Media Player (VideoLan Client). The software allows for the control of time during the footage in the form of pausing, rewinding, and watching in slow motion. Each player was assigned a shirt with unique identifiable number, and an ACT Head Impact Tracker (act-tracker.com, Northern Sports Insight and Intelligence Oy), which they wore during each session. The tracker measured any impacts to the head over a force of 10G. Each observed header was noted, and the timestamp of the header, whether the header was intentional, and the shirt number of the player was recorded. After each session, the players were also asked how many headers they thought they made during the session, and their response was recorded. The timestamps of the impacts were aligned to the timestamps of the headers observed in the video footage, and the corresponding G-forces were recorded. Any impact forces not associated with a header were not included in the analyses.

3.4.2 Concussions

Any suspected concussions were identified by a side-line spotter and assessed by medical staff, present at every training and match session. In the event that a suspected concussion was confirmed by the medical staff, video footage of the incident was reviewed to identify the mechanism and cause of the concussion.

3.4.3 Ocular markers

The ocular-markers were assessed via the BioEye EyeCon device (Bioeye.com) at the start and end of the training week. The measurements were conducted by a trained and experienced instructor. The test consists of 4 components to the EyeCon test battery: smooth pursuit (SMP), pupillary light response (PLR), near point convergence (NPC), and horizontal gaze nystagmus (HGN).

3.4.3.1 Smooth Pursuit

The SMP assesses how the eyes respond to the movement of a tracking target. In comparison to healthy individuals, concussed individuals tend to have greater latency in responding to the movement of a tracking target. The norm values for this test are between 200 and 250ms, and an increase of 50ms from the baseline (first) measurement may imply a suspected concussive state.

3.4.3.2 Pupillary light response

The PLR test measures the response of the eye to a light stimulus. The size of each pupil is measured before the stimulus when dilated, and after the stimulus, when totally constricted. The norm size of a dilated pupil is between 4 and 6mm, and an increase of 1.5mm from the baseline (first) measurement may imply a suspected concussive state. An asymmetry in dilated pupil size (difference between left and right) of more than 0.5mm from the baseline (first) measurement may also imply a suspected concussive state. The norm size of a constricted pupil is between 1 and 2mm, and an increase of 1mm from the baseline (first) measurement may imply a suspected concussive state. The PLR test was repeated at the end of the EyeCon test battery.

3.4.3.3 Near Point Convergence

For the NPC test an object is moved towards and away from your face until your eyes lost and regained convergence (saw one image). The norm values for the loss of convergence are 7-9cm and regained convergence is 10-15cm, and an increase of 3mm from the baseline (first) measurement for both lost and regained convergence may imply a suspected concussive state.

3.4.3.4 Horizontal Gaze Nystagmus

The HGN test screens for nystagmus, a condition where the eyes make repetitive, involuntary movements, which result in poor vision and depth perception.

3.5 PROCEDURES

Prior to the training weeks, each player attending the training camp or academy was emailed information about the objectives and procedures of the study by their respective national players union. If interested in the study, each participant gave their electronic consent and completed an electronic survey. The survey, compiled in English (Typeform Professional), consisted of several questions related to age, gender, height, weight, duration of elite football career, studies and work outside of football, and field position. Once completed, the data was saved on a secured server that only the two principal investigators had access to. Each player was assigned a number, and no information regarding the identity of the player was recorded. Players participated voluntarily in the study and did not receive any financial remuneration for their participation. Data was collected in February, March and June 2022.

3.6 ANALYSES

For our primary objective, descriptive statistics (average, maximum and minimum) were used to analyse the players exposure to headers, and the results of the Bio-Eye assessments. For our secondary objective, a repeated measure analysis of variance was used to assess the significance of changes in ocular markers between the concussive and non-concussive players. For our tertiary objective, the interclass correlation coefficient (ICC) was used to determine the reliability of self-reported exposure to heading, compared to video analysis. ICC values were evaluated as follows: “poor” reliability when ICC was lower than 0.50; “moderate” reliability when ICC ranged from 0.50 to 0.75, “good” reliability when ICC ranged between 0.75 and 0.90, and “excellent” when ICC values were above 0.90.[14] IBM SPSS 26 and Microsoft Excel for Microsoft 365 were used to perform the data analyses.

