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Validation and Calibration of HeadCount, a Self-Report Measure for Quantifying Heading Exposure in Soccer Players

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Abstract

The long-term effects of repetitive head impacts due to heading are an area of increasing concern and exposure must be accurately measured; however, the validity of self-report of cumulative soccer heading is not known. In order to validate HeadCount, a two week recall questionnaire, the number of player reported headers was compared to the number of headers observed by trained raters for a men's and a women's collegiate soccer teams during an entire season of competitive play using Spearman's correlations and intraclass correlation coefficients (ICCs), and calibrated using a generalized estimating equation. The average Spearman's rho was 0.85 for men and 0.79 for women. The average ICC was 0.75 in men and 0.38 in women. The calibration analysis demonstrated that men tend to report heading accurately while women tend to overestimate. HeadCount is a valid instrument for tracking heading behavior, but may have to be calibrated in women.

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Introduction

Soccer, the most popular sport worldwide, is played by over 265 million people (Kunz, 2007). Heading –use of the unprotected head to direct the ball during game play – is increasingly recognized as a major source of exposure to concussive and sub-concussive repetitive head impacts (Comstock, Currie, Pierpoint, Grubenhoff, & Fields, 2015; Haran, Tierney, Wright, Keshner, & Silter, 2013; O'Kane et al., 2014; Spiotta, Bartsch, & Benzel, 2012; Witol & Webbe, 2003). These impacts have been linked to changes in brain structure visible on neuroimaging (Koerte et al., 2016; Lipton et al., 2013; Sortland & Tysvaer, 1989) as well as decreased performance on cognitive tasks both with short term (Webbe & Ochs, 2003; Zhang, Red, Lin, Patel, & Sereno, 2013) and long term (Rutherford & Fernie, 2005; Tysvaer & Lochen, 1991) exposure. However, this association remains controversial with some studies failing to find an effect (Kaminski, Wikstrom, Gutierrez, & Glutting, 2007; Putukian, Echemendia, & Mackin, 2000; Straume-Naesheim, Andersen, Dvorak, & Bahr, 2005) or suggesting that the effect may reverse after cessation of exposure (Vann Jones, Breakey, & Evans, 2014). For review of the effects of heading on brain structure and function see (Rodrigues, Lasmar, & Caramelli, 2016). Although much of this evidence indicates that outcomes are exposure dependent, low-cost, scalable, reliable, and valid methods of measuring exposure to heading have not been developed.

Heading is common across all levels of soccer play (youth, high school, college, professional) though the estimates of how frequently players head the ball in any given context vary. Studies of youth soccer players have found averages of 1.95 headers per game for girls and 1.18 headers per game for boys (Salinas, Webbe, & Devore, 2009). At the high school level male and female players combined averaged 0.8 headers per game, while collegiate male and female players averaged 2.7 headers per game (Kaminski et al., 2007). In a separate study looking specifically at collegiate women, the average heading was found to be 1.0 times per game (Kaminski, Cousino, & Glutting, 2008). Other estimates that include professional level players, suggest an average of 6-12 headers per game (Spiotta et al., 2012). Our previous research based on player self report found a range of 32-5400 headers per year in amateur players (Lipton et al., 2013).

Several methods have been used to quantify heading. Direct observation of players or structured analysis of video recording, while often considered the gold standard, is labor intensive, expensive, and not easily scaled to large samples or longitudinal studies. Moreover, this method is not suitable for quantifying heading in amateur players who are not typically tracked by coaches or athletic trainers. Wearable accelerometers are attractive because they offer the promise of quantitative characterization of head impacts (Gutierrez, Conte, & Lightbourne, 2014; McCuen et al., 2015) and because they are becoming smaller and thus less cumbersome to wear during athletics, as well as more affordable (Ciuti, Ricotti, Menciassi, & Dario, 2015). However, the reliability and validity of these devices has been shown to be low in soccer (Press & Rowson, 2016), and they still require confirmation with direct observation or analysis of video to determine impact types (Hanlon & Bir, 2012). The lower limit of head acceleration associated with head impacts that can be accurately distinguished from changes in acceleration related to running, walking, or jumping is generally thought to be about 10 G (King, Hume, Brughelli, & Gissane, 2015); however, a

study that used video analysis to confirm accelerometer recorded impacts in female soccer players found that when using the 10 G threshold, 42.2% of the impacts identified by the accelerometer were false positives (Press & Rowson, 2016).

