Supplementary Online Content

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eMethods. Estimation of the Number of Former College Football Players Who Played in American Colleges between 1960 and 2020 and of Former Players who are Ages 60 to 82

eTable 1. University of Notre Dame (ND) Sample Survey Questionnaire and Health and Retirement Study (HRS) 2016 Survey: Variable Matching

eTable 2. Comparison of Former University of Notre Dame (ND) Players Who Completed the Survey and Those Who Did Not Complete the Survey

eTable 3. Non-Responder Weighted Health Outcomes: University of Notre Dame (ND) Players Compared with Health and Retirement Study (HRS) Sample

eTable 4. Demographics of Former University of Notre Dame (ND) Players Who Only Played Through College Compared with Those Who Went on to Play Professional Football

eTable 5. Health Outcomes: Former University of Notre Dame (ND) Players Who Only Played Through College Compared with Those Who Went on to Play Professional Football

eTable 6. Health Outcomes: Former University of Notre Dame (ND) Players by Position

eTable 7. Standardized Mortality Ratios for Former University of Notre Dame (ND) Players Who Only Played Through College Compared with Other Studies of Former National Football League (NFL) Players **eReferences.**

This supplementary material has been provided by the authors to give readers additional information about their work.

eMethods. Estimation of the Number of Former College Football Players Who Played in American Colleges between 1960 and 2020 and of Former Players who are Ages 60 to 82.

The NCAA Sports Sponsorship and Participation Rates report and database¹ have reported annual counts of the Number of Teams, Total Athletes, and Average Squad Size for collegiate American football every five years between 1957 and 1977 and later annually beginning in 1982. These three categories are not *explicitly* related, but it can be closely estimated that Number of Teams multiplied by Average Squad Size would result in Total Athletes.

Total Athletes = Number of Teams x Average Squad Size

To estimate the Total Athletes over the age of 60, this formula was applied to the years 1960 to 1981 when annual NCAA data was not available. Assuming senior roster players were 22 years old, we set a cutoff at the year 1960 to include all individuals less than or equal to 82 years old as of 2020. The Number of Teams was based on those in major, minor, and independent American football conferences across randomly sampled years which was then extrapolated based on averages. Similarly, Average Squad Size was estimated by randomly sampling rosters from various teams in various years and extrapolating. At this point, Total Athletes could be estimated.

It is important to note that early college football included separate freshmen and varsity teams until the NCAA allowed freshmen to join the varsity rosters in 1972. Because we do not have access to freshmen team rosters, we calculated the total number players assuming individuals played three years of varsity football prior to 1972 and four years including and after 1972. It is important to note that we are potentially overestimating by assuming one third of the roster were seniors in the early college football years, rather than one fourth due to the inclusion of freshman. However, the average number of years on the varsity roster in our study sample was three, which further justifies our calculations.

Total Athletes Between 1960 and 2020 (Seasons 1960-2020) = (1960 to 1971: Number of Teams x Average Squad Size x 1/3) + (1972 to 2020: Number of Teams x Average Squad Size x 1/4) = 814,122

 Total Athletes Ages 60 to 82 as of 2020 (Seasons 1960-1982) =

 (1960 to 1971: Number of Teams x Average Squad Size x 1/3) + (1972 to 1982: Number of Teams x Average Squad Size x 1/4) =

 = 251,309

eTable 1. University of Notre Dame (ND) Sample Survey Questionnaire and Health and Retirement Study (HRS) 2016 Survey: Variable Matching

| Characteristic (Matched Variable) | ND Variable | ND Question | HRS Variable | HRS Question |
|--------------------------------------|---|---|----------------------------------|--|
| | | | | |
| Age | age | How old are you currently? | PA019 | Current Age Calculation |
| Race | raceusacat1, raceusacat2, raceusacat3, raceusacat4 | What do you consider your current race? | PB089M1M PB089M2M PB089M3M | What race do you consider yourself to be? |
| Highest level of Education | edulevel | What is the highest grade or level of school you have completed or the highest degree obtained? | PB017M | What is the highest degree you have earned? |
| Married/Domestic partnership | marital | What is your current marital or partner status? | PB063 | Marital Status Assigned |
| Employment status | employ | What is your current employment status? | PJ005M1 | Are you working now, temporarily laid off, unemployed and looking for work, disabled and unable to work, retired, a homemaker, or what? |
| Living situation | home | What is your current living situation? | PH004 | Do you [and your] [husband/wife/partner] own your home, rent it, or what? |
| Cognitive impairment | dxd | Have you ever been diagnosed with, or treated for dementia, Alzheimer's disease, CTE, mild cognitive impairment, or something similar by a doctor or other healthcare provider? | PC273 | Has a doctor ever told you that you have dementia, senility or any other serious memory impairment? |
| Cardiovascular disease | heartdx | If "yes" to any of the following: Have you ever had a heart attack or myocardial infarction (MI)? Have you ever been diagnosed with coronary artery disease and/or blocked blood vessels to the heart? Have you ever been diagnosed with angina? Have you ever been diagnosed with congestive heart failure (CHF)? | PC036 | Has a doctor ever told you that you have had a heart attack, coronary heart disease, angina, congestive heart failure, or other heart problems? |

