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Occupational Heat Exposure and Male Infertility: Implications for Reproductive Health in High-Heat Work Environments

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ABSTRACT

This study examines the effect of high temperatures in work environments on sperm viability and motility, which may lead to rising concerns in occupational health circles. For the purposes of this study, specimens were carefully chosen from a diverse range of individuals, an artificial setup was created to subsequently subject the specimen to various temperatures ranging from 34 degrees Celsius to 45 degrees Celsius, and parameters were recorded. We then compared this dataset with samples from ambient temperatures. This investigation assessed parameters such as sperm count, sperm viability, and motility. Preliminary results indicated a significant negative correlation between prolonged exposure to high-temperature environments and sperm viability and motility. These results highlight the importance of enhancing occupational safety protocols and implementing focused public health interventions for individuals working in environments with elevated temperatures. The data gathered from this research adds to the growing evidence connecting occupational risks to reproductive health concerns. Additionally, there is a need for extensive investigations to validate these results and investigate possible preventive and mitigating strategies.

Keywords: Temperatures, Sperm, Fertility, Motility, Testis.

INTRODUCTION

Occupational health and safety is a constantly evolving field, with researchers continuously identifying and understanding new potential hazards. While there has been significant research on chemical exposure, ergonomic problems, and stress-related issues, there has been less attention given to the impact of physical environmental conditions on workers' health. These conditions, such as air quality and temperature, have been associated with health risks such as heat stress, cardiovascular diseases, and renal diseases. It is important to fill in this research gap. Less attention has been given to the potential reproductive health implications of such conditions, and the gap in research is more relevant considering the rise in the infertility rate among males. In this context, the potential impact of occupational heat exposure on sperm quality needs closer study.

Understanding the relationship between high-temperature work environments and sperm viability and motility is crucial for several reasons. Firstly, previous studies have shown that scrotal temperature can significantly influence sperm production and quality. Therefore, it is important to investigate the potential impact of occupational heat exposure on sperm quality to identify potential risks to male reproductive health. Secondly, with the rise in male infertility rates, it is essential to explore all possible factors that may contribute to this trend. Studying the effects of high-temperature work environments on sperm quality will help us identify potential risks to male reproductive health and improve occupational safety measures. These findings can then be used to enhance occupational safety measures and protect the reproductive health of male workers.

LITERATURE REVIEW

A comprehensive review of male fertility factors shows that a major cause of heat exposure is occupation or way of living. Under normal, healthy, optimal conditions, testicular thermoregulation supports scrotal hypothermia to ensure ideal testicular function, as presented by Thonneau, P.; Bujan, L.; Multigner, L.; and Mieusset[1]. According to an article by Jung A and Schill WB [2], the testicles must be at a lower temperature than the body core for optimal spermatogenesis. This is accomplished as blood in the testicular artery is precooled by the surrounding veins of the plexus pampiniformis, heat loss via the scrotal skin, and increased circulation of air around the genitals. If the combination of these variables is adverse, spermatogenesis and fertility may be disrupted. Similarly, excessive exposure to electromagnetic waves may affect spermatogenesis by inducing heat in the testicles. Exposure to heat poses a risk factor for male infertility, as it can have a detrimental impact on fertility. The maintenance of lower temperatures in the testicles, compared to the core body temperature of 36.9°C, is crucial for supporting normal spermatogenesis and optimal sperm characteristics. The physical position of the human testes, located outside the body, plays a significant role in ensuring a lower temperature for optimal spermatogenesis and optimal sperm attributes. Homeothermic animals maintain a steady core body temperature regardless of shifting environmental temperatures. Changing the body's metabolism is accomplished by controlling heat generation and loss. Temperature affects testicular function, and a change in temperature that is either above or below the physiological range needed to support testicular activity, interferes with spermatogenesis [3]. Mieusset and Bujan [4] presented a historical review of scrotal temperature, posture, and potential heat exposure (exogenous factor). Male fertility, which is frequently assessed through conditions such as sperm vitality, and sperm count, is known to be influenced by diverse environmental stressors, including heat. The process of spermatogenesis, which entails the production of sperm, is inherently sensitive to temperature and ideally transpires at temperatures slightly lower than the average body temperature.