4. RESULTS

4.1 PARTICIPANTS’ CHARACTERISTICS

4.1.1 WOMEN PLAYERS

Sixteen elite academy level women participated in the project (n=16; 2 goalkeepers, 5 defenders, 4 midfielders and 5 forwards). 100% of the footballers were currently studying, and 6% were working outside of football. An overview of the age, height, weight, and playing experience (seasons training in an academy setup) of the players is shown in the table below.

	AVERAGE	MODE	MINIMUM	MAXIMUM
AGE	16 years	16 years	14 years	18 years
HEIGHT	167cm	170cm	158cm	187cm
WEIGHT	59kg	57kg	48kg	84kg
PLAYING EXPERIENCE	6 years	5 years	4 years	10 years

4.1.2 MEN PLAYERS

Fifteen professional male footballers participated in the project (n=15; 1 goalkeeper, 5 defenders, 7 midfielders and 3 forwards). 33% of the footballers were currently studying, and 20% were working outside of football. An overview of the age, height, weight, and playing experience (seasons playing professional football) of the players is shown in the table below.

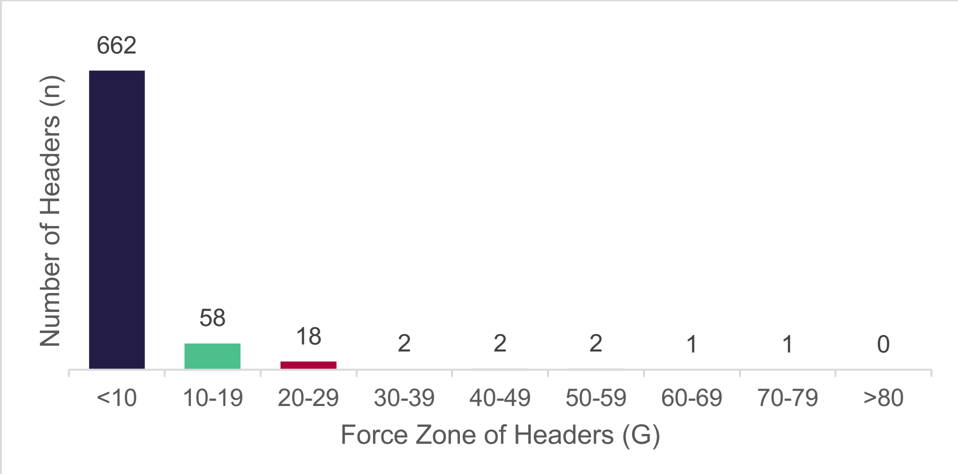
	AVERAGE	MODE	MINIMUM	MAXIMUM
AGE	25 years	22 years	22 years	33 years
HEIGHT	182cm	185cm	169cm	189cm
WEIGHT	78kg	75kg	68kg	90kg
PLAYING EXPERIENCE	4 years	1 year	1 year	13 years

4.2 EXPOSURE TO HEADERS

4.2.1 WOMEN PLAYERS

A total of 746 headers were observed over the 5 training sessions, with an average of 149 headers per session (11 headers per player per session). However, 87% (n=650) of the headers were made in session 1 of day 2. Due to player availability, the match on day 3 was cancelled, and replaced with an extra training session. The table below provides an overview of the average and maximum number and forces of the headers the players made. The force of the headers was not recorded during day 1's sessions. Only 65 out of the 677 headers observed on day 2 & 3 (10%) and had a G force over 10G. The average force of the headers above 10G was 19G. No observed headers were above 80G in any of the sessions. There were two unintentional headers (0.3%), one had a G-Force of less than 10G and the second had a G-Force of 19G. The figure below provides a visual of the number of headers made in each force zone.