Going forward, it will be critical to have a convenient, inexpensive method for assessing head impact exposure in order to determine risk for long-term sequelae and to ultimately evaluate and implement public health interventions, such as the use of protective headgear or appropriate “heading technique” (Elbin et al., 2015), to mitigate adverse outcomes. Subject self-report questionnaires are a proven method used for quantifying physical activity across a range of recall periods (Atienza & King, 2005; Ekelund et al., 2006; Friedenreich et al., 2006; Johnson-Kozlow, Rock, Gilpin, Hollenbach, & Pierce, 2007). Additionally, self-report measures have been successfully used to quantify repeated head impacts in football players (Kerr et al., 2015; Montenigro et al., 2016). Montenigro et al. calculated a cumulative head impact index score based on the players' self report of number of seasons of play at different levels (youth, high school, college) play, weighted by estimates of the frequency of head impacts by position and level of play drawn from published helmet accelerometer studies. This method demonstrated predictive validity for subsequent cognitive and emotion symptoms. Kerr et al. used a 30 minute long structured interview to estimate the number of hours of contact exposure as proxy metric for exposure to for sub-concussive head impacts. This head impact exposure estimate was able to discriminate between football players who had retired after playing in college and players who had continued to complete a professional career, but was not validated using either direct observation or clinical outcomes.

Similar techniques for head impact exposure estimation may be applicable in soccer players. However, self-reported measures of heading in soccer have not yet been proven to be reliable or valid. A prior study on reporting of heading activity by 25 soccer players that asked players to report the exact number of headers per game demonstrated that players' reports were inaccurate, but positively correlated with their observed heading activity (Rutherford & Fernie, 2005). Our report describes the validation and calibration of a two-week recall questionnaire for heading that asks players to report the number of games played in a two week period and the average number of headers per game.

Methods

Male and female players were recruited from the NCAA Division I soccer teams at a single American university. All members of the university's men's and women's soccer teams were eligible to participate. The study was reviewed and approved by the local institutional review board and complied with the Health Insurance Portability and Accountability Act. Written informed consent was obtained for all subjects. During the 10-week fall soccer season of 2014, each participant was given the heading questionnaire, HeadCount, once every two weeks. Self-reported data were validated and calibrated using direct observation of heading by trained staff.

Two-Week Recall Questionnaire

HeadCount is a web-based, structured, self-administered questionnaire, previously described for assessment of longer term heading exposure (Lipton et al., 2013). For this study, players were asked to report on soccer play and heading during the two weeks immediately preceding administration of the questionnaire. Specific questions were asked about the 1) the number of competitive soccer games they played during the two-week epoch and 2) the average number of times they headed the ball during a game. These two values were multiplied to generate a count of total *reported headers* during the epoch.

Direct Observation

Four student athletic trainers were trained to identify, characterize, and record headers during soccer games. In a validation study, conducted prior to initiation of the present study, two raters' records of observed headers were compared with the number of headers identified during structured analysis of video recordings of five games, with each rater reporting on the same five games. The intra-class correlation coefficient (ICC) between the live observation and the video recording for these two raters was 0.98. For the present study, the team of four raters attended each game and recorded the number of headers for each player participating in the game. The raters worked as a team and discrepancies in observed header counts were resolved by consensus. The players were not blind to being observed. The total number of headers observed during all games within each two-week epoch was summed to generate a count of total *observed headers* during the epoch.

Analysis

All analyses were performed using STATA Version 13.1. The observation data and self-report data were summarized and analyzed separately for male and female players. The absolute error was defined as the difference between the reported and observed headers – thus a positive absolute error represents an overestimation of heading activity. Estimates of heading derived from the questionnaire were directly compared with observed heading activity for each epoch using ICCs (two-way mixed effects model for consistency of measurement) (Weir, 2005) and Spearman's correlations to assess the validity and consistency of self-report of heading. It has been proposed that an ICC of greater than >0.40 can be considered reflective of fair reliability, >0.60 of moderate reliability, and >0.80 of substantial reliability (Shrout, 1998). However, the ICC may be vulnerable to artificial inflation when the group dataset shows a wide range of variability. The standard error of measurement (SEM) describes the dispersion of measurement errors in units of measure (in this case, headers per two week epoch) and thus reflects absolute rather than relative reliability and can be used to adjust the ICC by taking overall group variability into account (Weir, 2005). Because the players who completed the survey each epoch varied across the season we did not pool the data across epochs to estimate the Spearman's correlations, ICCs, or SEMs.