| | | Have you ever had or been in cardiac arrest (separate from heart attack above)? Have you ever been formally diagnosed with atrial fibrillation (AFib)? Have you ever been diagnosed with cardiomyopathy? Have you ever been diagnosed with valvular heart disease, or bad heart valve? Have you ever been diagnosed with congenital heart disease (present at birth)? | | |
|--------------------------------|------------------|--|---------------------------|--|
| Cardiovascular risk factors | hbp, hchol, diab | If "yes" to any of the following: Have you ever been formally diagnosed or treated with high blood pressure or hypertension? Have you ever been formally diagnosed or treated for high cholesterol? Have you ever been formally diagnosed or treated for diabetes? | PC005, PC283, PC010 | If "yes" to any of the following: Has a doctor ever told you that you have high blood pressure or hypertension? Have you ever been told by a doctor or other health professional that your blood cholesterol level was high? Has a doctor ever told you that you have diabetes or high blood sugar? |
| High blood pressure | hbp | Have you ever been formally diagnosed or treated with high blood pressure or hypertension? | PC005 | Has a doctor ever told you that you have high blood pressure or hypertension? |
| High cholesterol | hchol | Have you ever been formally diagnosed or treated for high cholesterol? | PC283 | Have you ever been told by a doctor or other health professional that your blood cholesterol level was high? |
| Diabetes | diab | Have you ever been formally diagnosed or treated for diabetes? | PC010 | Has a doctor ever told you that you have diabetes or high blood sugar? |
| Stroke | strktiatyp1 | Have you ever had a stroke or transient ischemic attack (TIA)? If yes: What event(s) did you have? Please check [+] all that apply. (choice=Stroke(s)) | PC053 | Has a doctor ever told you that you have had a stroke? |
| Psychiatric diagnosis | psychdx | If "yes" to any of the following: Have you ever been formally diagnosed or treated for depression? Have you ever been formally diagnosed or treated with anxiety? | PC065 | Have you ever had or has a doctor ever told you that you have any emotional, nervous, or psychiatric problems? |

| | | Have you ever been formally diagnosed or treated with Bipolar Disorder or Manic Depression? Have you ever been formally diagnosed or treated with Psychosis or Schizophrenia? Have you ever been formally diagnosed or treated with Post Traumatic Stress Disorder, also known as PTSD? Have you ever been diagnosed or treated for any other psychiatric, behavioral, or mood disorders? | | |
|-----------------------------|---------|--|-------|---|
| Depression | dpr | Have you ever been formally diagnosed with or treated for depression? | PC271 | Has a doctor ever told you that you have had problems with depression? |
| Sleep apnea | slapn | Have you ever been diagnosed with sleep apnea? | PC292 | What was the sleep disorder? (choice=1.Sleep Apnea) |
| Cancer | cancer | Have you ever been diagnosed with cancer? | PC018 | Has a doctor ever told you that you have cancer or a malignant tumor, excluding minor skin cancer? |
| Lung condition | lung | Have you ever been diagnosed with lung or pulmonary condition or disease (other than cancer)? | PC030 | Has a doctor ever told you that you have chronic lung disease such as chronic bronchitis or emphysema? |
| Alcohol use | alcfreq | How often do you have a drink containing alcohol? | PC128 | Do you ever drink any alcoholic beverages such as beer, wine, or liquor? |
| Alcohol frequency | alcfreq | How often do you have a drink containing alcohol? | PC129 | In the last three months, on average, how many days per week have you had any alcohol to drink? (For example, beer, wine, or any drink containing liquor.) |
| Alcohol number of drinks | alcnum | How many drinks containing alcohol do you have on a typical day when you are drinking? | PC130 | In the last three months, on the days you drink, about how many drinks do you have? |

HRS = Health and Retirement Study; ND = University of Notre Dame

eTable 2. Comparison of Former University of Notre Dame (ND) Players Who Completed the Survey and Those Who Did Not Complete the Survey^a

