

Retrospective Analysis of Seasonal Changes in Semen Analysis Parameters

Sinan ATES¹, Cem YENER², Mehmet Gurkan ARIKAN³, Ersan ARDA³, Deniz COKAY¹, Koray ELTER¹

Edirne, Türkiye

ABSTRACT

OBJECTIVE: Seasonal and environmental temperature changes may affect semen analysis results. This study aimed to evaluate the effect of seasonal changes on semen analysis parameters.

STUDY DESIGN: Cross-sectional study conducted at Trakya University Faculty of Medicine, Department of Obstetrics and Gynecology, Edirne, Türkiye. Data from 2055 semen analyses collected between January 2014 and December 2019 from 1358 patients living in the Thrace region of Türkiye were analyzed retrospectively. Sperm analysis was performed according to 2010 WHO criteria.

RESULTS: Sperm concentration was significantly higher in autumn months compared to spring and summer months ($p < 0.05$). The total motility rate of sperm was significantly lower in winter months compared to other months ($p < 0.05$). No statistically significant seasonal differences were observed in semen volume or morphology ($p > 0.05$).

CONCLUSIONS: Our study showed that seasonal changes in semen analysis parameters, including peak sperm concentrations in autumn and low motility rates in winter, may be related to air temperature, daylight duration, etc., and may prompt further study of environmental conditions on male fertility.

Keywords: Environment, Infertility, Seasonal, Semen analysis

Gynecol Obstet Reprod Med 2023;29(3):188-195

Introduction

Infertility, a global public health problem defined as the inability to conceive after 12 months of regular unprotected sexual intercourse, is found in 15-20% of couples (1). The overall prevalence of isolated male factor infertility is about 17% (2). Sperm quality is affected by obesity, smoking, alcohol consumption, malnutrition, leukemia, and testicular cancer (3). Like many biological functions with cyclical variations, sperm

quality is affected by the duration of sunlight and other seasonal changes (4-6).

Anatomic structures such as scrotal skin, arteries, and spermatic vessels have the physiologic function of regulating the temperature of the testicles. Adverse effects of high environmental temperature and humidity on sperm production and sperm quality have been observed in several animal studies, suggesting that the ability to regulate temperature in the scrotum is limited (7,8).

Literature reviews have reported that sperm production and quality increase in spring and decrease in summer and winter months (5,6) indicating that sperm quality correlates with optimal temperature. A significant seasonal influence has been shown not only on human sperm counts but also on sperm chromatin condensation, with a shift of about 6 months between the southern and northern hemispheres (9).

Exposure to daylight also affects sperm quality. Melatonin, which is produced in the pituitary gland and is inhibited by daylight, has been shown to affect sperm motility (4,10). Melatonin concentration is high during winter months due to reduced exposure to daylight (11). Similarly, it can be said that sperm quality increases during the winter months.

Although there have been many studies investigating the relationship between semen analysis parameters and seasonal

¹ Trakya University Faculty of Medicine, Department of Obstetrics and Gynecology, Edirne, Türkiye

² Tekirdag City Hospital, Division of Perinatology, Tekirdag, Türkiye


³ Trakya University Faculty of Medicine, Department of Urology, Edirne, Türkiye

Address of Correspondence: Cem Yener
Tekirdag City Hospital, Division of
Perinatology, Tekirdag, Türkiye
drcemyener@hotmail.com

Submitted for Publication: 05.01.2023 Revised for Publication: 21.03.2023

Accepted for Publication: 15.10.2023 Online Published: 12.12.2023

ORCID IDs of the authors: SA: 0000-0001-9650-8340,
CY: 0000-0002-3976-4492, MGA: 0000-0002-9707-596X,
EA: 0000-0002-5430-6561, DC:0000-0001-5480-5347,
KE: 0000-0001-7143-6037

Quick Response Code:	Access this article online
	Website: www.gorm.com.tr e-mail: info@gorm.com.tr
	DOI:10.21613/GORM.2023.1390

How to cite this article: Ates S.Yener C. Arıkan MG. Arda E. Cokay D. Elter K. Retrospective Analysis of Seasonal Changes in Semen Analysis Parameters. *Gynecol Obstet Reprod Med*. 2023;29(3):188-195



Copyright© 2023. Ates et al. This article is distributed under a Creative Commons Attribution 4.0 International License.

changes, the results are controversial (5,12,13). We hypothesized that contradictions can be resolved and more consistent results obtained by conducting studies in geographical regions that experience four distinct seasons. In this study, we aimed to investigate the possible relationship between seasonal changes and semen analysis parameters.

