[Primary Care]

Life Span Exercise Among Elite Intercollegiate Student Athletes

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Background: Despite prominent public attention, data on life span health and exercise outcomes among elite, competitive athletes are sparse and do not reflect the diversity of modern athletes.

Hypothesis: Life span exercise behavior differs between National Collegiate Athletic Association (NCAA) student athletes and a nonathlete control group. Sustained exercise is associated with improved cardiopulmonary health outcomes.

Study Design: Cross-sectional, descriptive epidemiology study.

Level of Evidence: Level 3.

Methods: A total of 496 students and alumni (age range, 17-84 years) at a large, NCAA Division I university, including student athletes and an age- and sex-matched nonathlete control group, completed anonymous, self-report health and exercise questionnaires. Age-stratified, cross-sectional analysis evaluated previous week's total exercise volume (ExVol), self-rated exercise importance (ExImp), and compliance with American College of Sports Medicine (ACSM) exercise guidelines for healthy adults. The association of ACSM guideline compliance with lifetime cardiopulmonary health outcomes was also assessed.

Results: Current student athletes reported significantly greater ExVol ($P < 0.001$, Cohen $d = 0.99$, probability of clinically important difference [pCID] >99.5%), ExImp ($P < 0.001$, $d = 1.96$, pCID = 96%), and likelihood of compliance with ACSM guidelines (odds ratio [OR], 95% confidence interval [CI] = 30.6, 11.0-84.6) compared with nonathletes. No significant differences were found between alumni student athletes and nonathletes. Alumni student athletes demonstrated substantially lower ExVol ($P < 0.001$, $d = -0.94$, pCID >99.5%) and guideline compliance (OR = 0.09, 95% CI = 0.05-0.19) compared with current student athletes, whereas nonathletes had similar exercise behavior across their life spans. Among alumni, ACSM guideline compliance was associated with significant attenuation of cardiopulmonary health concerns ($P = 0.02$, $d = -0.50$, pCID = 14%) independent of intercollegiate athletic participation.

Conclusion: Although current NCAA Division I student athletes demonstrated significant, clinically important differences in exercise behavior compared with nonathletes, no group differences were evident later in life. Irrespective of collegiate athletic status, healthy exercise behavior among alumni was associated with cardiopulmonary health benefits.

Clinical Relevance: To realize life span health benefits, it is imperative that student athletes maintain consistent patterns of healthy exercise beyond retirement from competitive sports.

Keywords: athletes; cardiopulmonary; questionnaires; NCAA; life span exercise

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The long-term health impact of elite competitive sports participation is receiving increasing public attention and scrutiny. Accounts of joint injury,[30] cardiopulmonary disease,[3] head injury,[25] and related psychosocial health concerns[1] have prompted investigations from the US Congress,[14,15] compelled organizations such as the National Collegiate Athletic Association (NCAA) to make far-reaching policy changes,[35] and brought about legal accountability.[7] Enhanced understanding and promotion of athletes' health has emerged as an imminent priority, yet scientific data concerning life span health and exercise among elite athletes remain surprisingly sparse.

Regular exercise provides well-established health benefits, including reduced all-cause mortality and cardiovascular disease (CVD), increased muscle strength, preserved bone mass, reduced fall risk, and improved measures of integrated and psychosocial health, including depression, anxiety, cognitive function, overall well-being, and quality of life.[8] Elite competitive athletes participate in routine, organized exercise training and have greater cardiorespiratory fitness, strength, and power compared with the general population, all of which are positively associated with health.[6,10] At the same time, competitive sports also carry well-recognized health risks.[11,16]

Importantly, it is unclear whether young adult athletes maintain their exercise behavior and attitudes across their life spans or how those factors relate to long-term health. Data from the Finnish former athlete cohort demonstrated that athletes had greater lifetime physical activity and reduced risk of CVD.[18] Similarly, Lynch et al[19] reported higher levels of physical activity from ages 20 to 64 years among retired National Football League (NFL) players, along with reduction of select CVD risk factors. In contrast, other investigators have reported no association between high school and college sports participation and later physical activity patterns[2,5] and a higher risk of CVD among former athletes no longer involved in sports.[23] Additional research is needed to understand the overall balance of risks versus rewards.