| | Completers | Non- | Р | FDR |
|------------------------------------|-------------|-------------|-------|------------------------------|
| | N=234 | Completers | value | Adjusted ^b |
| | | N=213 | | |
| Living Status, n (%) | | | <0.01 | <0.01 |
| Alive | 216 (92) | 155 (73) | | |
| Deceased | 18 (8) | 58 (27) | | |
| Senior Season, n (%) | | | 0.06 | 0.12 |
| 1964 | 7 (3) | 17 (8) | | |
| 1965 | 6 (3) | 14 (7) | | |
| 1966 | 15 (6) | 13 (6) | | |
| 1967 | 15 (6) | 8 (4) | | |
| 1968 | 14 (6) | 12 (6) | | |
| 1969 | 13 (6) | 15 (7) | | |
| 1970 | 16 (7) | 11 (5) | | |
| 1971 | 16 (7) | 20 (9) | | |
| 1972 | 16 (7) | 13 (6) | | |
| 1973 | 14 (6) | 20 (9) | | |
| 1974 | 18 (8) | 9 (4) | | |
| 1975 | 18 (8) | 8 (4) | | |
| 1976 | 20 (9) | 12 (6) | | |
| 1977 | 14 (6) | 7 (3) | | |
| 1978 | 7 (3) | 14 (7) | | |
| 1979 | 14 (6) | 11 (5) | | |
| 1980 | 11 (5) | 9 (4) | | |
| Number of Varsity Seasons at ND, n | | | 0.52 | 0.62 |
| (%) | | | | |
| 1 | 10 (4) | 9 (4) | | |
| 2 | 20 (9) | 19 (9) | | |
| 3 | 188 (80) | 162 (76) | | |
| 4 | 16 (7) | 23 (11) | | |
| Senior Year BMI, median (IQR) | 27.8 (26.0, | 27.8 (25.8, | 0.33 | 0.50 |
| | 29.5) | 29.9) | | |
| Position Played, n (%) | | | 0.80 | 0.80 |
| Lineman/Linebacker | 126 (54) | 115 (54) | | |
| Back/Receiver | 89 (38) | 82 (38) | | |

| Quarterback | 10 (4) | 11 (5) | | |
|-------------------------------------|---------|---------|-------|-------|
| Kicker | 9 (4) | 5 (2) | | |
| Professional Football Experience, n | 38 (16) | 62 (29) | <0.01 | <0.01 |
| (%) | | | | |

^aData reported for living and deceased ND players regardless of survey completion status. ^bFDR = False discovery rate correction for multiple testing BMI = Body mass index; FDR = False discovery rate; IQR = Interquartile range; ND = University of Notre Dame

| Health Outcome Variable | ND | HRS | P value | FDR |
|--------------------------------------|--------------------|----------|---------|----------|
| Nourological disorders n (%) | n=216 ⁸ | n=638 | | Adjusted |
| | | 0 (4) | 0.01 | 0.04 |
| | 11 (5) | 8(1) | <0.01 | <0.01 |
| Parkinson's disease ^d | 1 (1) | | | |
| Recurrent headaches | 22 (10) | 22 (4) | <0.01 | <0.01 |
| Vascular conditions, n (%) | | | | |
| Cardiovascular disease | 70 (33) | 128 (20) | <0.01 | <0.01 |
| Heart attack history ^d | 11 (5) | | | |
| Abnormal heart rhythm ^d | 44 (21) | | | |
| Artery blockage ^d | 33 (15) | | | |
| Valve problem ^d | 9 (4) | | | |
| Heart failure ^d | 7 (3) | | | |
| Heart surgery ^d | 30 (14) | | | |
| Cardiovascular risk factors | 150 (70) | 429 (68) | 0.45 | 0.55 |
| High blood pressure | 101 (47) | 340 (54) | 0.09 | 0.15 |
| High cholesterol | 112 (53) | 182 (29) | <0.01 | <0.01 |
| Diabetes | 24 (11) | 146 (23) | <0.01 | <0.01 |
| Stroke | 6 (3) | 31 (5) | 0.25 | 0.35 |
| Psychiatric diagnosis, n (%) | 37 (18) | 112 (18) | 0.96 | 0.96 |
| Depression | 32 (15) | 94 (15) | 0.85 | 0.90 |
| Anxiety ^d | 17 (8) | | | |
| Bipolar disorder ^d | 1 (1) | | | |
| Psychosis/Schizophrenia ^d | 0 (0) | | | |
| Neurodevelopmental diagnosis, n (%) | | | | |
| ADHD ^d | 6 (3) | | | |
| Dyslexia ^d | 5 (2) | | | |
| Sleep diagnosis, n (%) | | | | |
| Sleep apnea | 58 (27) | 124 (19) | 0.02 | 0.05 |

eTable 3. Non-Responder Weighted Health Outcomes: University of Notre Dame (ND) Players Compared with Health and Retirement Study (HRS) Sample^a