In order to calibrate the estimate of total heading activity from HeadCount, we used a generalized estimating equation (GEE), which is designed for panel or repeated measures data (Hanley, Negassa, Edwards, & Forrester, 2003), to predict observed headers as a function of reported headers across multiple epochs. This generated a linear calibration

equation (regression coefficient and constant terms) for the header estimation from the questionnaire:

$$\text{Headers}_{\text{Observed}} = \beta_0 + \beta_1 \text{Headers}_{\text{Reported}}$$

We calculated calibration errors, defined as the difference between observed headers and expected headers based on the calibration of the reported headers. We performed a sensitivity analysis for outlier observations by excluding observations with calibration errors outside two standard deviations (SD) of the mean calibration error and rerunning the GEE to assess the degree of change in the regression coefficients.

Results

During the fall 2015 season there were a total of 24 male (mean age 21 ± 1.2 years) and 24 female (mean age 19.7 ± 1.2 years) potential participants. The questionnaire was sent to every player for each epoch, but data for women were not available for one epoch due to an error in the questionnaire administration software that led to questions being improperly displayed. Over the course of the study a total of 40 unique players consented to participation and completed the questionnaire at least once. An average of 10.2 male players (range: 9-12) and 12.5 female players (range: 9-18) completed the questionnaire during each two-week epoch. Of these, each athlete completed the questionnaire an average of 2.5 times, yielding 51 observations in men and 50 in women. With respect to position of play, 48% of the observations were from forward/mid-field players, 32% from defense players, 3% from goalkeepers, and 17% were unstated. There was no significant difference in the composition of the self-report observations between men and women (Fischer's Exact Test Statistic = 0.12).

For this study all games during the season were observed. For the women's team there were four games in the first, third, and fifth epochs and three games in the fourth epoch. For the men's team there were four games in the first, second, and fifth epochs, and three games in the third and fourth epochs. Observed headers were higher than reported headers in men and were lower than reported headers in women (Table 1). Additionally, men were observed to head more than women: the average number of headers per two week period was 17.59 for men and 4.56 for women and the average number of headers per game was 5.15 for men and 1.30 for women.

For men, the mean ICC across all epochs was 0.75 (SD=0.13) and the mean SEM was 8.03 headers (SD=2.81) (Table 2). For women, the mean ICC was 0.38 (SD=0.20) and the mean SEM was 9.38 headers (SD=2.82). Across all epochs, the mean Spearman's rho was 0.85 (SD=0.08) for men and 0.79 (SD=0.12) for women.

The GEE analysis resulted in a coefficient of 0.95 ($p < 0.001$) with a constant term of 3.74 ($p = 0.149$) for men (Figure 1a) and a coefficient of 0.21 ($p = 0.015$) with a constant term of 1.85 ($p = 0.248$) for women (Figure 1b). The distribution of errors between the headers predicted by the calibration and the observed headers is shown in Figure 2. The sensitivity

analyses after exclusion of all outliers outside two SD's of the mean calibration error showed a migration in the regression coefficient of less than 0.11 for men and 0.05 for women.

Discussion

Overall these results indicate that HeadCount is a valid and reliable measure of heading exposure over a two-week period. The Spearman's correlations between reported and observed headers were greater than 0.6 for all epochs indicating a reasonable degree of positive correlation.

Notably, there appeared to be a sex difference in reporting, with men more accurately reporting heading than women. This was demonstrated both with ICCs, where the ICCs for men were all greater than 0.6 indicating moderate to excellent agreement, but the ICCs for women ranged from 0.17 to 0.63 indicating poor to moderate agreement; and with the calibration analysis where the calibration coefficient for men approached one, but the calibration coefficient for women reflected a tendency towards overestimation by a factor of five. However, the sex difference in reporting accuracy was less pronounced with the Spearman's correlations and the SEMs— a measure of absolute rather than relative reliability. This suggests that the ICC, at least, may have been artificially depressed in women as a result of low variation in headers across the whole group (Weir, 2005); indeed women, as a group, tended to head much less than men. However, the pronounced difference in the calibration analysis – with men requiring little to no adjustment and women requiring a reduction in their reported heading count by a factor of five is surprising. The reasons behind this discrepancy are not clear. Although few others studies have examined reporting accuracy in both male and female soccer players, a study of self report of heading for youth soccer found a regression coefficient between observed and reported heading of 0.77 for boys but only 0.52 for girls (Salinas et al., 2009). A study examining player reporting of soccer-related injuries also identified a sex difference in reporting: female players were more likely to endorse having an injury on the questionnaire, but were also more likely to report willingness to hide the presence of an injury in order to play (Babwah, 2014).