The increasingly intensive, structured, and specialized nature of modern sports brings into question the generalizability of previous studies.[17] Additionally, the sexes and racial diversities of modern athletes are not reflected by research studies to date. NCAA intercollegiate athletics include more than 440,000 active participants in 23 sports[22]—one of the broadest representations of today's elite competitive athletes. We are unaware of any studies to date evaluating life span exercise among current and former NCAA athletes compared with a representative control group.

Therefore, as part of a collaborative research and education program—Trojan Lifetime Champions (TLC)—we assessed life span health, exercise, and health-related quality of life (HRQoL) among current and former university students, including NCAA intercollegiate student athletes. The primary objective of the present study was to document life span exercise behaviors and attitudes. A secondary goal was to evaluate the association between exercise behavior and cardiopulmonary health.

METHODS

Study Design

This cross-sectional epidemiological study included students and alumni of the University of Southern California, a large, NCAA Division I university. Current and former varsity student athletes and nonathletes completed anonymous questionnaires documenting lifetime physical, mental, and emotional health; HRQoL; and exercise behaviors and attitudes. Each participant provided informed consent, and the experimental protocol was approved by the University of Southern California Health Sciences Institutional Review Board.

Participants

Participants included a convenience sample of student athletes and nonathletes. Student athletes must have practiced or competed in Division I intercollegiate athletics at the University of Southern California. Nonathletes were current and former undergraduate University of Southern California students who never practiced or competed in Division I intercollegiate athletics or organized club sports at any university.

Study participants were recruited using athletic department and university records, student and alumni organizations, and personal referrals. The study population was selected to provide a representative cross-section of the University of Southern California student athlete source population[27] and a control group of similar age and sex distribution.

Data Collection

Participants anonymously completed the TLC survey (see Appendix 1, available at http://sph.sagepub.com/content/suppl). Details of the survey, including a formal validity and reliability assessment, have been described elsewhere.[27] Briefly, the questionnaire recorded basic demographic information (age, sex, ethnicity, height, and weight), history of intercollegiate sports participation, a standard HRQoL measure (Short Form–12 [SF-12v2]),[31] a health inventory including 6 domains (joint, bone and muscle, cardiopulmonary, neurological, other clinical, and psychosocial), recent (previous week's) exercise, and perceptions of exercise and health. All participants received a $5 coffeehouse gift card incentive, as approved by the University of Southern California Office of Athletic Compliance.

Previous week's exercise was compared with guidelines for healthy adults published by the American College of Sports Medicine (ACSM).[10] The survey did not distinguish between formally organized, structured, supervised exercise (eg, sports training) and informal and/or unsupervised recreational physical activity. Self-reported exercise importance was measured using a 4-point ordinal scale.

Current student athletes represented all 20 varsity sports and approximately 74% of the student athlete population. This sample was considered representative of the overall source population. The survey response rate among alumni recruited for the study was 79%, including 76% of student athletes and 82% of nonathletes. Responders and nonresponders were

similar in sex, age, intercollegiate sports participation, and survey type (ie, paper vs electronic).[27] Thirty-four surveys containing incomplete or illegible data (27 current student athletes, 6 nonathlete current students, and 1 nonathlete alumnus) were excluded.

Data Analysis

Descriptive statistics (mean [standard deviation] or number [percentage]) were calculated to compare demographic characteristics of student athletes and nonathletes. Primary independent variables included intercollegiate athletic participation (ie, student athlete vs nonathlete) and age. Participants were classified into age groups as follows: current students, younger alumni, and older alumni. Younger and older alumni were stratified based on the median age (43 years) of alumni participants.