| Restless leg syndrome ^d | 2 (1) | | | |
|--|----------|----------|------|------|
| REM sleep behavior disorder ^d | 5 (2) | | | |
| Drthopedic, n (%) | | | | |
| Joint replacement ^d | 73 (34) | | | |
| Back surgery ^d | 24 (11) | | | |
| Other orthopedic surgery ^d | 127 (60) | | | |
| Other medical, n (%) | | | | |
| Cancer ^e | 33 (16) | 83 (13) | 0.22 | 0.35 |
| Lung condition | 17 (8) | 27 (4) | 0.04 | 0.07 |
| Liver disease ^d | 8 (4) | | | |
| Kidney disease ^d | 12 (6) | | | |
| Gastrointestinal disorder ^d | 28 (13) | | | |
| Eye disorder ^d | 47 (22) | | | |
| Thyroid condition ^d | 27 (13) | | | |
| Low testosterone ^d | 15 (7) | | | |
| lcohol use, n (%) | 184 (85) | 489 (77) | 0.01 | 0.03 |
| Frequency among users | | | 0.60 | 0.69 |
| Monthly or less | 25 (14) | 82 (17) | | |
| 2-4 times a month | 45 (24) | 114 (23) | | |
| 2-3 times a week | 55 (30) | 124 (25) | | |
| 4+ times a week | 60 (32% | 167 (34) | | |
| Number of drinks when drinking | | | 0.26 | 0.35 |
| 1 or 2 | 137 (74) | 324 (80) | | |
| 3 or 4 | 40 (22) | 65 (16) | | |
| 5+ | 7 (4) | 14 (4) | | |
| Drug use, n (%) | | | | |
| Illicit drug use ^d | 104 (49) | | | |
| Prescription drug abuse ^d | 11 (5) | | | |
| Performance enhancing drugs ^d | 10 (5% | | | |

^aSpecific wording of questions are provided in eTable 1. ^bData reported for living ND players who completed the survey.

 $^{\circ}$ FDR = False discovery rate correction for multiple testing

^dHRS data not available.

^eDoes not include non-melanoma skin cancer.

Note: This sensitivity analysis was conducted to examine the possible impact of a nonresponse bias (i.e., survey responders having different health outcomes than survey nonresponders). Inverse probability weights for each ND subject were calculated by running a logistic regression, with years of senior football season at ND, number of varsity football seasons played at ND, senior season BMI, position played, and professional versus non-professional as predictors, and the response to the survey question as the outcome variable.

Statistics presented: n (%); median (IQR), Statistical tests performed: chi-square test of independence; Fisher's exact test. ADHD = Attention deficit hyperactivity disorder; BMI = body mass index; FDR = False discovery rate eTable 4. Demographics of Former University of Notre Dame (ND) Players Who Only Played Through College Compared with Those Who Went on to Play Professional Football^a

| | ND College- | ND | Р | FDR |
|-------------------------------------|-------------|--------------|-------|------------------------------|
| | Only | Professional | value | Adjusted ^b |
| | N=183 | N=33 | | - |
| Age, y, median (IQR) | 67 (64, 70) | 66 (63, 71) | 0.90 | 0.90 |
| Race, White, n (%) | 173 (95) | 28 (85) | 0.06 | 0.20 |
| Years of Education, n (%) | | | 0.26 | 0.44 |
| 16, y | 72 (39) | 17 (52) | | |
| ≥17, y | 111 (61) | 16 (48) | | |
| Highest Level of Education, n (%) | | | 0.05 | 0.20 |
| Bachelor's degree | 90 (49) | 23 (70) | | |
| Master's degree | 48 (26) | 3 (9.1) | | |
| Doctoral/Professional degree | 45 (25) | 7 (21) | | |
| Married/Domestic Partnership, n (%) | 153 (84) | 27 (87) | 0.82 | 0.90 |
| Employment Status, n (%) | | | 0.66 | 0.82 |
| Full/Part-time | 105 (57) | 18 (55) | | |
| Retired | 75 (41) | 14 (42) | | |
| Disabled | 3 (2) | 1 (3) | | |
| Living Situation, n (%) | | | 0.12 | 0.29 |
| Home Owner | 172 (94) | 28 (85) | | |
| Renter | 7 (4) | 3 (9) | | |
| Other | 4 (2) | 2 (6) | | |
| Senior Year BMI, median (IQR) | 27.4 (25.8, | 28.4 (26.4, | 0.31 | 0.45 |
| | 29.5) | 29.7) | | |
| Position Played, n (%) ^c | | | 0.01 | 0.05 |
| Lineman/Linebacker | 95 (52) | 20 (61) | | |
| Back/Receiver | 75 (41) | 8 (24) | | |
| Quarterback | 4 (2) | 5 (15) | | |
| Kicker | 9 (5) | 0 (0) | | |

^aData reported for only living ND players who completed the survey.

^bFDR = False discovery rate correction for multiple testing

^cLineman/Linebacker and Back/Receiver groups include both offensive and defensive positions.