Rutherford et al. (2005) also found a correlation of self-reported and observed heading with a tendency to over-estimation based on self-report. The key distinction between that study and ours was that the Rutherford questionnaire asked players to provide exact numbers of headers per game while our questionnaire asked players to estimate average heading over multiple games. These two approaches may be applicable to distinct contexts: exact reporting may be more useful to capture short-term exposure versus estimated reporting for cumulative mid- to longer-term exposure.

Other self-report instruments, such as those developed by Kerr et al. (2015) or Montenegro (2016), utilize a structured interview approach that may provide increased accuracy, but is not as easily scaled to large populations or remote (online) participation. Additionally, although these two studies resembled our study most closely in their technique for estimation of cumulative heading, they both relied on differences in player position to augment exposure estimation. This approach is based on the observation that head impacts vary with position for American football; differences in heading exposure and head

acceleration by position have not been demonstrated to the same degree in soccer players. Our study was not powered to detect a difference in reporting accuracy based on position – this will require a larger sample with assessment of multiple players on different soccer teams.

Our results are limited by the relatively small sample size and by heterogeneity in subject participation in answering the questionnaire. Additionally, we specifically studied heading during competitive game play. Although the questionnaire performed very well in this context, it might perform differently if used to assess heading during practice, including heading drills where a significant burden of heading exposure may occur. We report on young adult collegiate players. The findings might not generalize to other soccer populations, such as youth, high school, adult amateur, and professional players. Although a version of the questionnaire has been employed to assess longer term exposure (Lipton et al., 2013), because the reporting period in the present study is limited to two weeks, we cannot specifically generalize our calibration approach to exposure recall over different time periods. Finally, while the results of this study cannot be extrapolated to conclude the validity of self-report of head impacts in other contact sports (e.g. football, boxing, hockey), our hope is that these results will support the development of other sport specific self-report measures.

HeadCount is brief, inexpensive and easy to administer. Although it may not precisely quantify the absolute number of headers a player performs, it does index heading exposure in a consistent, reliable and valid way, which ranks players with respect to each other in terms of heading exposure. In the context of risk assessment of heading activity, such a reliable measure of the magnitude of exposure is essential, although absolute quantification may not be necessary if sexes are considered separately. Calibration of the questionnaire responses, using a calibration equation as offered here, may be another approach for using the self-report measure that allows for absolute quantification and combination of men and women despite differences in accuracy of reporting. Our findings indicate that HeadCount can be used to index exposure in population studies and, once generalizable safe exposure thresholds have been delineated, could be widely disseminated to monitor exposure and minimize risk.

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References

- Atienza AA, King AC. Comparing self-reported versus objectively measured physical activity behavior: a preliminary investigation of older Filipino American women. *Research Quarterly for Exercise and Sport*. 2005; 76(3):358–362. [PubMed: 16270713]
- Babwah T. Pain, injury and related behaviours among footballers partaking in tournaments. *Research in Sports Medicine*. 2014; 22(4):334–345. [PubMed: 25295472]
- Ciuti G, Ricotti L, Menciaci A, Dario P. MEMS sensor technologies for human centred applications in healthcare, physical activities, safety and environmental sensing: a review on research activities in Italy. *Sensors (Basel)*. 2015; 15(3):6441–6468. [PubMed: 25808763]