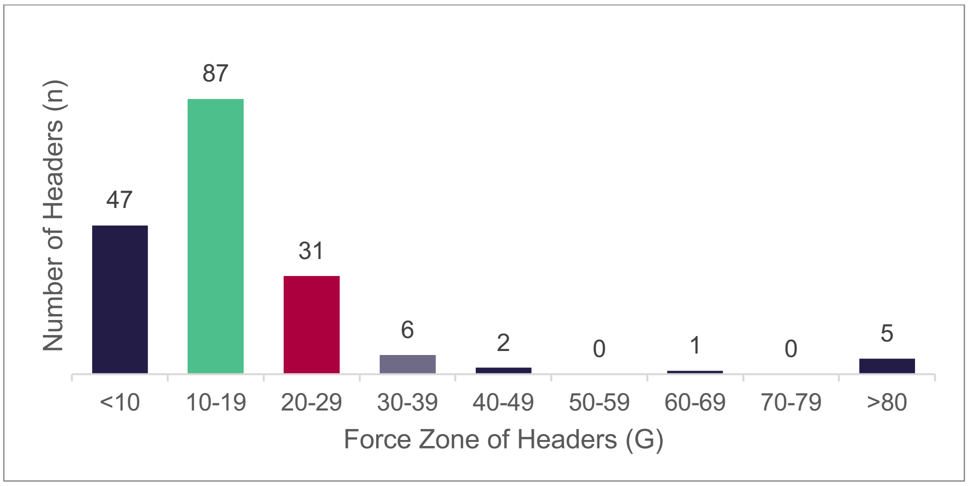
	DAY 1		DAY 2		DAY 3
SESSION	**1**	**2**	**1**	**2**	**1**
MAXIMUM HEADERS OBSERVED BY A SINGLE PLAYER (N)	7	2	72	10	3
AVERAGE HEADERS OBSERVED PER PLAYER (n)	4	<1	46	2	1
AVERAGE SELF-REPORTED HEADERS PER PLAYER (n)	11	1	33	2	1
INTRACLASS CORRELATION (ICC)	0.11	0.73	0.49	0.94	0.88
ICC INTERPRETATION	*Poor*	*Good*	*Moderate*	*Excellent*	*Good*
AVERAGE NUMBER OF HEADERS ABOVE 10G PER PLAYER (n)			4	2	<1
AVERAGE G FORCE OF HEADERS ABOVE 10G (G)			19G	17G	17G
NUMBER OF HEADERS ABOVE 80G (n)			0	0	0
MAXIMUM G FORCE OF A HEADER (G)			71G	27G	22G



4.2.2 MEN PLAYERS

There was a total of 179 headers observed over the 5 sessions, with an average of 35 headers per training session (2 headers per player per session) and 38 headers in the match (3 headers per player). 132 out of the 179 headers had a force over 10G, 72% in training and 82% in matches. The average force of the headers above 10G was 19G in training, and 29G in matches. There were 175 intentional headers, with an average force of 19G, and 4 unintentional headers, with an average force of 77G. 3 headers in training, and 2 in the match had a G-force above 80G.

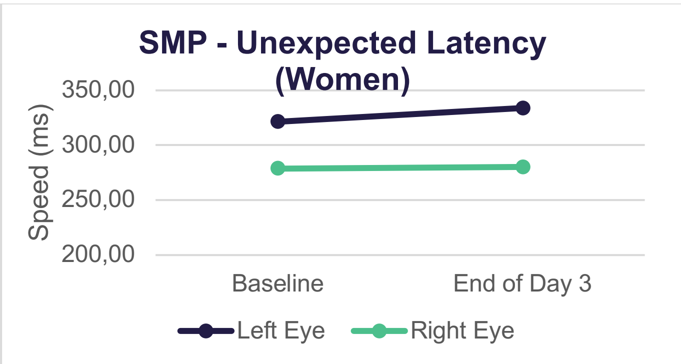
	DAY 1		DAY 2		MATCH
SESSION	**1**	**2**	**1**	**2**	**1**
MAXIMUM HEADERS OBSERVED BY A SINGLE PLAYER (n)	3	16	15	3	5
AVERAGE HEADERS OBSERVED PER PLAYER (n)	<1	8	1	1	3
AVERAGE SELF-REPORTED HEADERS PER PLAYER (n)	1	6	3	2	3
INTRACLASS CORRELATION (ICC)	0.07	0.77	-0.14	0.48	0.28
ICC INTERPRETATION	*Poor*	*Good*	*Poor*	*Poor*	*Poor*
AVERAGE NUMBER OF HEADERS ABOVE 10G PER PLAYER (n)	<1	6	1	<1	2
AVERAGE G FORCE OF HEADERS ABOVE 10G PER PLAYER (G)	11G	17G	34G	32G	27G
NUMBER OF HEADERS ABOVE 80G (n)	0	1	1	1	2
MAXIMUM G FORCE OF A HEADER (G)	13G	101G	111G	94G	137G