Primary dependent variables included total exercise volume, exercise importance, and rate of compliance with ACSM healthy exercise guidelines.[10] Exercise importance was modeled as a continuous variable. Compliance with ACSM exercise guidelines was computed as a dichotomous outcome, where compliant participants reported total exercise volume of ≥150 minutes and ≥2 resistance exercise sessions.

Our secondary interest was the association between cardiopulmonary domain summary scores and ACSM exercise guideline compliance. The summary score reflected a study participant's cumulative lifetime experience with cardiopulmonary health concerns, with a score of 0 indicating "perfect" health and higher scores indicating greater evidence of concerns.[27] The maximum possible score was 24.

All data were screened for integrity, including identification of spurious and outlier values.[27] All spurious and outlier data—including exercise data for 4 student athletes (0.9% of sample)—were excluded from subsequent statistical analysis.

For the primary analysis, stratified assessment of age and athletic participation effects on exercise volume and exercise importance was conducted using independent-samples *t* tests and magnitude-based methods.[12,13] Magnitude-based assessments include probabilistic interpretation of effects relative to a priori threshold values of substantial clinical meaning and may be a preferred alternative to traditional hypothesis testing versus the null value.[13] Threshold values were as follows: total weekly exercise volume (150 minutes, corresponding to the minimum ACSM guidelines for healthy adults)[10] and self-reported exercise importance (1 unit, corresponding to the minimum precision for the 4-point TLC exercise importance scale). The TLC survey has demonstrated adequate precision to detect effects of this magnitude.[27] A significance level of $\alpha = 0.05$ was used for the traditional statistical tests. Probabilistic interpretation of magnitude-based tests utilized the following scale, based on the guidelines of Hopkins et al[13]: <0.5%, most unlikely; 0.5% to 5%, very unlikely; 5% to 25%, unlikely; 25% to 75%, possibly; 75% to 95%, likely; 95% to 99.5%, very likely; and >99.5%, most likely.

In the secondary analysis, relative odds of ACSM exercise guideline compliance were evaluated using unconditional logistic regression (odds ratios with 95% confidence intervals) stratified across the primary independent variables. The Tarone test of homogeneity was used to assess the validity of Mantel-Haenszel common odds ratios across strata. Common odds are reported where the Tarone test indicated homogeneity ($P > 0.05$), and crude odds are reported otherwise.

Finally, we conducted an age-stratified analysis of cardiopulmonary health, with ACSM exercise guideline compliance as an independent factor. Independent-samples *t* tests and magnitude-based methods were utilized, with a 2-unit a priori threshold for substantial clinical meaning.

Sex, ethnicity, height, body mass, and body mass index (BMI) were evaluated as potential analysis covariates. Sex and ethnicity were excluded because of small sample size ($n < 10$) in selected combinations of the independent variables. Following assessment of confounding criteria,[24] analysis of covariance model assumptions (eg, homogeneity of variance and regression), and covariate effect magnitudes, the influence of each covariate was deemed minimal. Therefore, unadjusted values are reported throughout.

Statistical analyses were conducted using SPSS version 16 (SPSS, Inc, Chicago, Illinois), Intercooled STATA version 10 (StataCorp, College Station, Texas), and Hopkins' spreadsheet for magnitude-based inferences.[12]

RESULTS

Age and sex distributions were similar between the student athlete alumni source and study populations. There was a statistically significant difference in sport distribution between the alumni source and study populations (see Appendix 2, available at http://sph.sagepub.com/content/suppl). Subsequent to outlier screening, data from 4 participants (3 current and 1 alumni student athlete) were excluded from analysis.

Student athletes (SAs) were similar to nonathletes (NAs) in age and sex distribution (Table 1). SAs were taller and heavier but had similar BMI. The SAs had a lower proportion of Asian participants and a higher proportion of White participants than the NAs.

On average, current SAs reported more than 15 hours of exercise (Appendix 3 [available at http://sph.sagepub.com/content/suppl], Figure 1), substantially more than the approximate 4 hours reported by NAs ($P < 0.001$, Cohen $d = 0.99$, probability of clinically important difference [pCID] >99.5% [most likely]). A large majority (86%) of current SAs met the ACSM recommended weekly exercise guidelines. Current SAs were more than 30 times as likely as current NAs to do so. Current SAs reported significantly higher exercise importance than NAs ($P < 0.001$, Cohen $d = 1.96$, pCID = 96% [very likely]).