Material and Method

Collecting data and grouping participants: Data from 2055 semen analyses of 1358 patients with unknown fertility status who presented to the in-vitro fertilization unit and outpatient urology clinics of Trakya University School of Medicine between January 2014 and December 2018 were evaluated retrospectively. Patients diagnosed with azoospermia following semen analysis were excluded from the study. The following parameters were selected for evaluation: sperm concentration, total sperm count, sperm motility, and sperm morphology. The seasonal distribution of birth rates was also evaluated. Data were analyzed in four seasonal groups as follows: spring (March, April, May); summer (June, July, August); autumn (September, October, November), and winter (December, January, February).

Weather data (temperature, barometric pressure, humidity, etc.) and daylight and temperature measurements were obtained from a national weather database (www.havaizleme.gov.tr). The sunrise and sunset times of the Kandilli Observatory were used to calculate the daylight duration corresponding to the dates of specimen collection.

This cross-sectional study was reviewed and approved by the ethics committee of Trakya University Medical Faculty and was conducted in accordance with the Declaration of Helsinki (Approval No: TUTF-BAEK; 2020/231).

Semen analysis: Standard semen analysis was performed according to WHO guidelines (14). Semen samples were obtained by masturbation into a sterile container after 2-7 days of abstinence from sexual activity. Semen samples were collected in a designated room near the laboratory to minimize exposure to temperature changes and light that could adversely affect the samples and to maintain a consistent analysis time. Samples were kept at an ambient temperature of 20°C-37°C and analysis was performed 30-60 minutes after ejaculation.

Semen samples were first evaluated macroscopically; liq-

uefaction, viscosity, appearance, volume, and pH were recorded. Sperm concentration and motility assessments were performed with an Olympus CX-31 light microscope. A 10 µl drop of semen was deposited on a Makler counting chamber (Sefi Medical Instruments Ltd., Haifa, Israel). Sperm in 10 random squares of the Makler chamber were counted at 200× magnification and the sperm concentration was calculated. Sperm motility was determined by noting fast forward motion, slow forward motion, movement in place, and immobility of sperm in 100 squares.

To evaluate sperm morphology, a 20 µl aliquot of each sample was smeared onto a glass slide and air-dried. The slides were stained with the Spermac stain kit (Wellington, South Africa) after fixation in 10% formol for 5 minutes. The slides were washed with distilled water and treated with each stain (A, B, and C) for one minute. Morphology was assessed with a Nikon Eclipse E200 light microscope at 1000× magnification using Kruger criteria (15). At least 100 spermatozoa were evaluated for each sample; abnormalities (amorphous head, cytoplasmic droplets, neck, and tail defects) were recorded and a normal sperm percentage was calculated.

Statistical Analysis

Data analysis was done using R version 4.0.2 (R Foundation for Statistical Computing, Vienna, Austria) (16). Linear mixed effect models were created where semen analysis parameters (semen volume, sperm concentration, total sperm count, sperm motility, and sperm morphology) were dependent variables and age, season, weather parameters, and daylight duration were independent variables. Mean ± standard deviation, minimum and maximum values for semen volume, sperm concentration, total sperm count, motility, and sperm morphology were calculated. Residual errors of the models were within acceptable limits.

Results

Semen samples from 1358 men with a mean age of 32.75 ± 6.20 were included in the study; a total of 2055 sperm samples were evaluated. Semen volume, concentration, total sperm number, motility, and morphology are shown in Table I. There were 534 (25.9%) measurements in winter, 480 (23.3%) in spring, 586 (28.5%) in summer, and 455 (22.1%) in autumn. The total number of births in five years was 4004, with 1009 (25.19%) in spring, 1079 (26.94%) in summer, 969 (24.20%) in autumn, and 947 (23.65%) in winter.

Table I: Descriptive statistics of sperm parameters

	Volume (mL)	Concentration (mil/mL)	Total sperm number (mil)	Fast Motility (%)	Slow Motility (%)	Immotile (%)	Total Motility (%)	Morphology (%)
Min.-	0.1	01	03	0	0	0	0	0
Max.	9.60.	2300.	835.2	71	100	94	100	11
Mean±	2.77±	41.18±	106.90±	7.63±	28.91±	10.03±	46.58±	1.47±
SD	1.46	39.95	111.68	12.86	15.75	7.47	20.50	1.20

Paired comparisons of all sperm parameters between seasons are summarized in Table II-a and II-b. The mean air temperature and daylight duration were $14.75 \pm 8.13^\circ\text{C}$ and 12.16 ± 2.07 h, respectively. The seasonal means for air temperature and daylight duration are given in Table III, and the variation of semen analysis parameters with temperature and daylight is shown in Table IV.

Volume: The effects of seasons, air temperature, and daylight duration on mean sperm volume were not statistically

significant. Sperm volume decreased with age ($p=0.012$) (Figure 1-a).

Concentration: A statistically significant difference was found in mean sperm concentration between winter and summer, spring and autumn, and autumn and summer ($p=0.023$, $p=0.031$, and $p=0.001$, respectively). An increase in air temperature and daylight duration was significantly associated with a decrease in mean sperm concentration. ($p=0.001$ and $p=0.021$) (Figure 1-b).

