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Sperm concentration remains stable among fertile American men: a systematic review and meta-analysis

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Importance: Findings from several high profile meta-analyses have raised concerns about an ongoing global decline in sperm concentration and male fertility. However, these studies exhibit considerable heterogeneity in key variables including study population, methodology, fertility status, and geographic region.
Objective: To perform a systematic review and meta-analysis exploring temporal trends in sperm concentration among fertile men and men unselected for fertility status in the United States.
Data Sources: A literature search performed in Scopus and PubMed databases for studies published between 1970 and 2023. Additional studies were included from citations of prior global meta-analyses and reviews evaluating temporal trends in sperm count.
Study Selection and Synthesis: Studies were included if they presented original data on sperm concentration in US men without known infertility from 1970 to 2023. Aggregate data were assessed across all study populations, with additional subgroup analyses stratified by fertility status and US region.
Main Outcomes: Weighted generalized linear models were generated to evaluate the association between mean sperm concentration and sample collection year.
Results: A total of 874 articles were screened, with 58 meeting the inclusion criteria. These represented 75 unique study populations totaling 11,787 men in the United States. Across all study populations, no change in sperm concentration was observed between 1970 and 2018 in unadjusted models ($\beta = 0.14$ million/mL per year). When adjusting for US region, no statistically significant decline in sperm concentration was seen. When adjusting for both region and fertility status, a modest annual decline was observed to meet statistical significance ($\beta = -0.35$ million/mL per year). Of the 49 study populations reporting adequate data to determine mean total sperm count, there was a significant increase in total sperm count of 2.9 million per year between 1970 and 2018. Subgroup analysis found no statistically significant change in mean sperm concentration among any US census region or fertility status cohort.
Conclusion and Relevance: In contrast to prior global studies, this analysis suggests no clinically significant decline in sperm concentration among confirmed fertile men and the general male US population without known infertility. Although these findings provide some reassurance against a widespread rapid decline, further studies are necessary to better understand this important topic. (Fertil Steril® 2025;123:77–87. ©2024 by American Society for Reproductive Medicine.)
El resumen está disponible en Español al final del artículo.

Key Words: Sperm concentration, infertility, sperm count, andrology

In 1992, Carlsen et al. (1) published a systematic review and meta-analysis suggesting a rapid decline in worldwide sperm concentration. This study triggered extensive debate and prompted a wave of further research regarding global trends in sperm count including re-analysis of this data, which confirmed these findings (2). More recently, Levine et al. (3, 4) published two updated high profile meta-analyses of worldwide sperm count trends encompassing a large, geographically diverse population using modern statistical methodology and stringent search and inclusion strategies. Both studies demonstrated a relatively consistent annual decline in sperm concentration up to 1 million/mL per year (Table 1) (1–4), prompting significant public interest and concern.

The clinical significance, extent, and generalizability of these findings

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are topics of ongoing debate within the reproductive medicine community. Past studies have shown significant heterogeneity in sperm concentration trends based on study population and location. Levine et al. (3) observed a substantial decline of 1.38 million/mL per year in Western populations of unknown fertility status, but no decline was seen among fertile non-Western men. Swan et al. (2) noted the most significant decline among European populations (2.35 million/mL per year), followed by North American populations (0.8 million/mL per year), but no decline was observed in other countries. Geographically limited populations may face varying changes in climate, environmental gonadotoxin exposure, access to reproductive healthcare, and population characteristics. Thus, changes in semen parameters may be differentially observed across different regions and populations.

Within the US population, published data have shown mixed results regarding trends in sperm concentration. Saidi et al. (5) conducted a re-analysis of the Carlsen et al. (1) study including only US studies. Although an overall decline in sperm concentration was observed across all studies, this decline was not seen when a geographic subanalysis was performed. A study from Seattle found a slight increase in sperm concentration among healthy males from 1972 to 1993, but a recent study evaluating over 75,000 sperm donors in the same region found a significant decline in sperm concentration between 2008 and 2021 (6, 7). A New England sperm bank also observed a decline in sperm concentration among donors between 2003 and 2013 (8). In contrast, a study evaluating men banking sperm before vasectomy in California, Minnesota, and New York found an increase in sperm concentration over a 25-year period (9). Data among infertile populations and US men presenting with infertility concerns are similarly mixed. A study from New England found no decline in sperm concentration between 1989 and 2000 among men undergoing medical evaluation for infertility (10), whereas another study of men seeking infertility treatment in Boston found a significant decline in sperm concentration between 2000 and 2017 (11).

Data regarding temporal trends in sperm motility among the healthy US population are limited and show similarly mixed results to those evaluating sperm concentration. Declines in motility have been observed in sperm donors in

TABLE 1

Summary of prior meta-analyses evaluating global trends in sperm count.