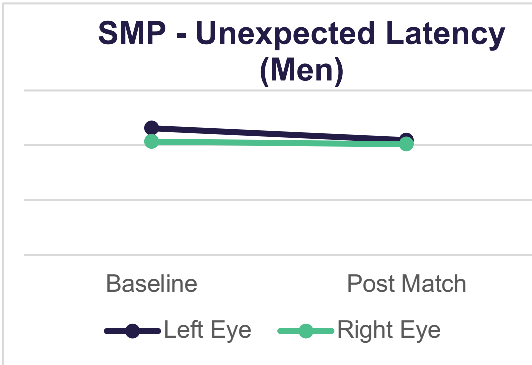


4.3 OCULAR MARKERS

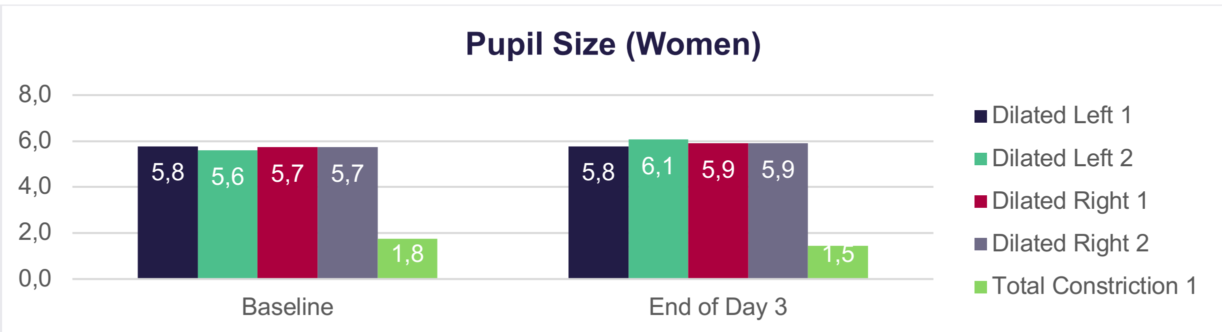
4.3.1 SMOOTH PURSUIT

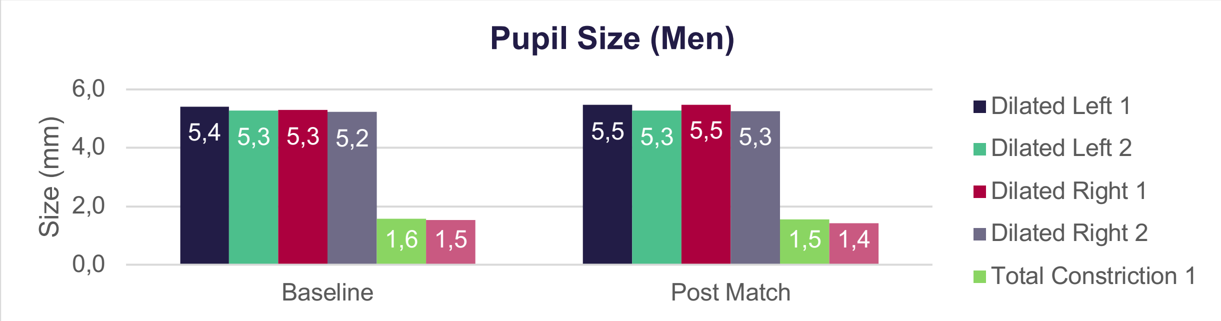
The graphs below show the average speed at which the group responded to the movement of the dot (tracking target). Although the groups average was above the norm (250 ms) the increase at the end of the week was less than 50 ms.