Note: Statistics presented: n (%); median (IQR), Statistical tests performed: chi-square test of independence; Fisher's exact test. BMI = body mass index; FDR = False discovery rate; IQR = Interquartile range; ND = University of Notre Dame

eTable 5. Health Outcomes: Former University of Notre Dame (ND) Players Who Only Played Through College Compared with Those Who Went on to Play Professional Football^a

| | ND College- | ND | Р | FDR |
|-------------------------------------|-------------|--------------|-------|-----------------------|
| | Only | Professional | value | Adjusted ^b |
| | N=183 | N=33 | | |
| Neurological disorders, n (%) | | | | |
| Cognitive impairment diagnosis | 5 (3) | 5 (15) | 0.01 | 0.13 |
| Parkinson's disease | 1 (1) | 0 (0) | >0.99 | >0.99 |
| Recurrent headaches | 17 (9) | 5 (15) | 0.35 | 0.93 |
| Vascular conditions, n (%) | | | | |
| Cardiovascular disease | 61 (34) | 9 (28) | 0.66 | >0.99 |
| Heart attack history | 11 (6) | 0 (0) | 0.22 | 0.77 |
| Abnormal heart rhythm | 36 (20) | 8 (25) | 0.67 | >0.99 |
| Artery blockage | 32 (17) | 1 (3) | 0.06 | 0.46 |
| Valve problem | 9 (5) | 0 (0) | 0.36 | 0.93 |
| Heart failure | 6 (3) | 1 (3) | >0.99 | >0.99 |
| Heart surgery | 30 (16) | 0 (0) | 0.01 | 0.13 |
| Cardiovascular risk factors | 130 (72) | 20 (61) | 0.26 | 0.80 |
| High blood pressure | 91 (50) | 11 (33) | 0.11 | 0.69 |
| High cholesterol | 95 (53) | 16 (48) | 0.79 | >0.99 |
| Diabetes | 21 (12) | 3 (9) | >0.99 | >0.99 |
| Stroke | 4 (2) | 2 (6) | 0.23 | 0.77 |
| Psychiatric diagnosis, n (%) | 27 (15) | 8 (26) | 0.23 | 0.77 |
| Depression | 22 (12) | 8 (26) | 0.05 | 0.46 |
| Anxiety | 14 (8) | 3 (9) | 0.73 | >0.99 |
| Bipolar disorder | 0 (0) | 1 (3) | 0.15 | 0.76 |
| Psychosis/Schizophrenia | 0 (0) | 0 (0) | >0.99 | >0.99 |
| Neurodevelopmental diagnosis, n (%) | | | | |
| ADHD | 5 (3) | 1 (3) | >0.99 | >0.99 |
| Dyslexia | 4 (2) | 1 (3) | 0.56 | >0.99 |
| Sleep diagnosis, n (%) | | | | |
| Sleep apnea | 49 (27) | 9 (27) | >0.99 | >0.99 |
| Restless leg syndrome | 2 (1) | 0 (0) | >0.99 | >0.99 |
| REM sleep behavior disorder | 4 (2) | 1 (3) | 0.58 | >0.99 |
| Orthopedic, n (%) | | | | |
| Joint replacement | 60 (33) | 13 (39) | 0.59 | >0.99 |
| Back surgery | 21 (11) | 3 (9) | >0.99 | >0.99 |

| Other orthopedic surgery | 107 (59) | 20 (62) | 0.87 | >0.99 |
|---|-------------|-------------|-------|-------|
| Other medical, n (%) | | | | |
| Cancer ^c | 34 (20) | 1 (3) | 0.04 | 0.45 |
| Lung condition | 14 (8) | 3 (9) | 0.73 | >0.99 |
| Liver disease | 6 (3) | 2 (6) | 0.35 | 0.93 |
| Kidney disease | 10 (6) | 2 (6) | >0.99 | >0.99 |
| Gastrointestinal disorder | 22 (12) | 6 (18) | 0.40 | 0.94 |
| Eye disorder | 41 (23) | 6 (18) | 0.70 | >0.99 |
| Thyroid condition | 23 (13) | 4 (12) | >0.99 | >0.99 |
| Low testosterone | 13 (7) | 2 (6) | >0.99 | >0.99 |
| Alcohol use, n (%) | 158 (86) | 27 (82) | 0.59 | >0.99 |
| Frequency among users | | | 0.41 | 0.94 |
| Monthly or less | 20 (13) | 5 (19) | | |
| 2-4 times a month | 36 (23) | 9 (33) | | |
| 2-3 times a week | 48 (30) | 7 (26) | | |
| 4+ times a week | 54 (34) | 6 (22) | | |
| Number of drinks when drinking | | | >0.99 | >0.99 |
| 1 or 2 | 117 (75) | 20 (74) | | |
| 3 or 4 | 34 (22) | 6 (22) | | |
| 5+ | 6 (4) | 1 (4) | | |
| Drug use, n (%) | | | | |
| Illicit drug use | 90 (50) | 14 (44) | 0.67 | >0.99 |
| Prescription drug abuse | 11 (6) | 0 (0) | 0.22 | 0.77 |
| Performance enhancing drugs | 5 (3) | 5 (16) | 0.01 | 0.13 |
| Satisfaction with Life, median (IQR) ^d | 30 (27, 33) | 28 (24, 32) | 0.13 | 0.69 |

^aData reported for only living ND players who completed the survey ^bFDR = False discovery rate correction for multiple testing

^cDoes not include non-melanoma skin cancer.