Study	Carlsen et al. (1)	Swan et al. (2)	Levine et al. (3, 4)
Publication years of included studies	1938–1990	1934–1996	1981–2013; 1981–2019
Location	Worldwide	Worldwide	Worldwide
Number of studies included	61	101	185; 223
Inclusion criteria	Publications reporting sperm count	Publications reporting sperm count	Publications reporting sperm count
Exclusion criteria	Men selected for infertility or subfertility; selected for semen parameters; selected for genital abnormalities Nonstandard methods to count sperm	Men selected for infertility or subfertility; selected for semen parameters; selected for genital abnormalities Nonstandard methods to count sperm Studies with fewer than 10 men Non-English	Men selected for infertility or subfertility; selected for semen parameters; selected for genital abnormalities other diseases or medication Nonstandard methods to collect or count sperm Men with exposures that might affect fertility Studies with fewer than 10 men Non-English
Search strategy	1930–1965: Cumulated Index Medicus (Current List 1957–1959) to identify relevant studies with spermatozoa, semen, and fertility as key words 1966–1991: MEDLINE Silver Platter database with the key words: sperm count, sperabase wm density, sperm concentration, male fertility, and semen analysis Additional studies from reference lists	Studies included in Carlsen et al. (1) that passed additional exclusion criteria 1990–1996: Medline search 1930–1990: Additional nonsystematic search	1981–2019: Searched MEDLINE and EMBASE databases using the MeSH term "sperm count," which includes seven additional terms, and added 13 related keywords (e.g., "sperm density" and "sperm concentration")
Annual decline in global sperm count	0.93 million/mL/y	0.94 million/mL/y	0.7 million/mL/y; 0.87/ million/mL/y

Lewis. Sperm count trends among American men. Fertil Steril 2025.

New England (8) and the greater Seattle area (7), the latter of which observed a >50% drop in total motile sperm count between 2008 and 2021. In contrast, a study evaluating men banking sperm before vasectomy in Minnesota, New York, and California found no decline in percent motility over the 25-year study period (9).

Given the conflicting evidence on temporal trends in semen analysis parameters among US men, we aimed to conduct a systematic review and meta-analysis evaluating sperm concentration and motility trends in the US population with a focus on fertile men and unselected men with unknown, but presumed, normal fertility status. On the basis of previous studies indicating differential trends in sperm concentration depending on region and fertility status, we conducted additional subanalyzes controlling for these confounders. Our secondary objectives included an assessment of trends in total sperm count, percent motility, and total motile sperm count. This study differs from prior meta-analyses evaluating sperm concentration trends by focusing exclusively on the US population while accounting for regional variations and fertility status and comprehensively evaluating all major semen analysis parameters.

METHODS

Search strategy

A systematic review and meta-analysis was registered in PROSPERO (CRD42021241473) and conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocols (12) (Supplemental Table 1, available online) and Meta-analyses of Observational Studies in Epidemiology (13) guidelines (Supplemental Table 2). A literature search was performed using PubMed and Scopus databases to identify studies published between 1970 and 2023. The following search term was used in Scopus search: “(TITLE-ABS-KEY (sperm AND concentration) AND TITLE-ABS-KEY (sperm AND count) AND TITLE-ABS-KEY (sperm AND density)) AND PUBYEAR > 1969 AND PUBYEAR < 2024 AND (LIMIT-TO (DOCTYPE , ”ar”)) AND (LIMIT-TO (AFFILCOUNTRY , ”United States”)) AND (LIMIT-TO (LANGUAGE , ”English”)) AND (LIMIT-TO (SUBJAREA , ”MEDI”))” and the following in a PubMed search “Search: (sperm AND (concentration OR density OR count)) AND United States Filters: Clinical Study, Observational Study, Humans, English, Male”. Additional studies were evaluated for inclusion by reviewing citations in the following meta-analyses and reviews: Carlsen et al. (1), Swan et al. (2), Levine et al. (3), Auger et al. (14), and Levine et al. (4). Only English language publications were included, because the analysis was limited to studies conducted in the United States.

Selection criteria

Individual studies were assessed for eligibility using the Population, Exposure, Comparison/Comparator, Outcome, Study type model system (15) (Supplemental Table 3). Studies were included if they reported primary data on sperm concentration in US men between 1970 and 2023. Studies were excluded if men were selected for infertility or concern for infertility (e.g., men seeking clinical care at a fertility clinic); selected for certain semen parameters; exposed to environmental toxins; used nonstandard collection and counting methods; or had a sample size of <5. If a study reported a control group and an experimental/exposure group, the control group only was eligible for inclusion. The selection of eligible studies was performed by two researchers who worked independently, with a third researcher available to address any conflicts.