In contrast, no appreciable differences in exercise behavior or perceptions were found between alumni SAs and NAs, with comparable weekly exercise volumes between groups, small effect sizes, and little evidence of clinically relevant differences

Table 1. Demographic characteristics for participants in the Trojan Lifetime Champions study, 2008-2011

Characteristics	Current Students			Alumni		
	Student Athletes (n = 380)	Nonathletes (n = 31)	*P* Value[a]	Student Athletes (n = 44)	Nonathletes (n = 41)	*P* Value[a]
Demographics, mean (SD)						
Age, y	19.6 (1.3)	19.8 (1.3)	0.34	45.6 (16.2)	46.2 (16.7)	0.88
Age range, y	17-23	18-22		24-77	24-84	
Height, cm	180.7 (11.2)	169.8 (9.2)	<0.001	180.8 (10.0)	172.2 (11.3)	<0.001
Mass, kg	79.0 (18.0)	66.8 (12.0)	<0.001	86.7 (17.1)	75.3 (17.6)	0.004
BMI, kg/m^2	24.1 (3.5)	23.1 (3.6)	0.12	26.3 (4.2)	25.1 (3.5)	0.18
Intercollegiate athletic experience, y	1.5 (1.3)	n/a	n/a	3.0 (1.3)	n/a	n/a
Sex, n (%)						
Male	208 (55)	15 (48)	0.58	32 (73)	25 (61)	0.36
Female	171 (45)	16 (52)		12 (27)	16 (39)	
Ethnicity, n (%)[b]						
White	240 (64)	12 (39)	<0.001	38 (88)	28 (68)	0.01
Black	52 (14)	4 (13)		3 (7)	2 (5)	
Hispanic	21 (6)	5 (16)		0 (0)	0 (0)	
Asian	22 (6)	8 (26)		0 (0)	9 (22)	
Other	42 (11)	2 (7)		2 (5)	2 (5)	

BMI, body mass index (calculated as mass in kilograms divided by height in meters squared); n/a, not applicable; SD, standard deviation.
[a]*P* values are for independent-samples *t* tests for age, height, mass, and BMI, and χ^2 proportion tests for sex and ethnicity.
[b]Because of rounding, percentages may not total 100. Four student-athletes responded "Prefer Not to Answer" to ethnicity. One student athlete did not provide sex data.

(see Appendices 3 and 4, available at http://sph.sagepub.com/content/suppl). Alumni SAs and NAs were equally likely (~40%) to meet ACSM exercise guidelines and had similar self-rated exercise importance. While NAs demonstrated consistent exercise patterns across the 3 age strata, alumni SAs reported significantly lower exercise volume compared with current SAs (see Appendix 4) and were approximately 10% as likely as current SAs to meet ACSM exercise guidelines.

Collapsed across intercollegiate athletic participation groups, alumni demonstrated differences in cardiopulmonary health associated with exercise behavior (Table 2, Figure 2). Participants who were compliant with ACSM exercise guidelines reported significantly better cardiopulmonary health. Effect sizes were moderate. The probability of clinically relevant differences was most unlikely (<0.5%) among younger alumni and possible (48%) among older alumni.