Table II-a: Sperm parameter statistics showing seasonal changes in sperm volume, concentration, total count, and progressive motility

	Volume (mL)	p	Concentration (mil/mL)	p	Total Count (mil)	p	Progressive Motility (%)	p
Winter - Spring	783 -2.779	0.967	46.844-46.736	0.955	120.133 -119.522	0.911	7.57 - 9.218	0.021
Winter - Summer	2.783 -2.798	0.824	46.844 -42.655	0.023	120.133 -107.833	0.018	7.57 - 9.275	0.013
Winter-Autumn	2.783 - 2.774	0.914	46.844 - 49.19	0.229	120.133 -129.544	0.089	7.57 - 9.482	0.008
Spring-Summer	2.779 - 2.798	0.797	46.736 - 42.655	0.031	119.522 -107.833	0.030	9.218 -9.275	0.935
Spring-Autumn	2.779 - 2.774	0.947	46.736 - 49.19	0.207	119.522 -129.544	0.071	9.218 -9.482	0.714
Summer-Autumn	2.798 - 2.774	0.747	42.655 - 49.19	0.001	107.833 -129.544	<0.001	9.275 -9.482	0.767

Table II-b: Sperm parameter statistics showing seasonal changes of sperm slow motility, immotility, total motility, and morphology

	Slow Motility (%)	p	Immotile (%)	p	Total Motility (%)	p	Morphology (%)	p
Winter-Spring	27.511-29.288	0.066	8.492-10.043	0.001	43.623-48.072	<0.001	1.641-1.702	0.355
Winter-Summer	27.511-28.593	0.238	8.492-11.332	<0.001	43.623-48.696	<0.001	1.641-1.529	0.075
Winter-Autumn	27.511-32.298	<0.001	8.492-9.885	0.003	43.623-51.368	<0.001	1.641-1.682	0.540
Spring-Summer	29.288-28.593	0.464	10.043-11.332	0.005	48.072-48.696	0.605	1.702-1.529	0.008
Spring-Autumn	29.288-32.298	0.003	10.043-9.885	0.745	48.072-51.368	0.010	1.702-1.682	0.766
Summer-Autumn	28.593-32.298	<0.001	11.33-9.885	0.002	48.696-51.368	0.029	1.529-1.682	0.020

Table III: Mean \pm SD values of daylight duration and temperature according to the seasons

	Daylight (Hours)	Temperature ($^\circ\text{C}$)
Winter	9.73 \pm 0.63	4.96 \pm 3.61
Spring	11.14 \pm 1.13	15.33 \pm 4.63
Summer	14.54 \pm 0.59	24.31 \pm 2.54
Autumn	13.02 \pm 1.09	13.32 \pm 4.51

Table IV: The variation of sperm parameters with increasing temperature and daylight

	Temperature	Daylight duration
Volume (mL)	--	--
Concentration (mil/mL)	↓	↓
Total Count (mil)	↓	↓
Progressive Motility (%)	↑	↑
Immotile (%)	↑	↑
Total Motility (%)	↑	↑
Morphology (%)	--	↓

Total sperm count: Total sperm count was statistically different between winter-summer, spring-summer, and summer-autumn ($p=0.018$, $p=0.030$, and $p<0.001$, respectively). The mean total sperm count was statistically lower with higher air temperature and daylight duration ($p<0.001$ and $p=0.021$). (Figure 1-c).

Total sperm motility: A statistically significant difference was found in the percentage of total motile sperm in all paired comparisons except spring and summer. Increasing age was

associated with a decrease in the mean percentage of total motile sperm ($p=0.010$). Increasing ambient temperature and sunlight correlated with an increase in the percentage of total motile sperm ($p<0.01$ and $p<0.01$, respectively). (Figure 1-d).

Percentage of progressive motile sperm: A statistically significant difference in the mean progressive motile sperm percentage was found in winter-spring and summer-autumn comparisons ($p=0.021$, $p=0.013$, and $p=0.008$). The average percentage of progressive motile sperm was higher in winter than