In most mammals, the primary role of the scrotum is to protect the testis from excessive heat by adapting to heat stress conditions. Occupational health hazards, which have traditionally been associated with the potential to cause acute and chronic physical diseases, are now being increasingly recognized for their possible impacts on reproductive health. One such hazard is the prolonged exposure to high temperatures often encountered in a range of work environments such as steel mills, glass manufacturing plants, firefighting, bakeries, and specific areas of construction. These high-heat occupational settings pose potential risks for various health issues, one of the less explored being male fertility. The scrotal thermogenic factors influenced by body and scrotum temperature include the following: body position, obesity, clothing, occupational exposure, and lifestyle. Sharpe [6] discussed the relationship between sperm counts, fertility, and men's challenges in a changing world. In a Science Society article published in 2012, the author addressed the declining sperm counts in men and its implications for fertility. The report highlighted the complex factors influencing male fertility, including environmental, genetic, and lifestyle factors. Below, we discuss some of the lifestyle factors that affect the scrotal temperature.

A. Posture

Testicular temperature is indeed impacted by changes in body posture. It's found to be at its lowest when a person is standing unclothed. This position allows for unobstructed heat dissipation from the unsupported testes. When we compare various body positions, the scrotum tends to be warmer when a person is sitting or lying down, compared to when he is standing. Interestingly, when a person is walking, even after factoring in the type of clothing worn, scrotal temperatures tend to be around 0.30 to 1.0°C cooler than when he is sitting. When it comes to sleep, scrotal temperatures typically rise, primarily because the body is typically in a flat position with minimal movement. The testes, which rest on the thighs, come into direct contact with the body, which generally has a higher temperature. It is also worth noting that sleepwear contributes to this effect. Scrotal temperatures have been observed to be at their lowest when sleeping in the nude, compared to sleeping in pyjamas or underwear.

B. Clothing

Clothing performs a significant task in the control of scrotal temperature, irrespective of body position. Clothing acts as an insulator, elevating scrotal temperature by around 1.5-2°C when compared to being unclothed, regardless of whether a person is standing or lying down. (For men who are resting and lightly dressed, the air layer trapped between the skin and the dress can be, on average, 3.5°C warmer than the surrounding ambient air, provided this ambient air temperature lies between 21°C and 32°C.) The decrease in air exchange, when dressed, can lead to a rise in scrotal skin temperature. Dresses that allow for better air circulation can facilitate the dissipation of scrotal heat, thereby maintaining temperatures closer to physiological levels. It's recommended that wearing a Scottish kilt may create a more ideal physiological environment for the scrotum, especially given that most men opt not to put on anything beneath their kilt. Similarly, in Asia, it's common for men to wear only a sarong when relaxing. This loose, breathable garment aids in dispersing the core temperature of the body relatively, thus, helping to maintain lower testicular temperatures. Mieusset and Bujan[4]

C. Laptop on lap

Sheynkin, Y.; Jung, M.; Yoo, P.; Schulsinger, D.; and Komaroff, E [5] in this study investigated the thermal impact of laptop computers (LC) on the scrotal temperature (ScT) in 29 healthy volunteers. The study found that the ScT significantly increased when the LC was used in a laptop position and to a lesser extent without the LC, attributable to posture and heat exposure. This rise was significantly higher when using an LC, implying that long-term exposure to LC related transient scrotal hyperthermia may negatively affect spermatogenesis, especially in teenage boys and young men. Further research on such thermal effects on male reproductive health is recommended.

Mieusset and Bujan conducted a review in 1995 to explore the effect of increased testicular temperature on sperm count and quality, highlighting its potential role in male infertility. The authors discussed the interconnection between scrotal temperature and varicocele and their effects on sperm parameters. The review provided valuable insights into the detrimental effects of testicular heating on male fertility.

An article by Al-Otaibi and T. [7] looks at prevalence of male infertility among bakers who work at high temperatures in the bakeries. 137 bakers from 20 bakeries and 107 people in the control group, varied in age, race, marital status and income were taken and it was found that 22.7% bakers and 3% of the control group had infertility. This correlates with the fact that the bakeries had a WBGT (Wet-bulb global temperature) index of 37.4°C much higher than WBGT for offices which was 25.5°C.