DISCUSSION

In this cross-sectional epidemiological study, current NCAA Division I intercollegiate student athletes reported substantially higher clinically relevant volumes of weekly exercise, perceived exercise importance, and likelihood of compliance with ACSM healthy exercise guidelines compared to an age- and sex-matched nonathlete control group of university students. However, no significant differences were found between alumni student athletes and nonathletes, suggesting that former student athletes fail to maintain elevated levels of exercise across their

Table 2. Cardiopulmonary health and exercise behavior for participants in the TLC Study, 2008-2011: Age-stratified comparison of cardiopulmonary health concerns, according to compliance with ACSM weekly exercise guidelines for healthy adults[a]

Measure	Age Group					
	Current Students		Younger Alumni		Older Alumni	
	ACSM Compliant	Not ACSM Compliant	ACSM Compliant	Not ACSM Compliant	ACSM Compliant	Not ACSM Compliant
Cardiopulmonary summary score, mean (SD)	0.33 (0.77)	0.53 (1.04)	0.33 (0.62)	1.04 (1.43)	2.12 (2.85)	4.07 (3.27)
Difference in mean summary scores	–0.20		–0.71		–1.95	
P value[b]	0.15[c]		0.04[c]		0.05	
Effect size[d]	–0.24		–0.71		–0.64	
Probability of CID,[e] %	<0.5		<0.5		48	

ACSM, American College of Sports Medicine; CID, clinically important difference; SD, standard deviation; TLC, Trojan Lifetime Champions.
[a]ACSM weekly exercise guidelines: ≥150 minutes of exercise volume and ≥2 sessions of resistance exercise.
[b]*P* values are for 2-sided, independent-samples *t* tests.
[c]Levene test for equality of variances $P \leq 0.05$. *t* test for unequal variances is reported.
[d]Effect sizes are Cohen *d*.
[e]Clinically important difference: 2 units.

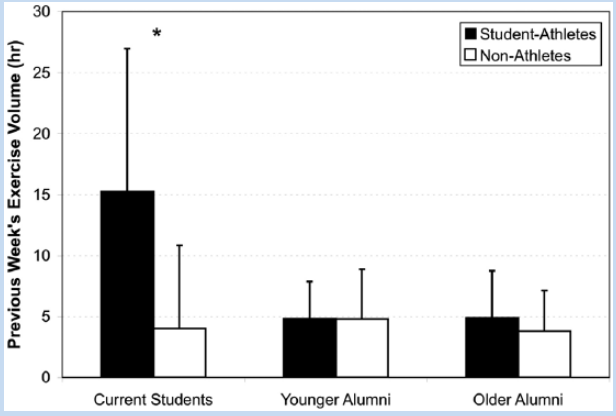

Figure 1. Life span exercise behavior for participants in the Trojan Lifetime Champions study, 2008-2011: Age-stratified comparison of previous week's total exercise volume, intercollegiate student athletes versus nonathletes. Error bars indicate 1 standard deviation. *Statistically significant difference between student athletes and nonathletes ($P \leq 0.05$).

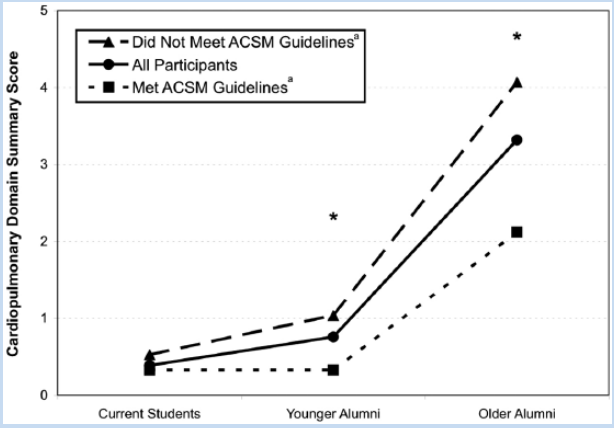

Figure 2. Cardiopulmonary health and exercise behavior for participants in the Trojan Lifetime Champions study, 2008-2011: Age-stratified comparison of cardiopulmonary health concerns, according to compliance with American College of Sports Medicine weekly exercise guidelines for healthy adults. *Statistically significant difference between participants who met ACSM guidelines versus those who did not ($P \leq 0.05$). [a]ACSM weekly exercise guidelines: ≥150 minutes of exercise volume and ≥2 sessions of resistance exercise. Cardiopulmonary domain summary score reflects a study participant's cumulative lifetime experience with cardiopulmonary health concerns. A summary score of 0 indicates "perfect" health, while progressively higher scores indicate greater evidence of concerns.

life spans compared with their nonathlete peers. Compliance with ACSM exercise guidelines was associated with a significant attenuation of age-dependent cardiopulmonary health concerns independent of intercollegiate athletic participation.