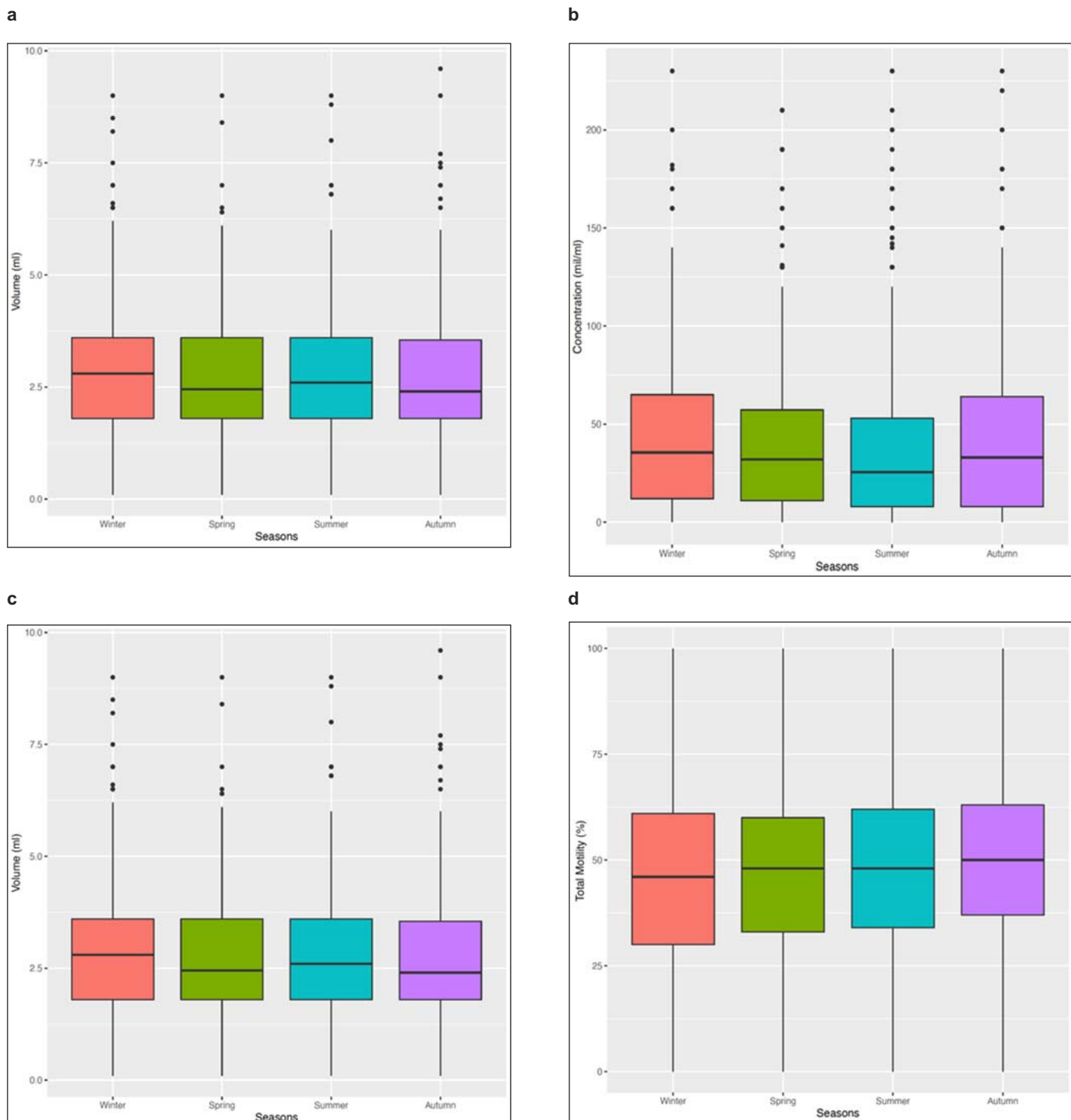


Figure 1: It depicts changes in sperm volume (a), concentration (b), total count (c), and total motility (d) with seasons.

in all other seasons. Increasing age also was associated with a statistically significant decrease in the percentage of progressive motile sperm ($p=0.027$). Increasing air temperature and duration of daylight were associated with an increase in the percentage of progressively motile sperm ($p=0.001$ and $p=0.03$) (Figure 2-a and 2-b).

Percentage of immotile sperm: In all paired comparisons except spring and autumn, a statistically significant difference was found in the percentage of immotile sperm. An increase in temperature and daylight duration correlated with an in-

crease in the mean percentage of immotile sperm ($p<0.001$ and $p<0.01$) (Figure 2-c).

Morphology: Morphology was significantly different between autumn-summer and spring-summer groups ($p=0.02$ and $p=0.008$). The effect of temperature on the mean percentage of sperm morphology was not statistically significant, but an increase in daylight duration was associated with a decrease in the percentage of sperm morphology ($p=0.028$) (Figure 2-d).