Data extraction

Data extraction was performed by two independent reviewers (K.L. and D.A.P.). The following parameters were collected, when available: sample collection years, geographic location, sample size, fertility status, subject age, sperm counting method, abstinence period, body mass index, smoking, and race. Semen analysis parameters (mean, median, and/or SD) collected included sperm concentration, total sperm count, semen volume, percent motility, and total motile sperm count. If a study reported multiple semen analyses over time from the same study subject, the values at the beginning of the study were used. If a study averaged values from multiple semen analyses from a single study subject, the resulting average was included in the analysis as a single value. If a study did not report mean total sperm count, then it was calculated using the formula: Total sperm count = (sperm concentration) × (semen volume). If the mean total motile sperm count was not reported, it was calculated using the formula: Total motile sperm count = (% motility) × (total sperm count). For some studies, only the median sperm concentration was reported. In these cases, mean sperm concentration was estimated by calculating the average difference between mean and median sperm concentration in studies reporting both measures. A similar method was used to estimate semen volume and percent motility in cases where only the median was reported. For studies that reported a range of collection years, the average year was used in the analysis. However, if a study reported individual sperm concentration estimates for each year, then they were analyzed as individual entries. For studies that did not report the semen collection year(s), it was estimated by calculating the average difference between collection year and publication year in studies that reported both values. Fertility status was categorized as either fertile or unknown fertility status, which was defined as individuals who have no risk factors for infertility (e.g., those attending an infertility clinic) but are not described as having proven fertility.

Statistical analysis

Statistical analysis was performed by an experienced statistician (F.L.) and overseen by a senior epidemiologist with extensive experience in population-based statistical analysis (J.C.). A proportional weighting model was used to account for the varying sample sizes across all studies included in the meta-analysis. The model assigns weights to each observation based on its proportionate representation in the overall study population. The mean sperm concentration was calculated across all studies utilizing weighted averages. Similar calculations were performed measuring averages among fertile men and men of unknown fertility status, as well as in each of the four US census regions; Northeast, Midwest, South, and West. Generalized linear models (GLMs) were used for analysis to evaluate the relationship between collection year and mean sperm concentration. Generalized linear models were generated with no adjustment, adjustment for US census region alone, and adjustment for US census region plus fertility status. Generalized linear models were then stratified to examine the association between sample collection year and mean sperm concentration in fertile men and men of unknown fertility status. Additionally, GLMs were stratified to examine the association between year and mean sperm concentration in each of the four US census regions. Generalized linear models were also generated to evaluate the relationship between the following variables: total sperm count and collection year, percent motility and collection year, total motile sperm count and collection year. The data were considered statistically significant for $P \leq .05$. All statistical analyses were performed using RStudio version 2023.12.1 (Posit, Inc., Boston, MA).

RESULTS

Search results and summary statistics

A total of 874 studies were identified for screening after a literature search. After removing duplicate records, 841 studies remained for the initial screening of titles and abstracts. The initial screening identified 162 studies for full manuscript eligibility assessment. A total of 58 studies were deemed to be eligible for inclusion (Fig. 1). The eligible studies included 75 unique sperm concentration estimates totaling 11,787 individuals. The identified studies had sample collection years ranging from 1970 to 2018, with a mean collection year of 1991. A table outlining data collected for all studies is provided in Table 2 (8, 9, 16–71). Within these 75 sperm concentration estimates, 51 were obtained from populations of men with unknown fertility status, with a mean of 77.6 million/mL across a total of 8,207 men. The remaining 24 estimates were obtained from fertile populations, with a mean of 69.4 million/mL across 3,580 men. There were 22 sperm concentration estimates encompassing 2,652 men from the Northeast (mean 88.3 million/mL), 14 estimates encompassing 1,861 men from the Midwest (mean 76.7 million/mL), 15 estimates encompassing 5,187 men from the South (mean 67.5 million/mL), and 19 estimates encompassing 1,219 men from the West (mean 80.2 million/mL).