4.3.2 PUPILLARY LIGHT RESPONSE

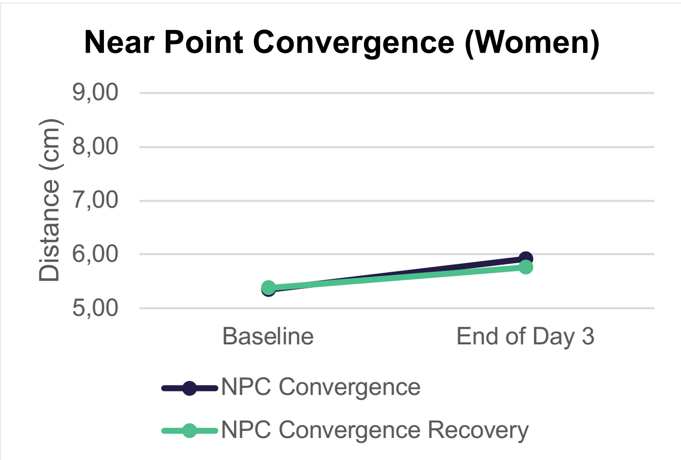


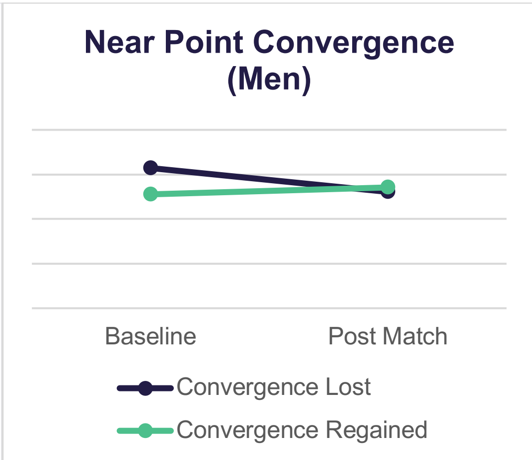


In the graphs above we see that women's and men's values fall within the norms. The asymmetry in pupil size was also less than 0.5 for all tests.

4.3.3 NEAR POINT CONVERGENCE

The results of the NPC assessments, for both the women's and men's groups fell within the norms.





4.3.4 HORIZONTAL GAZE NYSTAGMUS

There were no cases of HGN detected in either the women's or men's group.

4.4 CONCUSSIONS

There were no observed concussions at any of the women's or men's training or match sessions.

4.5 RELIABILITY OF SELF-REPORT

4.5.1 WOMEN PLAYERS

The reliability of the players to self-report the number of headers they made during training ranged from poor to excellent between the sessions.

4.5.2 MEN PLAYERS

The reliability of the players to self-report the number of headers they made during training ranged from poor to good between the sessions.

5. DISCUSSION

The purposes of this project were (1) to determine the exposure to headers in elite men's and women's football, and to describe the effects of the headers on ocular markers, (2) to observe the occurrence of concussions in elite men's and women's football training and matches, and to describe the effects of concussion on ocular markers, and (3) to determine the reliability of players' self-reporting the number of headers they make during a session. Female players made an average of 11 headers per player per session. Ninety percent of the headers were below 10G, and none were above 80G. Male players made an average of 3 headers per player per session, with 74% of the headers recording a G-force above 10G and 3% above 80G. There were no significant changes observed post-session in the ocular markers of the players, and no concussions were observed. Neither the women's nor men's football cohort were able to accurately self-report the number of headers they made in every session.