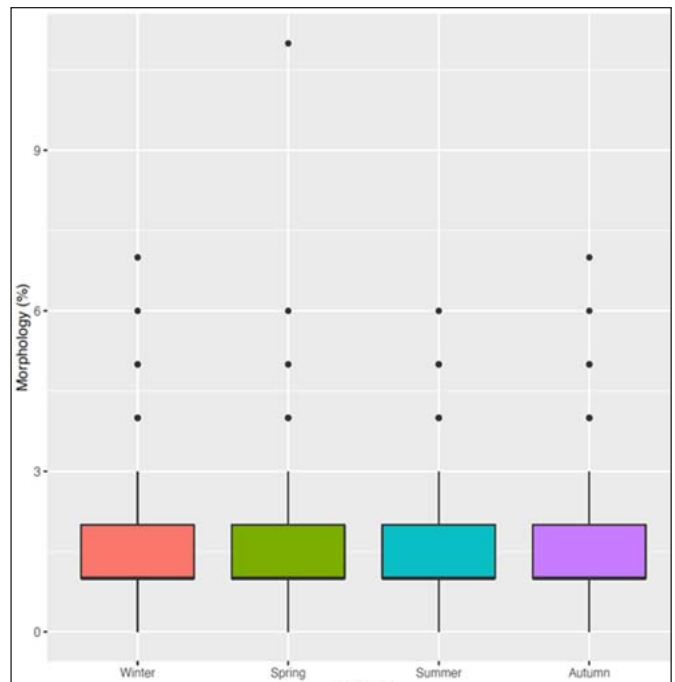
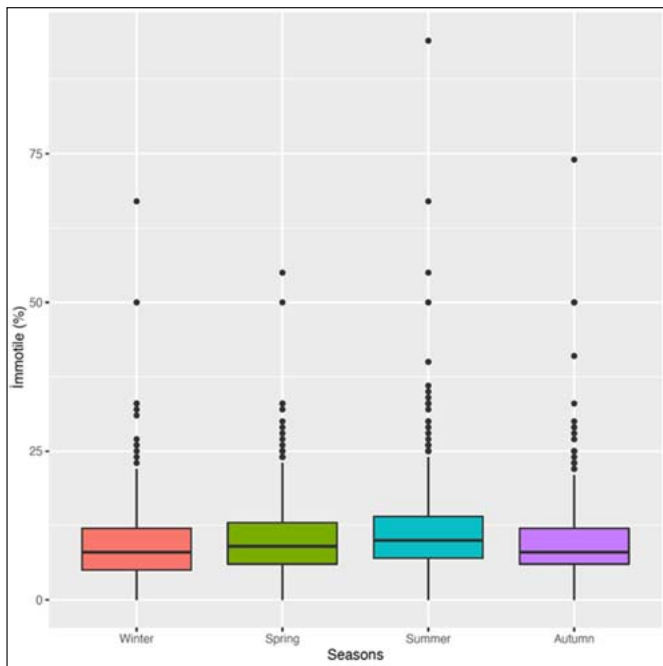
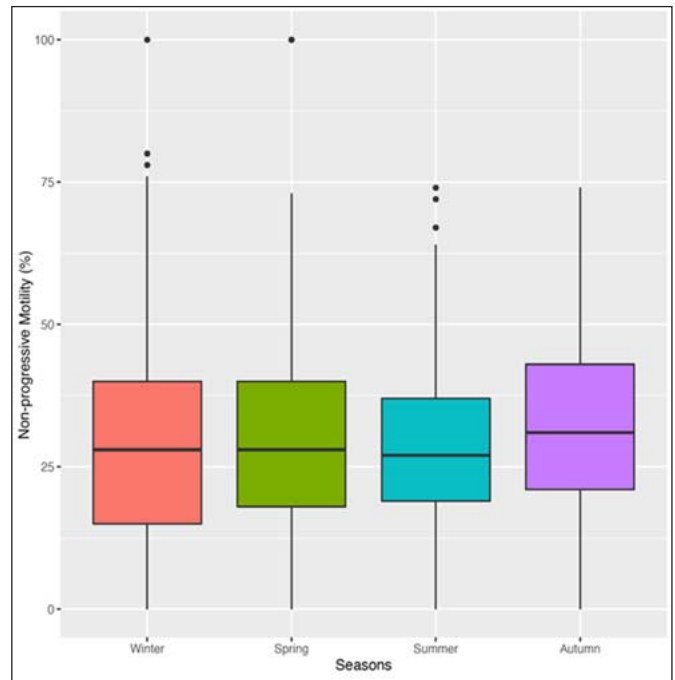
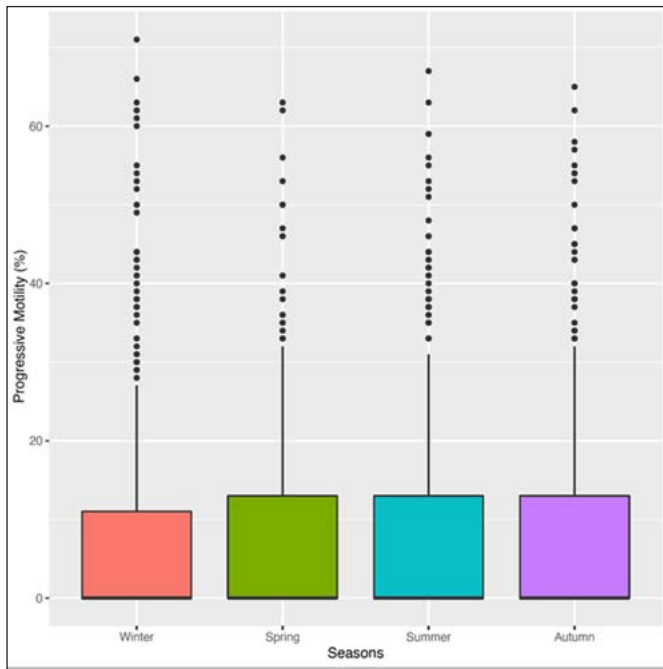


Figure 2: Percentages of progressive motility (a), non-progressive motility (b), immotile (c), and morphology (d) of sperms are shown according to the seasons.