^dBased on the Satisfaction with Life Scale³

Note: Statistics presented: n (%); median (IQR), Statistical tests performed: chi-square test of independence; Fisher's exact test. ADHD = Attention deficit hyperactivity disorder; FDR = False discovery rate; IQR = Interquartile range; ND = University of Notre Dame

| | Lineman or | Back or Receiver | Quarterback | Kicker | P value | FDR Adjusted ^b |
|---------------------------------|------------|---------------------|-------------|--------|---------|------------------------------|
| | N=115 | N=83 | 11-0 | 11-0 | | Auguotou |
| Neurological Disorders, n (%) | | | | | | |
| Cognitive impairment diagnosis | 7 (6) | 3 (4) | 0 (0) | 0 (0) | 0.41 | 0.94 |
| Parkinson's disease | 0 (0) | 0 (0) | 0 (0) | 1 (11) | 0.08 | 0.68 |
| Recurrent headaches | 11 (10) | 9 (11) | 2 (22) | 0 (0) | 0.49 | 0.94 |
| Vascular Conditions, n (%) | | | | | | |
| Cardiovascular disease | 38 (33) | 27 (34) | 2 (22) | 3 (33) | 0.96 | >0.99 |
| Heart attack history | 3 (3) | 8 (10) | 0 (0) | 0 (0) | 0.19 | 0.79 |
| Abnormal heart rhythm | 30 (26) | 13 (16) | 0 (0) | 1 (11) | 0.15 | 0.79 |
| Artery blockage | 14 (12) | 16 (19) | 2 (22) | 1 (11) | 0.43 | 0.94 |
| Valve problem | 5 (4) | 3 (4) | 0 (0) | 1 (11) | 0.63 | >0.99 |
| Heart failure | 3 (3) | 4 (5) | 0 (0) | 0 (0) | 0.71 | >0.99 |
| Heart surgery | 10 (9) | 19 (23) | 1 (11) | 0 (0) | 0.03 | 0.67 |
| Cardiovascular risk factors | 77 (68) | 63 (76) | 6 (67) | 4 (50) | 0.34 | 0.94 |
| High blood pressure | 61 (54) | 34 (41) | 3 (33) | 4 (44) | 0.24 | 0.88 |
| High cholesterol | 50 (45) | 53 (64) | 4 (44) | 4 (44) | 0.05 | 0.67 |
| Diabetes | 13 (11) | 10 (12) | 1 (11) | 0 (0) | 0.94 | >0.99 |
| Stroke | 3 (3) | 3 (4) | 0 (0) | 0 (0) | 0.82 | >0.99 |
| Psychiatric diagnosis, n (%) | 21 (19) | 14 (17) | 0 (0) | 0 (0) | 0.41 | 0.94 |
| Depression | 19 (17) | 11 (13) | 0 (0) | 0 (0) | 0.47 | 0.94 |
| Anxiety | 9 (8) | 8 (10) | 0 (0) | 0 (0) | 0.96 | >0.99 |
| Bipolar disorder | 1 (1) | 0 (0) | 0 (0) | 0 (0) | >0.99 | >0.99 |
| Psychosis/Schizophrenia | 0 (0) | 0 (0) | 0 (0) | 0 (0) | >0.99 | >0.99 |
| Neurodevelopmental diagnosis, n | | | | | | |
| (%) | | | | | | |
| ADHD | 4 (4) | 2 (3) | 0 (0) | 0 (0) | >0.99 | >0.99 |
| Dyslexia | 5 (4) | 0 (0) | 0 (0) | 0 (0) | 0.20 | 0.79 |
| Sleep diagnosis, n (%) | | | | | | |
| Sleep apnea | 32 (28) | 23 (28) | 0 (0) | 3 (33) | 0.30 | 0.94 |
| Restless leg syndrome | 1 (1) | 1 (1) | 0 (0) | 0 (0) | >0.99 | >0.99 |
| REM sleep behavior disorder | 2 (2) | 2 (3) | 0 (0) | 1 (12) | 0.29 | 0.94 |
| Orthopedic, n (%) | | | | | | |
| Joint replacement | 42 (37) | 28 (34) | 1 (11) | 2 (22) | 0.45 | 0.94 |
| Back surgery | 17 (15) | 7 (8) | 0 (0) | 0 (0) | 0.34 | 0.94 |

eTable 6. Health Outcomes: Former University of Notre Dame (ND) Players by Position^a