- Comstock RD, Currie DW, Pierpoint LA, Grubenhoff JA, Fields SK. An Evidence-Based Discussion of Heading the Ball and Concussions in High School Soccer. *JAMA Pediatrics*. 2015; 169(9):830–837. [PubMed: 26168306]
- Ekelund U, Sepp H, Brage S, Becker W, Jakes R, Hennings M, Wareham NJ. Criterion-related validity of the last 7-day, short form of the International Physical Activity Questionnaire in Swedish adults. *Public Health Nutrition*. 2006; 9(2):258–265. [PubMed: 16571181]
- Elbin RJ, Beatty A, Covassin T, Schatz P, Hydeman A, Kontos AP. A preliminary examination of neurocognitive performance and symptoms following a bout of soccer heading in athletes wearing protective soccer headbands. *Research in Sports Medicine*. 2015; 23(2):203–214. [PubMed: 25666112]
- Friedenreich CM, Courneya KS, Neilson HK, Matthews CE, Willis G, Irwin M, et al. Ballard-Barbash R. Reliability and validity of the Past Year Total Physical Activity Questionnaire. *American Journal of Epidemiology*. 2006; 163(10):959–970. [PubMed: 16524954]
- Gutierrez GM, Conte C, Lightbourne K. The relationship between impact force, neck strength, and neurocognitive performance in soccer heading in adolescent females. *Pediatric Exercise Science*. 2014; 26(1):33–40. [PubMed: 24091298]
- Hanley JA, Negassa A, Edwardes MD, Forrester JE. Statistical analysis of correlated data using generalized estimating equations: an orientation. *American Journal of Epidemiology*. 2003; 157(4): 364–375. [PubMed: 12578807]
- Hanlon EM, Bir CA. Real-time head acceleration measurement in girls' youth soccer. *Medicine and Science in Sports and Exercise*. 2012; 44(6):1102–1108. [PubMed: 22592278]
- Haran FJ, Tierney R, Wright WG, Keshner E, Silter M. Acute changes in postural control after soccer heading. *International Journal of Sports Medicine*. 2013; 34(4):350–354. [PubMed: 23175178]
- Johnson-Kozlow M, Rock CL, Gilpin EA, Hollenbach KA, Pierce JP. Validation of the WHI brief physical activity questionnaire among women diagnosed with breast cancer. *American Journal of Health Behavior*. 2007; 31(2):193–202. [PubMed: 17269909]
- Kaminski TW, Cousino ES, Glutting JJ. Examining the relationship between purposeful heading in soccer and computerized neuropsychological test performance. *Research Quarterly for Exercise and Sport*. 2008; 79(2):235–244. [PubMed: 18664047]
- Kaminski TW, Wikstrom AM, Gutierrez GM, Glutting JJ. Purposeful heading during a season does not influence cognitive function or balance in female soccer players. *Journal of Clinical and Experimental Neuropsychology*. 2007; 29(7):742–751. [PubMed: 17852597]
- Kerr ZY, Littleton AC, Cox LM, DeFreese JD, Varangis E, Lynall RC, et al. Guskiewicz KM. Estimating Contact Exposure in Football Using the Head Impact Exposure Estimate. *Journal of Neurotrauma*. 2015; 32(14):1083–1089. [PubMed: 25603189]
- King D, Hume PA, Brughelli M, Gissane C. Instrumented mouthguard acceleration analyses for head impacts in amateur rugby union players over a season of matches. *American Journal of Sports Medicine*. 2015; 43(3):614–624. [PubMed: 25535096]
- Koerte IK, Mayinger M, Muehlmann M, Kaufmann D, Lin AP, Steffinger D, et al. Shenton ME. Cortical thinning in former professional soccer players. *Brain Imaging and Behavior*. 2016; 10(3): 792–798. [PubMed: 26286826]
- Kunz M. 265 million playing football. *FIFA Magazine*(July). 2007
- Lipton ML, Kim N, Zimmerman ME, Kim M, Stewart WF, Branch CA, Lipton RB. Soccer heading is associated with white matter microstructural and cognitive abnormalities. *Radiology*. 2013; 268(3):850–857. [PubMed: 23757503]
- McCuen E, Svaldi D, Breedlove K, Kraz N, Cummiskey B, Breedlove EL, et al. Nauman EA. Collegiate women's soccer players suffer greater cumulative head impacts than their high school counterparts. *Journal of Biomechanics*. 2015; 48(13):3729–3732.
- Montenigro PH, Alosco ML, Martin B, Daneshvar DH, Mez J, Chaisson C, et al. Tripodis Y. Cumulative Head Impact Exposure Predicts Later-Life Depression, Apathy, Executive Dysfunction, and Cognitive Impairment in Former High School and College Football Players. *Journal of Neurotrauma*. 2016; 33:1–13. [PubMed: 25962860]
- O'Kane JW, Spieker A, Levy MR, Neradilek M, Polissar NL, Schiff MA. Concussion among female middle-school soccer players. *JAMA Pediatrics*. 2014; 168(3):258–264. [PubMed: 24446018]