Discussion

In this study, we showed that seasonal variation, temperature, and daylight duration affect some semen analysis parameters. This study was based on a population in the Thrace region, which experiences four distinct seasons. This is the first study conducted in Türkiye with these characteristics.

Köppen climate classification is one of the most frequently used climate classification methods worldwide (17,18) describes climate zones based on the distribution of vegetation cover, the mean annual-monthly temperature, and the amount of precipitation to establish climate zones. Thrace is in northwestern Türkiye, which has four distinct seasons dominated by a Mediterranean climate according to the Köppen classification.

While evaluating the studies, it should be kept in mind that every seasonal change is not standard, and the characteristics of the season may change according to the climatic conditions of a region. The only previous study on this subject in Türkiye was conducted (13), which showed that the percentage of sperm with normal morphology in spring samples was significantly higher than in autumn samples. We obtained similar results in our study, supporting the findings of Ozelci et al. However, unlike our study, Ozelci et al. found no significant relationship between sperm concentration and season. We think that this difference may be due to the different climates of the Thrace region and Ankara, which have Mediterranean and Terrestrial Köppen classifications, respectively. In a retrospective comprehensive study conducted in Barcelona, Spain, which has the same latitude as Thrace and a Mediterranean climate, (19) found a decrease in sperm parameters in the summer months and an improvement at the end of the winter was found; this result is compatible with our study.

This study shows sperm concentration and total sperm count are lower in summer compared to other seasons. Our results agree with the lowest sperm concentrations in the summer months reported in a meta-analysis investigating the effect of seasonal change on human reproduction (19). The cause of the seasonal change may be the negative effect of increasing air temperatures on spermatogenesis (20).

In a study conducted by Xie et al. in a population with a similar age range, sperm concentration and total sperm count were significantly higher in winter than in summer, and normal morphology was higher in summer (3). In our study, although concentration and total sperm count show similar seasonal changes, morphology did not change. This difference may be due to the different seasonal classifications in the Xie et al. study.

Studies have reported that the main factors affecting the seasonal cycle of semen analysis parameters are air temperature and daylight (20-23). Changes in ambient temperatures

can explain seasonal changes in semen parameters (20,24). Spermatozoa production occurs in the testicles inside the scrotum, where the temperature is about 35°C, a relatively cool environment (7). The scrotum helps regulate the temperature in testicles with its high vascularization, hair growth, abundant sweat glands, and thin skin without subcutaneous fat, reflecting the sensitivity of spermatogenesis to temperature (24,25). It is generally accepted that an increase in scrotal skin temperature results in impaired spermatogenesis (26,27). Garolla et al. reported that 24-hour monitoring of scrotal temperature in men with a varicocele and obese men revealed higher temperatures than control groups (28). This increase in scrotal temperature might be the reason for impaired sperm production in obese men and men with a varicocele. In another epidemiologic study, Chia et al. showed that the rate of oligozoospermia is higher in workers who are exposed to high temperatures at work (22). High temperature may be the reason that mean sperm concentrations were at the lowest level in summer and the highest level in winter and autumn, consistent with our study. Chia et al. reported that there was no significant change in semen volume and sperm concentration among men living in the tropics where the seasonal temperature difference is very low, supporting an influence of ambient temperature on sperm production (29).

Melatonin, produced by the pituitary gland and influenced by external light stimuli, has been shown to have a positive effect on sperm motility (10). Melatonin secretion is inhibited by light; therefore, sperm concentration rises during the winter months due to reduced exposure to daylight (11). In the study conducted by De Giorgi et al., total sperm count and concentration showed an inverse relationship with daylight duration (4). However, it was found that motility correlated with increasing daylight duration. Our results are consistent with this study, which is similar in terms of seasonal characteristics, and this result, which is contrary to the literature in general, suggests that the influence of daylight is at the beginning of the 70-90-day spermatogenesis process.

Controversial results have been reported for the relationship between birth rates and sperm parameters. In this study, birth rates did not show a statistically significant seasonal change. In addition, there was no relationship found between the seasonal change in semen analysis parameters and birth rates. Higher birth rates might be expected in autumn as a reflection of better sperm parameters in winter. The Ozelci et al. study does not support an impact of improved semen analysis parameters on birth rates, reporting the best sperm parameters in spring and winter but the lowest birth rates in winter. Further studies are needed to clarify these contradictory results (13).