As anticipated, the currently competitive elite athletes in our study exemplified high exercise levels and a strong self-rated value of exercise. Student athletes were more than 30 times as

likely to meet ACSM healthy exercise guidelines, reported exercise volume nearly 4 times that of nonathlete controls, and 77% described exercise as "very important" in their lives (versus just 16% of nonathletes). Student athlete alumni demonstrated striking reductions in exercise volume and guideline compliance compared with current student athletes. Meanwhile, nonathletes had similar exercise behavior across their life spans. Accordingly, younger and older alumni demonstrated similar exercise behavior and perceptions irrespective of intercollegiate athletic participation.

Our findings contrast with previous investigations conducted in the 1980s and 1990s showing higher levels of life span exercise among elite athletes compared with referent groups.[18,19] In 1985, former internationally competitive Finnish athletes with a mean age of 57 years reported approximately twice the weekly exercise volume of age-matched controls.[18] In a retrospective study conducted in 1998, Lynch et al[19] reported approximately 5, 3, and 3 times the weekly exercise volume for retired NFL players (mean age, 66 years) compared with controls at ages 20 to 34, 35 to 49, and 50 to 64 years, respectively. In our study, current student athletes (mean age, 20 years) reported 4 times the volume of age-matched controls, with no significant group difference among younger (mean age, 33 years) or older (mean age, 58 years) alumni. This discrepancy may in part be because of differences in the experience of our more contemporary population of athletes. The age of athletes in both the Finnish and NFL cohorts at the time of investigation suggests that the average participant's peak competitive years (age range, 20-40 years) occurred in the 1950s to 1960s, whereas the average alumnus in the TLC study was of comparable age in the 1980s and 1990s. Year-round, specialized, structured, and supervised training for a single sport or position/event has become more commonplace in recent years, with dedicated training patterns routinely adopted in youth sports. This could make transition from sports training to sustainable lifetime physical activity more difficult.

Sex differences in the study populations may also contribute to discrepancies. Several studies[4,34] have reported a positive association between athletic participation in the college years and physical activity in middle-aged women. The larger proportion of women in our study would imply greater lifetime exercise participation, opposite the observed effect. The experience of recent NCAA student athletes may differ from previous generations.

Alumni in our study reported lower rates of compliance with ACSM exercise guidelines (38%) compared with US adults in general (49%).[10] This is likely attributable to a 2007 update to the guidelines, which for the first time explicitly included muscle strengthening (ie, resistance training) as a core recommendation.

Beyond retirement from competitive sports, lifestyle and exercise behavior play important roles in long-term health. For instance, trained distance runners who continue high-intensity training maintain higher aerobic capacity (Vo_2max) across their life spans compared with sedentary controls.[6] However, Vo_2max regressed to sedentary levels upon cessation of training. Comparable findings have been reported among retired NFL players.[19] Similarly, although bone mineral density accrued in youth is believed to reduce osteoporosis risk throughout life,[20] continued physical activity may be necessary to preserve these gains.[9] Equivocal findings to date regarding cardiovascular health outcomes in former elite athletes[17,19,21,26,28,33] may in part be explained by differences in life span exercise behavior.

Valid and reliable measurement of exercise behavior is notoriously difficult and the subject of ongoing discussions in the literature.[29,32] Our study assessed exercise behavior in the previous week using a self-report questionnaire, which may not reflect life span exercise patterns. Its acute validity against actual behavior may also be reasonably questioned.