- Press JN, Rowson S. Quantifying Head Impact Exposure in Collegiate Women's Soccer. *Clinical Journal of Sport Medicine*. 2016
- Putukian M, Echemendia RJ, Mackin S. The acute neuropsychological effects of heading in soccer: a pilot study. *Clinical Journal of Sport Medicine*. 2000; 10(2):104–109. [PubMed: 10798791]
- Rodrigues AC, Lasmar RP, Caramelli P. Effects of Soccer Heading on Brain Structure and Function. *Frontiers in Neurology*. 2016; 7:38. [PubMed: 27047444]
- Rutherford A, Fernie G. The accuracy of footballers' frequency estimates of their own football heading. *Applied Cognitive Psychology*. 2005; 19(4):477–487.
- Salinas CM, Webbe FM, Devore TT. The Epidemiology of Soccer Heading in Competitive Youth Players. *Journal of Clinical Sport Psychology*. 2009; 3(1):15–33.
- Shrout PE. Measurement reliability and agreement in psychiatry. *Statistical Methods in Medical Research*. 1998; 7(3):301–317. [PubMed: 9803527]
- Sortland O, Tysvaer AT. Brain damage in former association football players. An evaluation by cerebral computed tomography. *Neuroradiology*. 1989; 31(1):44–48. [PubMed: 2717003]
- Spiotta AM, Bartsch AJ, Benzel EC. Heading in soccer: dangerous play? *Neurosurgery*. 2012; 70(1):1–11. discussion 11.
- Straume-Naesheim TM, Andersen TE, Dvorak J, Bahr R. Effects of heading exposure and previous concussions on neuropsychological performance among Norwegian elite footballers. *British Journal of Sports Medicine*. 2005; 39(1):i70–77. [PubMed: 16046359]
- Tysvaer AT, Lochen EA. Soccer injuries to the brain. A neuropsychologic study of former soccer players. *American Journal of Sports Medicine*. 1991; 19(1):56–60. [PubMed: 2008931]
- Vann Jones SA, Breakey RW, Evans PJ. Heading in football, long-term cognitive decline and dementia: evidence from screening retired professional footballers. *British Journal of Sports Medicine*. 2014; 48(2):159–161. [PubMed: 24026299]
- Webbe FM, Ochs SR. Recency and frequency of soccer heading interact to decrease neurocognitive performance. *Applied Neuropsychology*. 2003; 10(1):31–41. [PubMed: 12734073]
- Weir JP. Quantifying test-retest reliability using the intraclass correlation coefficient and the SEM. *Journal of Strength and Conditioning Research*. 2005; 19(1):231–240. [PubMed: 15705040]
- Witol AD, Webbe FM. Soccer heading frequency predicts neuropsychological deficits. *Archives of Clinical Neuropsychology*. 2003; 18(4):397–417. [PubMed: 14591454]
- Zhang MR, Red SD, Lin AH, Patel SS, Sereno AB. Evidence of cognitive dysfunction after soccer playing with ball heading using a novel tablet-based approach. *PloS One*. 2013; 8(2):e57364. [PubMed: 23460843]

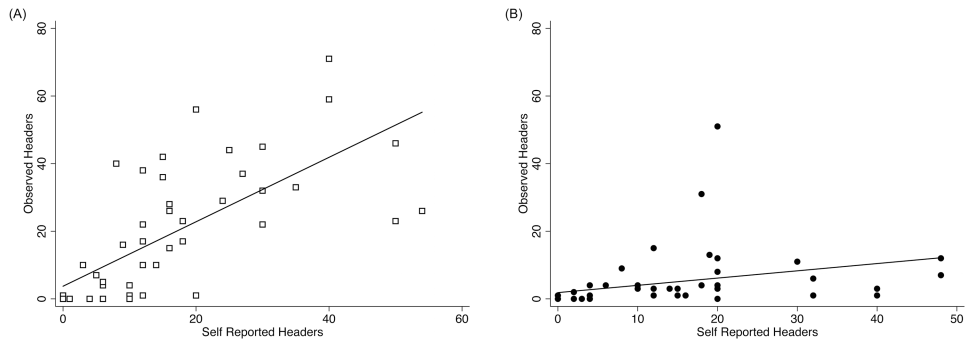


Figure 1. Observed vs. reported headers for (A) men and (B) women shown with linear fit (calibration) line.