5.1 EXPOSURE TO HEADERS

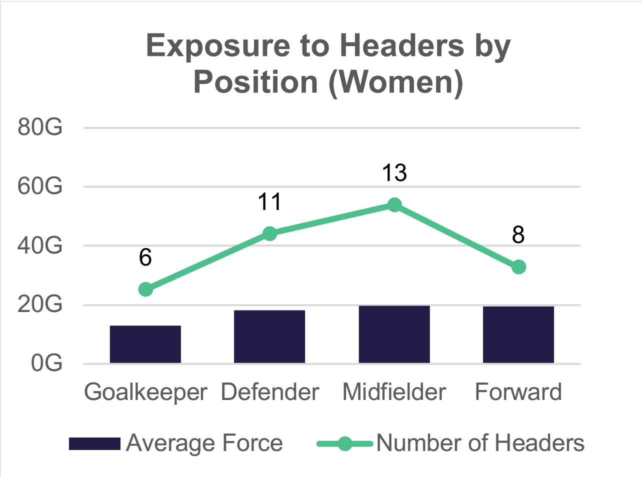
There was an average of 11 headers per player per training session in women's football, and an average of 2 and 3 headers per player per session in training and matches in men's football, respectively. The exposure to headers in men's football is similar to that reported in previous studies in men's and women's collegiate and elite football, with an average of 2 headers per player per training session,[4 15 16] and 4 headers in matches,[3 16] reported in both men's and women's football. Although the number of headers we identified in women's football was higher, 87% of these headers occurred in one session. If we exclude that outlying session from the calculation, there was an average of 2 headers per player per session in women's football. This highlights the impact the design of a training session can have on the players exposure to heading, and a possible need to educate coaches on the importance of designing training sessions that limit the exposure of heading in training, to reduce the risk of repetitive head impacts on brain health.

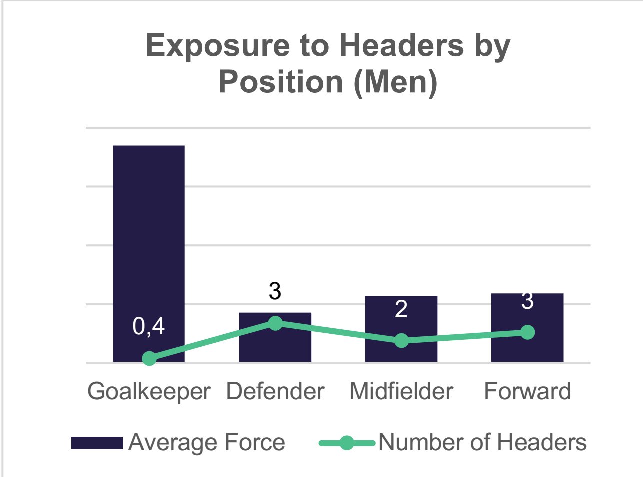
The average force of headers (calculated with those above 10G) in men and women's football training was 19G. Similar findings were found in collegiate players in a study by Saunders and colleagues, with an average force of 20G and 17G for women and men players, respectively.[17] Although, the percentage of headers above 10G was higher in men's football when compared to women's, as was the number of headers above 80G. Head impacts above 80G have been identified as a risk factor for concussion.[18] Although our findings suggest that the men were exposed to headers with greater impacts than women, it is important to note that the men's group was older than the women's (senior vs academy). Therefore, further research is required to describe the exposure to heading in men's and women's football, at different levels of play and different career stages.

POST HOC ANALYSIS – EXPOSURE TO HEADERS BY PLAYING POSITION

In a post hoc analysis we compared the exposure to headers by playing position in men's and women's football. The results are shown in the figures below, with the bars showing the average G-force of the headers (calculated with those above 10G), and the line graphs showing the average headers made per player per session for each positional group. In women's football, the midfielders made the most headers per session, followed by defenders. In men's football, defenders made the most headers per session, followed by forwards. The findings in men's football align with previous research in both men and women's football, that defenders are exposed to more headers than other playing positions.[2 3 15]

Interestingly, of the outfield positions (defenders, midfielders & forwards), defenders had the lowest average force of headers. Further research is required to describe the types of headers defenders make, and their technique, compared to other playing positions, to determine if there may be factors that could reduce the force absorbed by the head when heading. The average force of the goalkeeper's headers was notably higher than other positions in men's football. However, the two headers the goalkeeper made in training were both unintentional. Therefore, the higher average force the goalkeeper was exposed to may be more related to the intention to header, than their playing position.