The most important limitation of this study is its retrospective nature. The collection of semen samples was between 8 a.m. and 12 p.m. but was not fully standardized. Another limitation is; that out of 2055 samples that make up our study

group, 387 men have given multiple samples. However, %28 (108/387) of these men were given samples only in the same season. Number of men who have given at least one sample in each of the four seasons was eleven. Due to this limited number of subjects, statistical analysis would be inconclusive. We believe that semen analysis of samples of the same subject in four different seasons will be a good study in a prospective manner. The last limitation is that it is not possible to establish a relationship between infertility and birth rates because patients presented to the outpatient urology clinic for various reasons.

We clearly show a seasonal variation in semen analysis parameters with the highest sperm concentration in autumn and the lowest motility rates in winter. It seems that fluctuations throughout the year are affected by both environmental temperature and daylight changes. Hence, improvement of environmental factors may help in the treatment of infertility. More studies are needed to identify the mechanisms linking environment, hormonal changes, and semen analysis parameters in different seasons.

Acknowledgment: We are grateful for the tireless efforts of the research team members.

Disclosure of potential conflicts of interest: The authors declare no competing interests related to the subject matter or materials discussed in this article.

Funding: The authors received no funding for this work.

Availability of data and materials: The data supporting this study is available through the corresponding author upon reasonable request.

Ethics approval and consent to participate: Informed consent is not required as it is a retrospective study. This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of Trakya University Medical Faculty (approval number: 2020/231).

Authors' contributions: Conceived and designed the experiments: SA, CY; Performed the experiments: SA, CY, DC; Analyzed the data: MGA, EA, KE; Contributed reagents/ materials/ analysis tools: SA, DC; Wrote the manuscript: SA, CY, MGA; Final edit of paper: CY, KE.

References

1. Agarwal A, Mulgund A, Hamada A, Chyatte MR. A unique view on male infertility around the globe. *Reprod Biol Endocrinol.* 2015;13:37. Doi: 10.1186/s12958-015-0032-1. PMID: 25928197, PMCID: PMC4424520.
2. Odisho AY, Nangia AK, Katz PP, Smith JF. Temporal and geospatial trends in male factor infertility with assisted reproductive technology in the United States from 1999-2010. *Fertil Steril.* 2014;102(2):469-75. Doi:10.1016/j.fertnstert.2014.05.006. PMID: 24931206.
3. Xie M, Utzinger KS, Blickenstorfer K, Leeners B. Diurnal and seasonal changes in semen quality of men in subfertile partnerships. *Chronobiol Int.* 2018;35(10):1375-84. Doi: 10.1080/07420528.2018.1483942. PMID: 29913075.
4. De Giorgi A, Volpi R, Tiseo R, Pala M, Manfredini R, Fabbian F. Seasonal variation of human semen parameters: A retrospective study in Italy. *Chronobiol Int.* 2015;32(5):711-6. Doi: 10.3109/07420528.2015.1024315. PMID: 25938597.
5. Levine RJ. Seasonal variation of semen quality and fertility. *Scand J Work Environ Health.* 1999;25 Suppl 1:34-7; discussion 76-8. PMID: 10235406.
6. Saint Pol P, Beuscart R, Leroy-Martin B, Hermand E, Jablonski W. Circannual rhythms of sperm parameters of fertile men. *Fertil Steril.* 1989;51(6):1030-3. Doi:10.1016/s0015-0282(16)60738-0. PMID: 2721720.
7. Ivell R. Lifestyle impact and the biology of the human scrotum. *Reprod Biol Endocrinol.* 2007;5:15. Doi: 10.1186/1477-7827-5-15. PMID: 17448228, PMCID: PMC1863418.
8. Suriyasomboon A, Lundeheim N, Kunavongkrit A, Einarsson S. Effect of temperature and humidity on sperm morphology in duroc boars under different housing systems in Thailand. *J Vet Med Sci.* 2005;67(8):777-85. Doi: 10.1292/jvms.67.777. PMID: 16141664.
9. Henkel R, Menkveld R, Kleinhappl M, Schill WB. Seasonal changes in human sperm chromatin condensation. *J Assist Reprod Genet.* 2001;18(7):371-7. Doi: 10.1023/a:1016618405570. PMID: 11499320, PMCID: PMC3455827.
10. Ortiz A, Espino J, Bejarano I, Lozano GM, Monllor F, García JF, et al. High endogenous melatonin concentrations enhance sperm quality and short-term in vitro exposure to melatonin improves aspects of sperm motility. *J Pineal Res.* 2011;50(2):132-9. Doi: 10.1111/j.1600-079X.2010.00822.x. PMID: 20964711.
11. Arendt J. Melatonin and human rhythms. *Chronobiol Int.* 2006;23(1-2):21-37. Doi: 10.1080/07420520500464361. PMID: 16687277.
12. Chen Z, Godfrey-Bailey L, Schiff I, Hauser R. Impact of seasonal variation, age and smoking status on human semen parameters: The Massachusetts General Hospital experience. *J Exp Clin Assist Reprod.* 2004;1(1):2. Doi: 10.1186/1743-1050-1-2. PMID: 15507127, PMCID: PMC524369.
13. Ozelci R, Yılmaz S, Dilbaz B, Akpınar F, Akdag Cırık D, Dilbaz S, Ocal A. Seasonal variation of human sperm cells among 4,422 semen samples: A retrospective study in Turkey. *Syst Biol Reprod Med.* 2016;62(6):379-86. Doi: 10.1080/19396368.2016.1225322. PMID: 27611370.
14. World Health Organization. (2010). WHO laboratory manual for the examination and processing of human semen, 5th ed. World Health Organization. <https://apps.who.int/iris/handle/10665/44261>