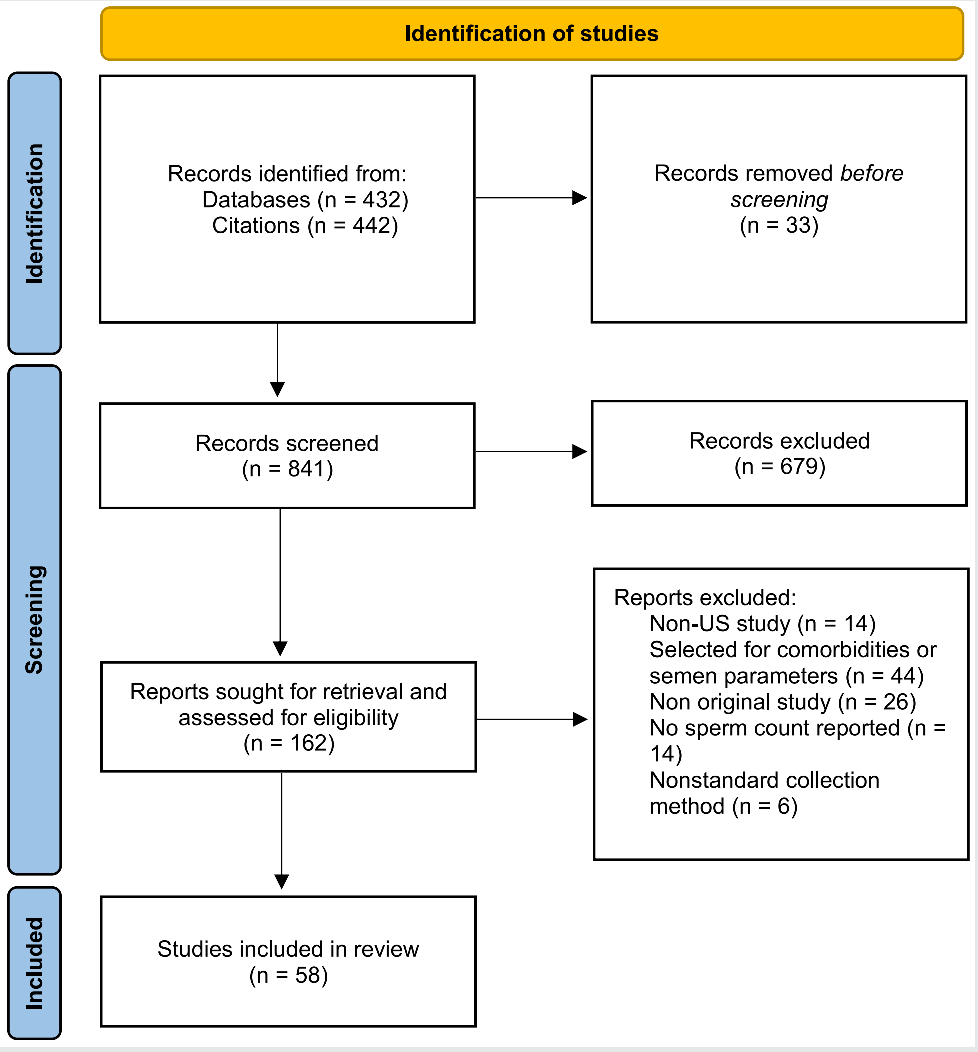
Generalized linear models

Across all study populations, no changes in sperm concentration were observed between 1970 and 2018 ($\beta = 0.14$ million/mL per year, $P = .42$, Fig. 2A). Similar results were observed when adjusting for US census region alone (Table 3). However, when adjusting for both US census region and fertility status, a modest decline of –0.35 million/mL per year was observed to reach statistical significance across all study populations reporting these variables ($P = .04$, Table 3). In a sensitivity analysis, the study contributing the largest sample size to the total population (31) was removed and similar results were observed in unadjusted and adjusted analyses. A total of 49 study populations reported sufficient data to determine mean total sperm count, and among these studies, there was a significant increase in total sperm count of 2.9 million per year between 1970 and 2018 (confidence interval [CI] = 0.35–5.4, $P = .03$, Fig. 1B). When populations were stratified by fertility status, no statistically significant change in sperm concentration was seen in fertile men ($\beta = -0.24$ million/mL per year, $P = .26$, Fig. 1C) or in men with unknown fertility status ($\beta = 0.46$ million/mL per year, $P = .06$, Fig. 1D). Study populations were stratified by US census region and no statistically significant change was observed in any US census region (Table 3). Motility was reported in 49 study populations, and among these studies, there was a decline of –0.23% per year in mean motility between 1972 and 2018 (CI = –0.36 to –0.09, $P = .002$, Fig. 1E). Total motile sperm count was reported in a total of 40 study populations, and no change was observed in the mean total motile sperm count between 1972 and 2018 ($\beta = -0.79$ million per year, CI = –2.3 to 0.67, $P = .30$, Fig. 1F).

DISCUSSION

There has been increasing concern among the scientific community and the general public alike regarding a potential decline in worldwide sperm concentration and male fecundity over the last few decades. Although some published data do support a possible decline starting as far back as the 1930s, there is considerable controversy regarding the presence or absence, extent, and clinical relevance of this decline, particularly across different populations and regions (1,3). Specifically among the US population, no consensus has been reached, and past studies have demonstrated mixed results (6, 7, 10, 11). To address this limitation, we conducted a rigorous systematic review and meta-analysis evaluating trends in sperm concentration isolated to the US population alone and identified 58 relevant studies totaling 11,787 men with either proven fertility or those from the general public without documented infertility. Within this cohort, we found no evidence of a clinically significant change in sperm concentration between 1970 and 2018. These results were consistent in further subgroup and sensitivity analyses and remained true for models adjusting for US census region alone. When adjusting for both US census region and fertility status, a single model predicted a modest decline of –0.35 million/mL per year was found to reach statistical difference. This decline is less than half the annual decline that has been observed in previous global meta-analyses and is of limited clinical significance, particularly given the significant variability in semen analysis parameters and the lack of any other models showing a decline. Importantly, the mean sperm concentration in fertile men and in those with unknown fertility status were similar in this study, with fertile men surprisingly having a slightly lower mean sperm concentration. Thus, the unadjusted model or adjustment for US geographic region alone likely represents

FIGURE 1



Flowchart of included studies.