In the study by Esfandiari, N.; Saleh, R. A.; Blaut, A. P.; Sharma, R. K.; Nelson, D. R.; Thomas, A. J., Jr; Falcone, T.; and Agarwal, A(2002), they evaluated the effect of temperature on sperm motility, sperm viability, sperm motion characteristics, and the production of reactive oxygen species in semen; they collected the semen from 12 infertile patients and 12 healthy donors. Each sample was divided into four aliquots just after liquefaction. One aliquot was analysed immediately and three were analysed after one hour of incubation at 4°C, 25°C, and 37°C, respectively. The result showed after the analysis that motility was highest at 37°C; even this study suggests a negative correlation between the temperature and sperm motility [8].

Appell, R. A. and Evans, P. R. [9] stated that sperm lose their motility and viability when kept at 37°C which is the core body temperature in specimens of sperm. They remain viable when kept at 4°C, but they lose their motility due to what is known as thermal shock. Preventing bacterial contamination with antibiotics does not completely prevent motility loss at 37°C, so the best temperature to keep sperm at is 20°C. Testicles must be 2 to 3°C cooler than the average body temperature for healthy spermatogenesis. Because of this, the testicles are located inside the scrotum, below the body. In undescended testes, the inability of the testicles to enter the scrotum and produce healthy sperm may result in infertility later in life. The ideal temperature to produce sperm is 34°C, which is about 3°C lower than the average body temperature. Sperm count and motility, which in turn affects sperm quality, will be affected if the scrotal temperature rises too high. The testicles must be kept at the right temperature to produce sperm. As a result, the scrotum shrinks to maintain the right temperature for the testicles. This takes place involuntarily. As a result, when it's cold, the scrotum contracts and pulls up closer to the body to keep warm.

In their 1977 study, Rodney A. Appell and Paul R. Evans examined the effects of temperature on sperm motility and viability in semen specimens from fertile prevasectomy patients. Semen specimens from fertile prevasectomy patients maintained at 4°C, 20°C, and 37°C were evaluated at 3, 6, 12, and 18 hours after collection. Sperm motility and viability, which were measured with an eosin-nigrosin stain, went down over time at both 20°C and 37°C, but the rate was much faster at 37°C, where motility dropped by half in 12 hours. The slope of the decrease in viability closely paralleled that of the motility except at 4°C, where motility was nearly absent at 6 hours but viability was retained through 18 hours. It is clear from this study that there is a correlation between temperature, sperm viability, and motility The close correlation between viability and motility at 20°C and 37°C suggests that as motility decreases, viability also decreases [10].

A study by Zhang, X.; Fan, Z.; Wang, Q.; Deng, X.; Xu, R.; Li, Y.; Liu, T.; Wang, R.; Shi, C.; Huang, S.; Lv, Z.; Chen, G.; Duan, Y.-G.; and Liu, Y,published in Environment International in 2020, examined the relationship between ambient temperature and sperm quality among 10,802 Chinese males. Researchers discovered an inverted U-shaped exposure-response relationship between air temperature and all semen quality parameters, with a 13°C optimal threshold. Both lower and higher temperatures than this threshold were associated with a reduction in the quality of the sperm. This study emphasises the importance of avoiding extreme ambient temperatures in order to maintain optimal sperm quality and suggests further investigation into the underlying mechanisms and causes of this association [11]. The literature states that temperature can significantly impact sperm motility and overall male fertility. However, more research is needed to fully understand the mechanisms underlying these effects and develop effective strategies for preserving male fertility in the face of environmental and physiological challenges.

METHOD

The aim of this study is to examine the impact of high temperature work environments on sperm motility and viability. In order to achieve this objective, the following methodology was used the samples were collected from males between the ages of 18 and 35, in a variety of workplaces. Semen samples were collected from participants following standard guidelines. The semen samples were collected after abstaining from ejaculation for 3-4 days. Samples were collected via masturbation, in a private and comfortable room in the laboratory itself, in a clean, sterile, wide-mouthed container. Immediately, the samples were kept in a controlled temperature environment to liquefy for 10-15 minutes. After 15 minutes, the initial base reading was taken at 34°Celsius.