This study has several strengths. Our study employed a survey instrument that has undergone rigorous validation of its psychometric properties[27] and a statistical approach blending traditional methods with progressive, probabilistic interpretations of clinical effect. There are also important limitations. Although our survey response rate (79%) was high,[27] we did not have adequate sample size to evaluate sex or ethnicity effects. University of Southern California student athletes do not necessarily represent the overall NCAA student-athlete population or those of professional and Olympic sports. We also found significant differences in sport distribution between the source and study populations but had insufficient sample size to evaluate sport-specific results. In this exploratory study, we performed numerous pairwise statistical tests, raising the possibility that some results occurred by chance. Finally, our cross-sectional study design provides less causative evidence than a longitudinal study.

In summary, current NCAA Division I student athletes demonstrated significant, clinically meaningful differences in exercise behavior and perceptions compared with nonathlete students, whereas alumni student athletes and nonathletes demonstrated similar involvement and interest.

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REFERENCES

1. Agostino J. Once an athletic star, now an unheavenly body. *New York Times*. July 6, 2006. http://www.nytimes.com/2006/07/06/fashion/06Fitness.html?pagewanted=all&_r=0. Accessed April 20, 2014.
2. Brill PA, Burkhalter HE, Kohl HW, Blair SN, Goodyear NN. The impact of previous athleticism on exercise habits, physical fitness, and coronary heart disease risk factors in middle-aged men. *Res Q Exerc Sport*. 1989;60:209-215.