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the more statistically robust model to support clinical decision making. Analysis of the mean total sperm count revealed an increase of 2.9 million per year, further supporting the lack of any concerning decline in this study population.

The results of this study contrast to those published in several prior worldwide meta-analyses evaluating general trends in sperm concentration and total sperm count (3, 4). Our findings from this rigorously selected cohort suggest that sperm concentration in fertile men in the United States has been remarkably stable over the past 50 years and indicate that these global declines previously observed may not apply to all regions and population groups. Interestingly, prior studies have shown that sperm concentration among those with unknown fertility status were declining more rapidly than those with proven fertility (3, 4). Several reasons may explain why our results from this study differ. One possibility is that a worldwide decline in sperm concentration is occurring; however, this decline is not impacting the US population for unknown reasons. Alternatively, it may be that prior meta-analyses may attempt to account for geographic variability using a different method. It is important to consider other sources of uncertainty related to population sampling, confounding variables, and collection/counting methods within all meta-analyses on this topic. Furthermore, this study focused solely on fertile men and men with unknown fertility (but presumed fertile) status, because they are likely a better overall proxy for population health than infertile populations. It certainly may be that patients with infertility, subfertility, or infertility risk factors are experiencing declines in sperm concentration, whereas healthy fertile populations remain stable, although this could not be assessed in this

TABLE 2

Summary of all studies included in the current meta-analysis.

Study	Publication year	N	Region	Fertility status	Mean sperm concentration
Nelson and Bunge (16)	1974	386	Midwest	Fertile	48
Rehan et al. (17)	1975	1300	Northeast	Fertile	80
Glaub et al. (18)	1976	13	West	Unknown	83
Polakoski et al. (19)	1977	7	Midwest	Unknown	53
Rehewy et al. (20)	1978	33	Midwest	Fertile	100
Smith et al. (21)	1979	50	West	Fertile	61
Glass et al. (22)	1979	22	West	Unknown	62
Rogers et al. (23)	1979	21	West	Fertile	114
Venable et al. (24)	1980	63	South	Unknown	114
Milby and Whorton (25)	1980	90	West	Unknown	94[a]
Fariss et al. (26)	1981	112	West	Mixed	Variable
Dougherty et al. (27)	1981	132	South	Unknown	83
Meyer (28)	1981	89	Midwest	Unknown	115
Wyrobek et al. (29)	1981	26	West	Unknown	66
Wyrobek et al. (30)	1981	34	West	Unknown	129
Tjoa et al. (31)	1982	4435	South	Unknown	66
Hamill et al. (32)	1982	90	South	Unknown	76
Borghi and Asch (33)	1983	22	South	Fertile	60
Fowler and Mariano (34)	1983	16	South	Fertile	70
Albertsen et al. (35)	1983	11	South	Fertile	99
Lewis et al. (36)	1984	9	West	Fertile	59
Swanson et al. (37)	1984	36	South	Fertile	59
Ward et al. (38)	1984	11	South	Unknown	87
Asch et al. (39)	1984	16	South	Fertile	71
Heussner et al. (40)	1985	20	South	Unknown	65
Rosenberg et al. (41)	1985	71	Variable/unknown	Unknown	99
Levin et al. (42)	1986	12	Northeast	Unknown	68
Ratcliffe et al. (43)	1987	43	West	Unknown	69
Giblin et al. (44)	1988	28	Midwest	Unknown	87
Welch et al. (45)	1988	40	Northeast	Unknown	79
Schrader et al. (46)	1988	45	Midwest	Unknown	47
Eskenazi et al. (47)	1991	48	West	Unknown	87
Levine et al. (48)	1992	140	South	Unknown	72
Kolon et al. (49)	1992	10	Northeast	Fertile	133
Arce et al. (50)	1993	28	Northeast	Unknown	126
Roberts et al. (51)	1993	5	West	Unknown	91
Hill et al. (52)	1994	17	Northeast	Fertile	63
Fisch et al. (9)	1996	1283	Variable/unknown	Unknown	Variable
Weyandt et al. (53)	1996	31	Variable/unknown	Unknown	38
Vine et al. (54)	1996	40	South	Unknown	94
Fahim and Wang (55)	1996	20	Midwest	Unknown	114
Wang et al. (56)	1997	20	Midwest	Unknown	64[a]
Muller et al. (57)	1998	38	West	Fertile	113[a]
Lemasters et al. (58)	1999	50	Variable/unknown	Unknown	66
Glazier et al. (59)	2000	42	Northeast	Fertile	53
Lee and Coughlin (60)	2001	53	Northeast	Unknown	82
Guzick et al. (61)	2001	696	Variable/unknown	Fertile	67
Uhler et al. (62)	2003	145	South	Unknown	64[a]
Eskenazi et al. (63)	2003	97	West	Unknown	106[a]
Mauras et al. (64)	2005	10	South	Unknown	60
Hammoud et al. (65)	2012	196	West	Unknown	88
Amory et al. (66)	2010	12	West	Unknown	81
Redmon et al. (67)	2013	763	Variable/unknown	Fertile	Variable
Mendiola et al. (68)	2014	221	Northeast	Unknown	65[a]
Centola et al. (8)	2016	492	Northeast	Unknown	Variable
Welliver et al. (69)	2016	20	Variable/unknown	Unknown	118
Dias et al. (70)	2020	15	Midwest	Fertile	95
Lundy et al. (71)	2021	12	Midwest	Fertile	94[a]