5.2 OCULAR MARKERS

The exposure to heading over the three days of training, in women's and men's football, did not have significantly affect the players' ocular markers. A review of research related to heading in football found that, in 75% of the studies reviewed, heading did not have a negative effect on cognitive functioning. These findings suggest that the impact of heading may not have an acute effect on cognitive functioning, however, longitudinal studies are required to determine the chronic effect the impact of heading may have on cognitive functioning across multiple months or years of training and matches.

5.3 THE RELIABILITY OF SELF-REPORT

The reliability of the players ability to reliably self-report how many headers they made in a session ranged from poor to excellent, and poor to good, in women's and men's football, respectively. It is, therefore, recommended that in future research objective measures (i.e., video analysis review) are used to quantify players exposure to heading in training and matches.

5.4 LIMITATIONS

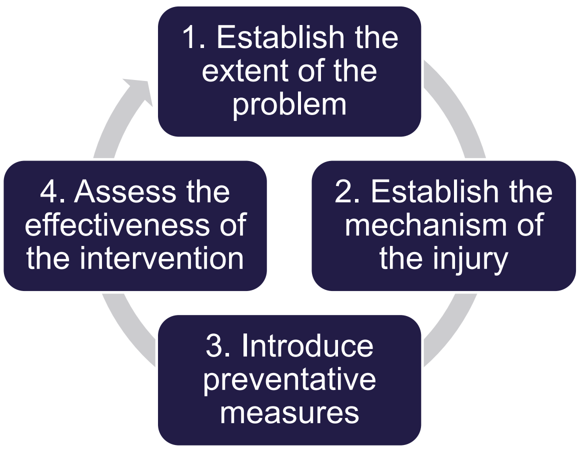
The purpose of a pilot project is to examine the methodology and procedures of a project on a small scale, and to explore the feasibility of the project and identify any limitations and considerations, before implementing the project on a larger scale. In this sense, this project was a success as several limitations and considerations were identified, which can inform future directions.

We observed the exposure to heading in men and women's football. Yet, although both groups compete at an elite level, the level of play, career stage, and the country where they played also differed between the groups. These factors may affect the level and style of training of the players, and the subsequent heading exposure. This can make it difficult to attribute differences between groups to a specific grouping factor (sex, level of play, etc.). We, therefore, recommend that future projects which analyse both men and women's football, consider the level of play, the country, and the career stage of the players.

There were a few technical errors related to the synching of the timestamps of the head impacts with the video footage. Namely, the time stamps from the head impacts during the men's training camp were incorrect due to a software issue, and the video footage of the women's training was not time stamped. This meant that, although we were able to quantify the number of headers (and any other head impacts) each player made in a session, and the force of the head impacts that occurred, we were not able to objectively know the force of each header. Future projects should therefore ensure that the impact trackers used are able to accurately record impacts from heading, and that the recordings of training and matches is timestamped.

5.5 FUTURE DIRECTIONS

The Sequence of Injury Prevention is a sports injury prevention model that was developed to provide researchers and practitioners with a road map to guide decision making and action plans when developing injury prevention strategies (figure below).[19] We recommend that future projects start with the first two steps of this model, namely to establish players exposure (number and force) to head impacts in training and matches, and the incidence, severity and mechanisms of changes in cognitive function (e.g., via ocular markers) in elite football. Therefore, observational longitudinal (over at least one season) studies should be designed and conducted across different levels of play, in both women and men's football. These studies are a prerequisite before the development of any evidence-based measures (step 3) aiming to prevent or mitigate the potential risks associated with headers and concussions in elite football.



6. CONCLUSION

Female players made an average of 11 headers per player per session. Ninety percent of the headers were below 10G, and none were above 80G. Male players made an average of 3 headers per player per session, with 74% of the headers recording a G-force above 10G and 3% above 80G. There were no significant changes observed post-session in the ocular markers of the players, and no concussions were observed. Neither the women's nor men's football cohort were able to accurately self-report the number of headers they made in every session.

7. ACKNOWLEDGMENTS

We are thankful to all members of Israeli Football Players Organisation (IFPO) and Jalkapallon Pelaajayhdistys Ry (JPY) who participated in the study.

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