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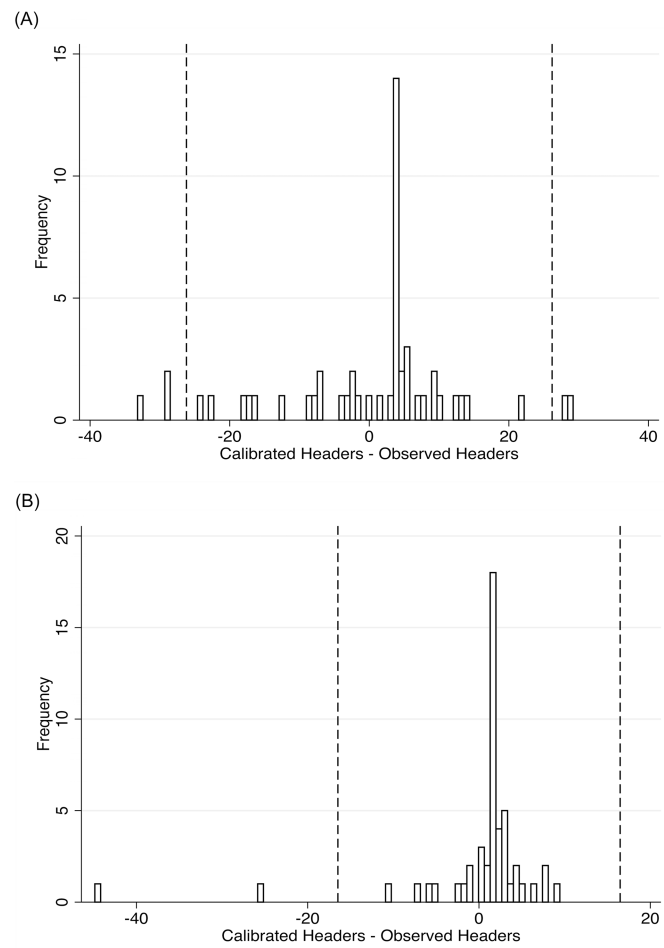


Figure 2. Histograms showing calibration errors (calibrated headers – observed headers) for (A) men and (B) women. Dashed lines indicate ± 2 standard deviations of the mean.

Table 1

HeadCount and observation results for the men and women's teams for the Fall 2014 season averaged across players and all epochs and treating each questionnaire as an independent observation. All variables presented as mean (standard deviation).

| Team | N (questionnaires) | Observed Headers | Reported Headers | Absolute Error (Reported-Observed Headers) |
|-------|--------------------|------------------|------------------|--|
| Men | 51 | 17.59 (18.98) | 14.53 (14.42) | -3.06 (13.11) |
| Women | 50 | 4.56 (8.71) | 12.6 (13.16) | 8.04 (13.22) |

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Reliability of HeadCount as assessed with the intraclass correlation coefficient (ICC; two way mixed effects model for consistency of agreement), standard error of measurement (SEM; given in units of headers per two week reporting period), and Spearman's correlations.

Table 2

| Group | Epoch | N (players) | ICC | | | Spearman's Correlation | | |
|-------|-------|----------------------------------|--------|---------|-------|------------------------|------|-------|
| | | | Single | Average | P | SEM | rho | P |
| Men | 1 | 9 | 0.89 | 0.94 | 0.000 | 5.01 | 0.84 | 0.004 |
| | 2 | 12 | 0.63 | 0.77 | 0.011 | 11.44 | 0.75 | 0.005 |
| | 3 | 9 | 0.72 | 0.84 | 0.010 | 6.46 | 0.90 | 0.001 |
| | 4 | 11 | 0.62 | 0.77 | 0.015 | 10.60 | 0.82 | 0.002 |
| | 5 | 10 | 0.87 | 0.93 | 0.000 | 6.67 | 0.95 | 0.000 |
| Women | 1 | 18 | 0.17 | 0.30 | 0.244 | 11.10 | 0.61 | 0.007 |
| | 2 | No data available for this epoch | | | | | | |
| | 3 | 13 | 0.30 | 0.46 | 0.149 | 8.28 | 0.80 | 0.001 |
| | 4 | 10 | 0.63 | 0.78 | 0.018 | 5.94 | 0.83 | 0.003 |
| | 5 | 9 | 0.41 | 0.58 | 0.118 | 12.19 | 0.90 | 0.001 |