Note: Some studies contain multiple sperm concentration (SC) estimates (e.g., studies with semen collection reported in different years or different geographic locations) and thus location or SC is reported here as variable.
[a] Denotes estimates that were calculated using median sperm concentration.

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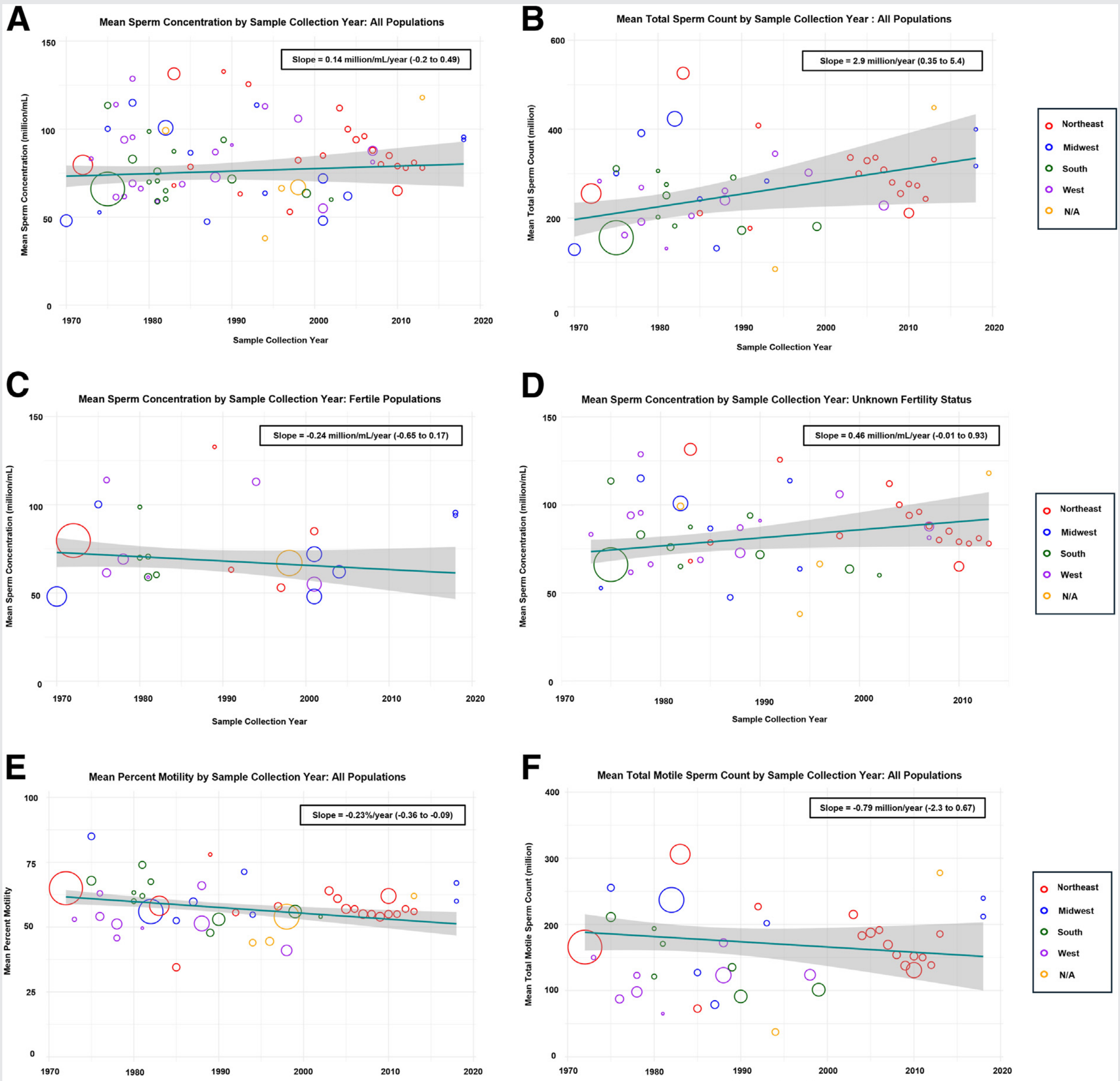
study because we excluded infertile cohorts. Although the results are reassuring for the general US population, further investigation is required into potential declines in these other subpopulations. A prospective longitudinal study with representative repeated sampling may be the best approach to answer questions regarding sperm concentration trends,