| Other orthopedic surgery | 64 (57) | 52 (63) | 5 (62) | 6 (67) | 0.83 | >0.99 |
|---|-------------|-------------|-------------|-------------|-------|-------|
| Other medical, n (%) | | | | | | |
| Cancer ^c | 18 (17) | 15 (19) | 0 (0) | 2 (25) | 0.54 | >0.99 |
| Lung condition | 9 (8) | 6 (7) | 1 (11) | 1 (11) | 0.74 | >0.99 |
| Liver disease | 5 (4) | 3 (4) | 0 (0) | 0 (0) | >0.99 | >0.99 |
| Kidney disease | 5 (4) | 6 (7) | 1 (11) | 0 (0) | 0.46 | 0.94 |
| Gastrointestinal disorder | 14 (12) | 9 (11) | 3 (33) | 2 (22) | 0.16 | 0.79 |
| Eye disorder | 32 (28) | 12 (15) | 0 (0) | 3 (33) | 0.04 | 0.67 |
| Thyroid condition | 14 (12) | 10 (12) | 2 (22) | 1 (11) | 0.80 | >0.99 |
| Low testosterone | 8 (7) | 4 (5) | 0 (0) | 3 (33) | 0.06 | 0.67 |
| Alcohol use, n (%) | | | | | | |
| Frequency among users | | | | | 0.77 | >0.99 |
| Monthly or less | 17 (17) | 7 (10) | 0 (0) | 1 (12) | | |
| 2-4 times a month | 24 (24) | 18 (26) | 2 (29) | 1 (12) | | |
| 2-3 times a week | 26 (2) | 22 (32) | 4 (57) | 3 (38) | | |
| 4+ times a week | 34 (34%) | 22 (32) | 1 (14) | 3 (38) | | |
| Number of drinks when drinking | | | | | 0.09 | 0.68 |
| 1 or 2 | 69 (69) | 58 (84) | 5 (71) | 5 (62) | | |
| 3 or 4 | 25 (25) | 11 (16) | 2 (29) | 2 (25) | | |
| 5+ | 6 (6) | 0 (0) | 0 (0) | 1 (12) | | |
| Drug use, n (%) | | | | | | |
| Illicit drug use | 50 (44) | 44 (54) | 4 (44) | 6 (67) | 0.41 | 0.94 |
| Prescription drug abuse | 7 (6) | 4 (5) | 0 (0) | 0 (0) | 0.91 | >0.99 |
| Performance enhancing drugs | 5 (4) | 4 (5) | 1 (11) | 0 (0) | 0.73 | >0.99 |
| Satisfaction with Life, median (IQR) ^d | 31 (26, 33) | 30 (26, 32) | 34 (30, 35) | 29 (28, 33) | 0.16 | 0.79 |

^aData reported for only living ND players who completed the survey ^bFDR = False discovery rate correction for multiple testing ^cDoes not include non-melanoma skin cancer.

^dBased on the Satisfaction with Life Scale³

ADHD = Attention deficit hyperactivity disorder; FDR = False discovery rate; IQR = Interquartile range; ND = University of Notre Dame