15. Kruger TF, Ackerman SB, Simmons KF, Swanson RJ, Brugo SS, Acosta AA. A quick, reliable staining technique for human sperm morphology. *Arch Androl.* 1987;18(3):275-7. Doi: 10.3109/01485018708988493. PMID: 2445315.
16. Core Team R. Foundation for Statistical Computing. R: a language and environment for statistical computing. Available at: <https://www.R-project.org/>
17. Koppen WP. Klassifikation der Klima nach Temperatur, Niederschlag und Jahreslauf. *Petermanns Geographische Mitteilungen.* 1918;64:193-203.
18. Koppen W. Das geographische system der klimat. *Handbuch der klimatologie.* 1936:46.
19. Andolz P, Bielsa MA, Andolz A. Circannual variation in human semen parameters. *Int J Androl.* 2001;24(5):266-71. Doi: 10.1046/j.1365-2605.2001.00297.x. PMID: 11554983.
20. Levine RJ. Male factors contributing to the seasonality of human reproduction. *Ann N Y Acad Sci.* 1994;709:29-45. Doi: 10.1111/j.1749-6632.1994.tb30386.x. PMID: 8154722.
21. Snyder PJ. Fewer sperm in the summer--it's not the heat, it's. *N Engl J Med.* 1990;323(1):54-6. Doi: 10.1056/NEJM199007053230110. PMID: 2355958.
22. Chia SE, Ong CN, Lee ST, Tsakok FH. Study of the effects of occupation and industry on sperm quality. *Ann Acad Med Singap.* 1994;23(5):645-9. PMID: 7847740.
23. Chik CL, Almeida OF, Libré EA, Booth JD, Renquist D, Merriam GR. Photoperiod-driven changes in reproductive function in male rhesus monkeys. *J Clin Endocrinol Metab.* 1992;74(5):1068-74. Doi: 10.1210/jcem. 74.5. 1569154. PMID: 1569154.
24. Zhang XZ, Liu JH, Sheng HQ, Wu HJ, Wu Y, Yao KS, et al. Seasonal variation in semen quality in China. *Andrology.* 2013;1(4):639-43. Doi: 10.1111/j.2047-2927.2013.00092.x. PMID: 23682039.
25. Skandhan KP, Rajahariprasad A. The process of spermatogenesis liberates significant heat and the scrotum has a role in body thermoregulation. *Med Hypotheses.* 2007;68(2):303-7. Doi: 10.1016/j.mehy.2006.06.058. PMID: 17011725.
26. Mieusset R, Bujan L, Mondinat C, Mansat A, Pontonnier F, Grandjean H. Association of scrotal hyperthermia with impaired spermatogenesis in infertile men. *Fertil Steril.* 1987;48(6):1006-11. Doi: 10.1016/s0015-0282(16) 59600-9. PMID: 3678498.
27. Wang C, Cui YG, Wang XH, Jia Y, Sinha Hikim A, Lue YH, et al. Transient scrotal hyperthermia and levonorgestrel enhance testosterone-induced spermatogenesis suppression in men through increased germ cell apoptosis. *J Clin Endocrinol Metab.* 2007;92(8):3292-304. Doi: 10.1210/jc.2007-0367. PMID: 17504903.
28. Garolla A, Torino M, Miola P, Caretta N, Pizzol D, Mene-gazzo M, et al. Twenty-four-hour monitoring of scrotal temperature in obese men and men with a varicocele as a mirror of spermatogenic function. *Hum Reprod.* 2015;30(5):1006-13. Doi: 10.1093/humrep/dev057. PMID:25779699.
29. Chia SE, Lim ST, Ho LM, Tay SK. Monthly variation in human semen quality in male partners of infertile women in the tropics. *Hum Reprod.* 2001;16(2):277-81. Doi: 10.1093/humrep/16.2.277. PMID: 11157820.