FIGURE 2



Temporal trends in semen parameters among US men. Circle size corresponds to relative sample size within each analysis and gray shading represents 95% confidence intervals. Circle color corresponds to U.S. region, with studies from multiple regions or undefined regions marked as N/A. (**A**) No change in mean sperm concentration was observed in US men across all studies between 1970 and 2018 ($\beta = 0.14$ million/mL/y, $P=.42$). (**B**) An increase in mean total sperm count of 2.9 million/y was observed between 1970 and 2018 ($P=.03$). (**C**) No change in sperm concentration among fertile men was observed in the study period ($\beta = -0.24$ million/mL/y, $P=.26$). (**D**) No change in sperm concentration among men with unknown fertility status was observed in the study period ($\beta = 0.46$ million/mL/ye, $P=.06$). (**E**) A decrease in mean percent motility of -0.23% per year was observed between 1972 and 2018 ($P=.002$). (**F**) No change in mean total motile sperm count was observed between 1972 and 2018 ($\beta = -0.79$ million/y, $P=.30$).

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although this study would be prohibitively time-intensive and costly.

Multiple hypotheses including environmental toxins (72), lifestyle factors (73), and obesity (74) have been proposed to explain the apparent decline in global sperm concentration as previously reported. The relationship between these factors and geographic location among men with variable fertility status adds additional complexity to understanding the decline. Exploring differences in sperm concentration trends by region may provide valuable insights into the mechanism of a worldwide decline by enabling future regional studies in population demographics, environment, and biological factors unique to each location. It is also important to consider the relevance of sperm concentration decline relating to fecundity. Prior research indicates that there is a positive linear relationship

TABLE 3

Generalized linear models assessing sperm concentration trends among United States men.

Population	N (SC estimates)	Years	Slope (CI) (million/mL/y)	*P* value[a]
All men				
All men	75	1970–2018	0.14 (–0.20 to 0.49)	.42
Adjusted—location[b]	70	1970–2018	–0.06 (–0.44 to 0.32)	.77
Adjusted—location and fertility status[c]	70	1970–2018	–0.35 (–0.68 to –0.02)	.04
Subgroup analyses				
Fertile	24	1970–2018	–0.24 (–0.65 to 0.17)	.26
Unknown fertility	51	1973–2013	0.46 (–0.01 to 0.93)	.06
Northeast	22	1972–2013	–0.06 (–0.64 to 0.53)	.85
Midwest	14	1970–2018	–0.14 (–1.27 to 0.98)	.81
South	15	1975–2002	0.15 (–0.59 to 0.88)	.70
West	19	1973–2007	–0.07 (–0.86 to 0.73)	.87

Note: CI = confidence interval; SC = sperm concentration.
[a] *P* values were generated with generalized linear models assessing for an association between sperm concentration and sample collection year. A proportional weighting model was used assigning weights to each observation based on its proportionate representation in the overall study population.
[b] Model includes adjustment for US census region.
[c] Model includes adjustment for both US census region and fertility status (fertile vs. unknown)

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between sperm concentration and fecundity, but only up to a threshold of 40–55 mL/million (75, 76). Although a relationship exists between sperm concentration and fertility, the significance of this correlation beyond certain thresholds remains unclear. A more clinically relevant measurement of male reproductive health concerning sperm concentration may be the proportion of the population below this threshold.

Finally, we also evaluated temporal trends in motility and total motile sperm count to add unique insights into key semen parameters not well studied in previous meta-analyses and to better capture overall reproductive health among US men (77). These results indicated a subtle decline of 0.23% per year in percent motility but no change in total motile sperm count, presumably because of a concomitant increase in total sperm count via increased semen volume. It is important to note that motility measures may be more technically challenging than sperm count and may fluctuate because of evolving analysis techniques and guidelines.