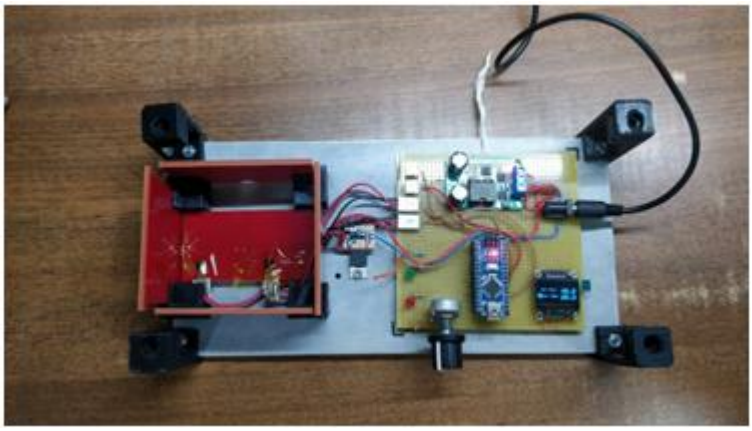

Figure 1. Heating setup for slides.

One aliquot was analysed at a temperature of 34°C. The other three aliquots were placed on a specially fabricated heating plate equipped with heating filaments and a Proportional Integral Derivative (PID) temperature controller. The PID temperature controller was used to adjust the temperature of the heating plate, as shown in figures. 2 to simulate the heat conditions at 37°C, 40°C and 45°C. The second aliquot was heated for 15 minutes to investigate the immediate effects of heat exposure at 37°C. The third aliquot was exposed to heat of 40°C and fourth aliquot was exposed to high heat of 45°C. Post-heating, sperm motility in the samples was analysed under the guidance of a trained embryologist, and the results were compared to the baseline and between the groups. This will allow us to ascertain the impact of heat exposure on sperm motility and vitality. This methodology ensures a controlled and replicable investigation into the impacts of high-heat environments on sperm motility and viability, thereby providing reliable and valuable insights into this critical occupational health concern.

In my project, I faced a host of challenges that underscored the complexity of the task at hand. First and foremost, accessing sperm samples was significantly hurdled by ethical, legal, and privacy concerns. This was compounded by the fact that sperm are temperature sensitive, necessitating precise monitoring and adjustments to avoid compromising the viability of our samples. This sensitivity further required the intricate development of an apparatus capable of maintaining specific temperature parameters, a task that demanded technical troubleshooting. The task was complicated further by the need to control not only the temperature but also the rate of change, as rapid fluctuations risked damaging our samples. Finally, amidst these multilayered challenges, validating the results proved to be a formidable hurdle. The sensitive nature of the samples and the complex handling process made ensuring the accuracy and repeatability of findings a rigorous task.

RESULTS AND DISCUSSION

The experiment consisted of testing the concentration and motility of sperm under various temperature conditions: 34°C, 37°C, 40°C, and 45°C. To analyse the sperm samples, slides were prepared following standard procedures and maintained at a constant temperature. The slides were observed under a microscope sample image shown in figure 2, and an embryologist measured the following parameters during the observation: concentration, slow progressive sperm (S), rapidly progressive sperm (R), non-progressive sperm (N), immotile, and motile percentages

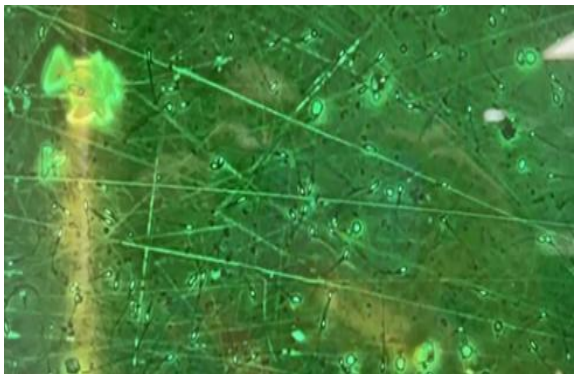

Figure 2.Sperm Sample seen from microscope

For which the reading is displayed in table 1 and the mean of this readings is shown in table 2.