3. Brown C. Former players dealing with lingering health issues. *New York Times*. February 1, 2007. http://www.nytimes.com/2007/02/01/sports/football/01disability.html. Accessed April 20, 2014.
4. Conroy MB, Cook NR, Manson JE, Buring JE, Lee IM. Past physical activity, current physical activity, and risk of coronary heart disease. *Med Sci Sports Exerc*. 2005;37:1251-1256.
5. Dishman RK. Supervised and free-living physical activity: no differences in former athletes and nonathletes. *Am J Prev Med*. 1988;4:153-160.
6. Faulkner JA, Davis CS, Mendias CL, Brooks SV. The aging of elite male athletes: age-related changes in performance and skeletal muscle structure and function. *Clin J Sport Med*. 2008;18:501-507.
7. Fendrich H. NFL concussion saga moves to new phase: litigation. *Washington Times*. October 20, 2011. http://www.washingtontimes.com/news/2011/oct/20/nfl-concussion-saga-moves-to-new-phase-litigation/?page=all. Accessed April 20, 2014.
8. Garber CE, Blissmer B, Deschenes MR, et al. American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. *Med Sci Sports Exerc*. 2011;43:1334-1359.
9. Gustavsson A, Olsson T, Nordstrom P. Rapid loss of bone mineral density of the femoral neck after cessation of ice hockey training: a 6-year longitudinal study in males. *J Bone Miner Res*. 2003;18:1964-1969.
10. Haskell WL, Lee IM, Pate RR, et al. Physical activity and public health: updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Med Sci Sports Exerc*. 2007;39:1423-1434.
11. Hootman JM, Dick R, Agel J. Epidemiology of collegiate injuries for 15 sports: summary and recommendations for injury prevention initiatives. *J Athl Train*. 2007;42:311-319.
12. Hopkins WG. A spreadsheet for deriving a confidence interval, mechanistic inference and clinical inference from a p value. *Sportscience*. 2007;11:16-20.
13. Hopkins WG, Marshall SW, Batterham AM, Hanin J. Progressive statistics for studies in sports medicine and exercise science. *Med Sci Sports Exerc*. 2009;41:3-13.
14. Jensen M. Congressional panel hears testimony on concussions. *Philadelphia Inquirer*. September 24, 2010. http://articles.philly.com/2010-09-24/sports/24977128_1_effects-of-multiple-concussions-mild-concussions-cte. Accessed April 20, 2014.
15. Johnson G. NFL is focus of Senate hearing. *Los Angeles Times*. September 18, 2007. http://articles.latimes.com/2007/sep/18/sports/sp-nflhearing18. Accessed April 20, 2014.
16. Kujala U, Orava S, Parkkari J, Kaprio J, Sarna S. Sports career-related musculoskeletal injuries: long-term health effects on former athletes. *Sports Med*. 2003;33:869-875.
17. Kujala UM, Marti P, Kaprio J, Hernelahti M, Tikkanen H, Sarna S. Occurrence of chronic disease in former top-level athletes. Predominance of benefits, risks or selection effects? *Sports Med*. 2003;33:553-561.
18. Kujala UM, Sarna S, Kaprio J, Tikkanen HO, Koskenvuo M. Natural selection to sports, later physical activity habits, and coronary heart disease. *Br J Sports Med*. 2000;34:445-449.
19. Lynch NA, Ryan AS, Evans J, Katzel LI, Goldberg AP. Older elite football players have reduced cardiac and osteoporosis risk factors. *Med Sci Sports Exerc*. 2007;39:1124-1130.
20. McArdle WD, Katch FI, Katch VL. *Exercise Physiology: Energy, Nutrition, & Human Performance*. Baltimore, MD: Lippincott Williams & Wilkins; 2007.
21. Miller MA, Croft LB, Belanger AR, et al. Prevalence of metabolic syndrome in retired National Football League players. *Am J Cardiol*. 2008;101:1281-1284.
22. National Collegiate Athletic Association. *1981-82–2010-11 NCAA Sports Sponsorship and Participation Rates Report*. Indianapolis, IN: National Collegiate Athletic Association; 2011.
23. Paffenbarger RS Jr, Hyde RT, Wing AL, Steinmetz CH. A natural history of athleticism and cardiovascular health. *JAMA*. 1984;252:491-495.
24. Rothman KJ. *Epidemiology: An Introduction*. New York, NY: Oxford University Press; 2002.
25. Schwarz A. Dark days follow hard-hitting career in N.F.L. *New York Times*. February 2, 2007. http://query.nytimes.com/gst/fullpage.html?res=9501E7DE123FF931A35751C0A9619C8B63. Accessed April 20, 2014.
26. Sorenson SC, Romano R, Scholefield RM, et al. Holistic lifespan health outcomes among elite intercollegiate student-athletes. *J Athl Train*. In press.
27. Sorenson SC, Romano R, Scholefield RM, Schroeder ET, Azen SP, Salem GJ. The Trojan Lifetime Champions health survey: development, validity, and reliability. *J Athl Train*. In press.
28. Tucker AM, Vogel RA, Lincoln AE, et al. Prevalence of cardiovascular disease risk factors among National Football League players. *JAMA*. 2009;301:2111-2119.
29. van Poppel MN, Chinapaw MJ, Mokkink LB, van Mechelen W, Terwee CB. Physical activity questionnaires for adults: a systematic review of measurement properties. *Sports Med*. 2010;40:565-600.
30. Vecsey G. Accepting the costs of a life in football. *New York Times*. May 12, 2008. http://www.nytimes.com/2008/05/12/sports/football/12vecsey.html. Accessed April 20, 2014.
31. Ware JE, Kosinski M, Turner-Bowker DM, Gandeck B. *User's Manual for the SF-12v2 Health Survey With a Supplement Documenting SF-12 Health Survey*. Lincoln, RI: QualityMetric; 2002.
32. Warren JM, Ekelund U, Besson H, Mezzani A, Geladas N, Vanhees L. Assessment of physical activity—a review of methodologies with reference to epidemiological research: a report of the exercise physiology section of the European Association of Cardiovascular Prevention and Rehabilitation. *Eur J Cardiovasc Prev Rehabil*. 2010;17:127-139.
33. Weir DR, Jackson JS, Sonnega A. *National Football League Player Care Foundation: Study of Retired NFL Players*. Ann Arbor: University of Michigan; 2009.
34. Wyshak G, Frisch RE. Breast cancer among former college athletes compared to non-athletes: a 15-year follow-up. *Br J Cancer*. 2000;82:726-730.
35. Zarda B. Lawsuit prompts NCAA to screen athletes for sickle cell. *USA Today*. July 2, 2010. http://usatoday30.usatoday.com/sports/college/2010-06-30-sickle-cell-ncaa-cover_N.htm. Accessed April 20, 2014.