Limitations in this study include the inability to control for certain possible confounding variables because of insufficient data, particularly with regard to smoking status, body mass index, ethnicity, and age, which were all collected in our data set but not included in the analysis because of the limited number of studies reporting these variables. One study contributed a significant proportion of the overall sample size to the analysis (4,435/11,787), although sensitivity analyses excluding this study did not significantly impact the results (31). The studies included in the analysis occurred over a 50-year time period, and semen handling, collecting, and processing are not uniform across each study or over time, potentially introducing bias into the results. In subgroup analysis of geographic location, the timeframes for study years were disparate for each region, making comparisons across these subgroups challenging to interpret. In general, meta-analyses may not be the most appropriate study type to assess temporal trends in sperm count, because the heterogeneity in populations, regions, collection and counting methods cannot fully be accounted for in regression analyses. A more appropriate method may be large, prospective random sampling in a single population, however, these types of studies are both time-intensive and costly. This study also has notable strengths, including the large number of studies analyzed encompassing a large sample of men across a 50-year period. Additionally, modern statistical methods (GLMs) were used to evaluate the relationship between sample collection year and sperm concentration, which allowed for modeling with multiple explanatory variables and handling of non-normal data distributions. Our results were consistent across multiple subgroup and sensitivity analyses, indicating reliability in the data.

CONCLUSION

In this meta-analysis evaluating fertile men and men with unknown fertility status in the United States, no clinically significant change in sperm concentration was observed in unadjusted models and subgroup analyses. The findings suggest that in contrast to prior meta-analyses, semen quality in most US men may be more stable than previously thought and may provide further reassurance against an impending epidemic of male factor infertility in fertile men in future generations. Whether these findings can be generalized to infertile men remains unknown and should be assessed in future work.

CRediT Authorship Contribution Statement

Kieran Lewis: Writing – review & editing, Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation. **Rossella Cannarella:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Data curation. **Fangzhou Liu:** Writing – review & editing, Writing – original draft, Visualization, Software, Methodology, Investigation, Formal analysis, Data curation. **Bradley Roth:** Writing – review & editing, Methodology, Investigation, Formal analysis, Data curation.

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Declaration of Interests

K.L. has nothing to disclose. R.C. has nothing to disclose. F.L. has nothing to disclose. B.R. has nothing to disclose. L.B. has nothing to disclose. J.M. has nothing to disclose. S. Kuribayashi has nothing to disclose. S. Kuroda has nothing to disclose. D.A.P. has nothing to disclose. S.C.V. has nothing to disclose. J.C. has nothing to disclose. S.D.L. has nothing to disclose.

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La concentración de esperma se mantiene estable en los hombres estadounidenses fértiles: una revisión sistemática y meta-análisis

Importancia: Hallazgos de varios meta-análisis de elevada calidad han aumentado la preocupación sobre un posible descenso global en la concentración del esperma y la fertilidad masculina. Sin embargo, estos estudios muestran una considerable heterogeneidad en variables clave, como la población estudiada, la metodología, el estado de fertilidad y la región geográfica.

Objetivo: Realizar una revisión sistemática y un meta-análisis para explorar las tendencias temporales en la concentración de esperma entre hombres fértiles y hombres no seleccionados según su estado de fertilidad en los Estados Unidos.

Fuentes de datos: Se realizó una búsqueda en las bases de datos Scopus y PubMed para estudios publicados entre 1970 y 2023. Se incluyeron estudios adicionales citados en meta-análisis globales y revisiones previas que evaluaron tendencias temporales en el conteo de espermatozoides.

Selección y síntesis de estudios: Se incluyeron estudios que presentaban datos originales sobre la concentración de espermatozoides en hombres estadounidenses sin infertilidad conocida desde 1970 hasta 2023. Se evaluaron datos agregados de todas las poblaciones estudiadas, con análisis de subgrupos estratificados por estado de fertilidad y región de los EE. UU.

Resultados principales: Se generaron modelos lineales generalizados ponderados para evaluar la asociación entre la concentración promedio de espermatozoides y el año de recolección de la muestra.

Resultados: De 874 artículos analizados, 58 cumplieron los criterios de inclusión, representando 75 poblaciones de estudio únicas con un total de 11787 hombres en los EE. UU. En las poblaciones estudiadas, no se observó ningún cambio en la concentración de espermatozoides entre 1970 y 2018 en los modelos no ajustados (b = 0.14 millones/mL por año). Al ajustar por región de EE. UU., no se encontró un descenso estadísticamente significativo. Al ajustar por región y estado de fertilidad, se observó un ligero descenso anual estadísticamente significativo (b = -0.35 millones/mL por año). En las 49 poblaciones de estudio con datos adecuados para calcular el conteo total de espermatozoides, se observó un aumento significativo de 2.9 millones al año entre 1970 y 2018. El análisis de subgrupos no encontró cambios estadísticamente significativos en la concentración promedio de espermatozoides por región del censo de EE. UU. ni por estado de fertilidad.

Conclusión y relevancia: A diferencia de estudios globales previos, este análisis sugiere que no hay una disminución clínicamente significativa en la concentración de espermatozoides entre hombres fértiles confirmados y la población masculina general sin infertilidad conocida en los Estados Unidos. Aunque estos hallazgos aportan cierta tranquilidad sobre un descenso rápido generalizado, se necesitan más estudios para comprender mejor este tema tan importante.