Table 1: Raw data of sperm parameters at different temperatures

Temperature	Concentration	S	R	N	Immotile	Motile
34°C	72	41	20	11	32	68
	71	38	18	8	38	62
	72	40	18	8	35	65
37°C	61	33	17	13	37	63
	68	36	15	8	41	59
	65	34	17	8	41	59
40°C	52	24	15	8	53	47
	51	26	13	7	54	46
	55	23	13	7	57	43
45°C	55	11	6	8	75	25
	52	10	8	5	77	23
	55	9	10	6	75	25

At the nominal temperature of 34°C and the observed sperm concentration is approximately 71.67 million/ml. The percentage of slow progressive sperm was 39.67%, rapidly progressive sperm accounted for 18.67%, and non-progressive sperm represented 9%. The percentages of immotile and motile sperm were 35% and 65%, respectively. As the temperature increased to 37°C, there was a slight decrease in sperm concentration to 64.67 million/ml. The slow progressive sperm percentage dropped to 34.33%, and the rapidly progressive sperm percentage decreased to 16.33%. The non-progressive sperm percentage slightly increased to 9.67%, and there was a small increase in immotile sperm to 39.67%, leading to a corresponding decrease in motile sperm to 60.33 Further elevating the temperature to 40°C, the sperm concentration continued to decrease to 52.67 million/ml. Slow progressive sperm decreased to 24.33%, rapidly progressive sperm decreased to 13.67%, and non-progressive sperm slightly increased to 7.33%. The percentage of immotile sperm increased notably to 54.67%, which corresponded with a decrease in the motile sperm percentage to 45.33 At the highest temperature of 45°C, the sperm concentration was almost the same as at the previous temperature of 54 million/ml. The percentage of slow progressive sperm drastically dropped to 10%, rapidly progressive sperm to 8%, and non-progressive sperm slightly decreased to 6.33%. The immotile sperm percentage significantly increased to 75.67%, causing a corresponding decrease in the motile sperm percentage to 24.33%.

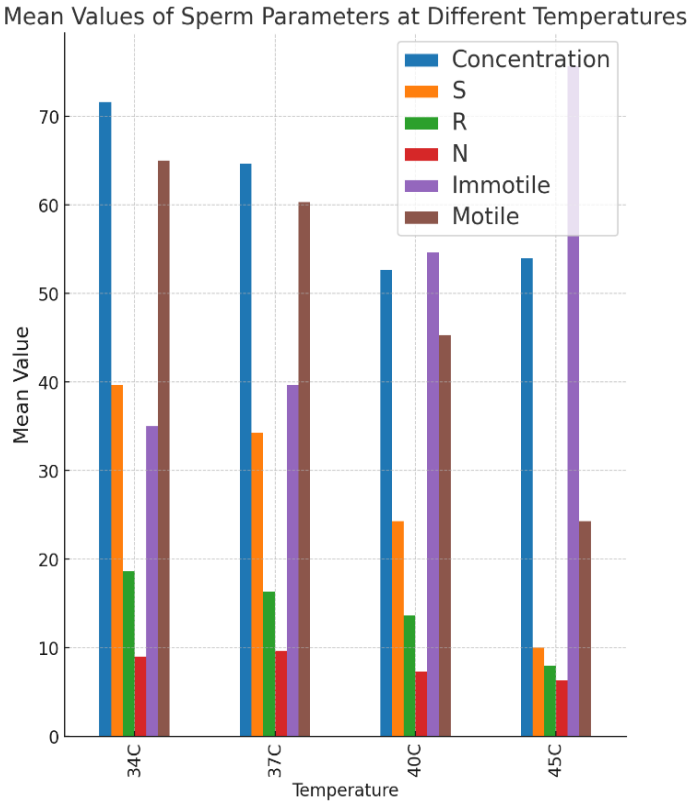

Figure 3.Sperm Parameters at Different Temperatures

From the figure 3 plot, we can visually observe the changes in mean values across different temperatures. The sperm concentration seems to decrease slightly as the temperature increases. The percentage of slow-progressive (S) and rapidly progressive (R) sperm decreases as the temperature increases. The percentage of non-progressive sperm (N) also decreases slightly as the temperature increases. With rising temperatures, there is a corresponding increase in the percentage of immotile sperm and a decrease in the percentage of motile sperm. Again, these observations suggest that increasing temperatures might have a negative impact on sperm motility and progressiveness