| | | ND College-Only | | Lincoln et. al (2018) ⁴ | | Lehman et. al (2012) ⁵ | |
|---|---|-----------------|-------------------|------------------------------------|------------------|-----------------------------------|------------------|
| Cause of death | | Ν | SMR (95% CI) | Ν | SMR (95% CI) | Ν | SMR (95% CI) |
| All-cause | | | 0.51 (0.39-0.67) | 227 | 0.46 (0.40-0.52) | 334 | 0.53 (0.48–0.59) |
| | All cancers | | 0.60 (0.34-0.97) | 23 | 0.41 (0.26-0.62) | 85 | 0.58 (0.46–0.72) |
| | Benign and unspecified nature neoplasms ^b | 0 | 0.00 (0.00-11.45) | 1 | 0.75 (0.02-4.16) | | |
| | Diseases of blood and blood-forming organs ^b | | 0.00 (0.00-7.89) | 1 | 0.34 (0.01-1.88) | | |
| | Diabetes mellitus ^b | | 0.57 (0.07-2.07) | 4 | 0.38 (0.10-0.96) | | |
| | Mental, psychoneurotic, and personality disorders ^b | | 0.46 (0.01-2.58) | 2 | 0.23 (0.03-0.82) | | |
| | Diseases of the nervous system and sense organs ^b | 2 | 0.96 (0.12-3.45) | 5 | 0.65 (0.21-1.53) | | |
| | Neurodegenerative causes ^{b,c} | 2 | 1.22 (0.15-4.41) | | | 10 | 2.83 (1.36–5.21) |
| | Alzheimer's disease ^b | 0 | 0.00 (0.00-5.14) | | | 2 | 1.80 (0.22–6.50) |
| | Amyotrophic lateral sclerosis ^b | 1 | 1.85 (0.05-10.31) | | | 6 | 4.04 (1.48-8.79) |
| | Parkinson's disease ^b | 1 | 2.63 (0.07-14.63) | | | 2 | 2.14 (0.26–7.75) |
| | Other diseases of the nervous system and sense organs ^b | 0 | 0.00 (0.00-8.31) | | | | |
| | Diseases of the heart | 16 | 0.69 (0.39-1.12) | 47 | 0.68 (0.50-0.90) | 126 | 0.68 (0.56–0.81) |
| | Hypertension w/heart disease ^b | 1 | 0.49 (0.01-2.73) | 8 | 0.87 (0.38-1.71) | | |
| | Ischemic heart disease ^b | 12 | 0.74 (0.38-1.30) | 22 | 0.58 (0.36-0.87) | | |
| | Cardiomyopathy ^b | 0 | 0.00 (0.00-2.43) | 7 | 0.75 (0.30-1.54) | | |
| | Conduction disorder ^b | 2 | 1.34 (0.16-4.86) | 3 | 0.63 (0.13-1.84) | | |
| | Other heart disease ^b | 1 | 0.64 (0.02-3.55) | 7 | 1.17 (0.47-2.41) | | |
| | Other diseases of the circulatory system ^b | 2 | 0.31 (0.04-1.13) | 12 | 0.56 (0.29-0.98) | | |
| | Cerebrovascular disease ^b | 2 | 0.52 (0.06-1.88) | 6 | 0.53 (0.19-1.14) | | |
| | Diseases of the arteries, veins, and lymphatic vessels ^b | 0 | 0.00 (0.00-2.19) | 6 | 0.85 (0.31-1.85) | | |
| | Diseases of the respiratory system ^b | 0 | 0.00 (0.0-0.61) | 2 | 0.15 (0.02-0.53) | | |
| | Diseases of the digestive system ^b | 0 | 0.00 (0.00-0.65) | 8 | 0.41 (0.18-0.80) | | |
| | Diseases of musculoskeletal and connective tissue ^b | 0 | 0.00 (0.00-11.24) | 1 | 0.61 (0.01-3.42) | | |
| Diseases of the genitourinary system ^b | | 0 | 0.00 (0.00-1.93) | 1 | 0.17 (0.00-0.96) | | |
| Symptoms and ill-defined conditions ^b | | 0 | 0.00 (0.00-2.24) | 7 | 0.64 (0.26-1.32) | | |
| | Transportation injuries ^b | 1 | 0.19 (0.00-1.08) | 34 | 0.65 (0.45-0.91) | | |
| | Falls ^b | 0 | 0.00 (0.00-4.55) | 2 | 0.58 (0.07-2.10) | | |

eTable 7. Standardized Mortality Ratios for Former University of Notre Dame (ND) Players Who Only Played Through College Compared with Other Studies of Former National Football League (NFL) Players^a

| Other injuries | | 1 | 0.21 (0.01-1.17) | 24 | 0.53 (0.34-0.79) | 41 | 0.63 (0.45–0.86) |
|----------------------|--------------------------------------|----|-----------------------------|----|------------------|----|------------------|
| Drowning | g ^b | 1 | 1.93 (0.05-10.75) | 2 | 0.45 (0.05-1.61) | | |
| Forces of | f nature ^b | 0 | 0.00 (0.00-23.40) | 3 | 2.74 (0.56-8.00) | | |
| Accident | al poisoning ^b | 0 | 0.00 (0.00-2.01) | 15 | 0.64 (0.36-1.06) | | |
| Other inj | ury undetermined intent ^b | 0 | 0.00 (0.00-6.46) | 2 | 0.36 (0.04-1.29) | | |
| Other inj | uries ^b | 0 | 0.00 (0.00-7.41) | 2 | 0.55 (0.07-1.99) | | |
| Violence | | 1 | 0.14 (0.00-0.76) | 39 | 0.38 (0.27-0.52) | 13 | 0.27 (0.14–0.46) |
| Intentional | self-harm ^b | 1 | 0.29 (0.01-1.64) | 20 | 0.58 (0.35-0.90) | | |
| Assault and | d homicide ^b | 0 | 0.00 (0.00-0.93) | 19 | 0.28 (0.17-0.43) | | |
| Other and uns | specified causes | 1 | 0.22 (0.01-1.25) | 14 | 0.69 (0.38-1.16) | 59 | 0.34 (0.26–0.43) |
| Unknown ^b | | 12 | Not applicable ^d | | | | |

^aStandardized mortality ratios (SMRs) were calculated based on age, sex, and race with the Life Table Analysis System46 (LTAS.NET version 4.5.0) using U.S. male mortality rates (1960-2014) for 119 cause of death categories. Only Underlying Cause SMRs are presented. Multiple Cause data were also assessed and did not meaningfully change the results. Total University of Notre Dame cohort (regardless of living status or survey completion): N = 447.

^bData not available in all studies.

°SMRs for three neurodegenerative causes of death assessed with updated custom rate files utilized in previous studies.^{29,48}

^dWe were unable to locate causes of death for a subset of individuals. The LTAS.NET⁴⁶ software does not calculate SMRs for "Unknown" causes of death.

CI = Confidence internal; ND = Notre Dame; SMR = Standard mortality ratio

Supplemental References

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