Table 2: Mean values of sperm parameters at different temperatures

Temperature	Concentration	S	R	N	Immotility	Motility
34°C	71.67	39.67	18.67	9	35	65
37°C	64.67	34.33	16.33	9.67	39.67	60.33
40°C	52.67	24.33	13.67	7.33	54.67	45.33
45°C	54	10	8	6.33	75.67	24.33

The figure 4 plot shows that as the temperature increases from 34°C to 45°C, there is a steady decrease in the percentage of motile sperm and an increase in the percentage of immotile sperm. These trends align with the overall findings from the experiment, further suggesting that higher temperatures may negatively impact sperm motility and increase sperm immotility. The decreasing trends in sperm concentration and motility, and the increasing trend in immotile sperm with increasing temperatures, all suggest a possible negative impact of heat on sperm viability.

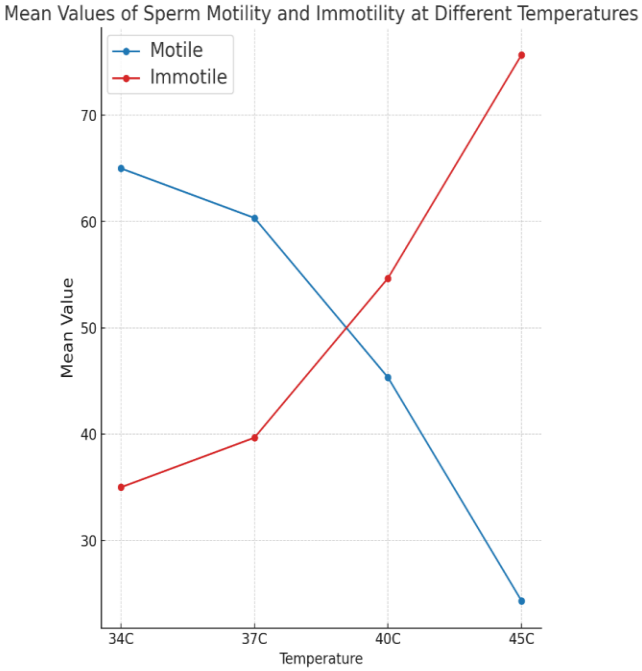

Figure 4. Mean value of motility and immotility at different temperature

CONCLUSION

The study investigated in depth the effect of temperature on sperm quality parameters such as concentration, motility, and progressiveness. Sperm samples were tested at 34°C, 37°C, 40°C, and 45°C in the experiment. Research revealed a uniform pattern across all parameters. As the temperature increased, the concentration of sperm decreased slightly, and the proportions of both slowly and rapidly progressing sperm decreased significantly. In addition, there was an obvious increase in the proportion of immotile sperm, which resulted in a decrease in overall motility. Notably, the negative effects were most pronounced at the highest temperature of 45°C, with a substantial increase in sperm immotility and a drastic decrease in the percentage of motile sperm. These findings provide strong evidence that elevated temperatures can negatively impact the quality of sperm in numerous ways, including concentration, motility, and progression. It suggests that men exposed to higher temperatures, whether as a result of their occupation or their lifestyle, may experience diminished sperm quality, which may have an effect on their fertility. While this study offers valuable initial insights, it is essential to note that it serves as a preliminary exploration into the relationship between temperature and sperm parameters. Future research should incorporate other factors, such as the duration of heat exposure, variations in heat stress protocols, and individual physiological responses to temperature. Such studies would provide a more comprehensive understanding of how temperature affects sperm quality and male fertility.

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