STUDIES

1960's

I. Control of Human Spermatogenesis Intrascrotal Temperature

The authors showed that alterations of intrascrotal temperature markedly affect spermatogenesis and sperm counts. In euspermic subjects, scrotal exposure for 30 minutes to a 150-watt electric light bulb resulted in reversal of the scrotal-rectal temperature ratio by a mean of 2.9 °C. Such treatment on 14 consecutive days caused depression of spermatogenesis followed by rebounds to temporarily high sperm counts. Application of an ice bag to the scrotum for a mean of about 30 minutes cooled the testicular environment by a mean of 6.9 C. Such cold treatment on 14 consecutive days, beginning not less than 12 days following cessation of exposure to heat, stimulated spermatogenesis without initial inhibition, nearly tripling the mean pretreatment count.

(Robinson D, Rock J, Menkin MF. "Control of Human Spermatogenesis Intrascrotal Temperature." JAMA. (1968); 204(4):290-297. doi:10.1001/jama.1968.03140170006002.)

1970's

II. Early Changes in the Germinal Epithelium of Rat Testes Following Exposure to Heat

Quantitative changes in the seminiferous epithelium of rat testis were observed within 24 hours of exposure to heat at 43°C for 15 minutes, with young spermatids morphing after only one hour of exposure. As exposure increased with time, so did the damage and the intervals of change. The location of the damage varied among spermatids and spermatocytes, yet both consistently exhibited inhibited functioning. Conclusions confirmed earlier observations on the susceptibility of testicular germinal cells to heat.

(Chowdhury, A. K., and E. Steinberger. "Early changes in the germinal epithelium of rat testes following exposure to heat." Journal of Reproduction and Fertility 22.2 (1970): 205-212)

1980's

III. Chronic Scrotal Hypothermia as a Treatment for Poor Semen Quality

Studying infertility in six married men with poor semen quality and elevated testicular temperature, the authors experimented with a device using evaporation to obtain normal testicular temperature. After a 20-week period of treatment, three wives had become pregnant. Semen analysis showed improvement in all three men. In two of the patients who did not achieve pregnancy, semen improvements were also noted after 12 weeks. With no associated cause for improvement other than hypothermia, this strengthens the theory that elevated temperature plays a role in male infertility and that scrotal hypothermia seems to be an effective treatment for men with varicoceles, varicocelectomy failure, or idiopathic infertility where intrascrotal temperature is elevated.

(Zorgniotti AW, Seaflon A, Toth A: "Chronic scrotal hypothermia as a treatment for poor semen quality." Lancet (1980), 315(8174):904-906.)

IV. Further Clinical Experience with Testis Hypothermia for Infertility Due to Poor Semen

Elaborating on previous research (III), the authors studied the effects of chronic hypothermia treatments on 25 infertile patients with elevated testicular temperature. 16 of 25 patients showed improvements in semen quality with 6 of the 25 intensely infertile couples achieving pregnancy (with a mean period of previous infertility of 6.0 years) after wearing an evaporative scrotal cooling device for sixteen hours daily for a mean of 14.5 weeks, while a discontinuance of treatment resulted in a return to pretreatment poor semen quality.

(Zorgniotti AW, Seaflon AI, Toth A: "Further clinical experience with testis hypothermia for infertility due to poor semen." Urology (1982), 19(6):636-640.)

V. Scrotal Hypothermia and the Infertile Man
Tested the effects of scrotal cooling ice packs on 50 men with reduced sperm motility. Every night, jockey shorts held the cooling mechanism in place and resulted in at least a 2-fold increase in sperm quantity as well as an increase in motility for 65% of the patients; success in treatment was independent of whether a varicocele was present or not.
(Mulcahy JJ: "Scrotal hypothermia and the infertile man." The Journal of Urology (1984), 132:469-470.)

VI. Scrotal Hypothermia: New Therapy for Poor Semen
The authors proposed scrotal hypothermia as a treatment for male infertility. Referring to the long-standing and well-supported evidence that elevated testicular temperature results in poor semen, they investigated the effects of a testicular hypothermia device, which resulted in lowered temperature and improved semen for patients with a varicocele, failed varicocelectomy, or "subclinical" varicocele, remarking that the device was noninvasive, well tolerated, and suitable as a method of treatment.
(Zorgniotti AW, Seaflon AI: "Scrotal hypothermia: new therapy for poor semen." Urology (1984), 23(5):439-441.)

VII. Chronic Scrotal Hypothermia: Results in 90 Infertile Couples
The authors studied the use of a testicular hypothermia device worn by 90 men with sub-fertile semen and elevated testicular temperatures. For the patients who underwent a trial period lasting at least 16 weeks (64 men), improvement of one or more semen parameters was detected in 42 of the patients (65%). Semen analysis was converted into the "motile oval index", a numerical value representing the count, motility and normal morphology of sperm. The motile oval index helped predict pregnancy outcome. Of 21 patients with pre-treatment motile oval indexes greater than 4.8 million per ml, 11 (52.4%) produced pregnancy. Patients with lower starting indexes did not fare as well. Of 20 patients who met the criteria, and who wore the device for less than 2 weeks or not at all, having no other treatment, 1 (5.0%) produced pregnancy.
(Zorgniotti AW, Cohen MS, Seaflon I: "Chronic scrotal hypothermia: results in 90 infertile couples." The Journal of Urology (1986), 135:944-947.)

VIII. Improved Seminal Characteristics in Infertile Men after a Conservative Treatment Regimen Based on the Avoidance of Testicular Hyperthermia
The study examined semen samples from 128 men for six seminal characteristics both before and after a 3-month "conservative treatment" regimen. Evidence was found supporting the improvement of male fertility by avoiding testicular hypothermia, specifically hot baths and tight clothing.
(Lynch, R., et al. "Improved seminal characteristics in infertile men after a conservative treatment regimen based on the avoidance of testicular hyperthermia." Fertility and Sterility 46.3 (1986): 476-479.)

IX. Association of Scrotal Hyperthermia with Impaired Spermatogenesis in Infertile Men
Studying 150 infertile and 37 fertile men, researchers recorded scrotal temperatures, testicular volumes, and sperm characteristics. They found the mean scrotal temperatures of the infertile men to be significantly higher than that of the fertile men. The study also showed that the higher the scrotal temperature, the greater the abnormalities in sperm characteristics. No other specific pathological factor, infectious or surgical, was found to be responsible for the scrotal hyperthermia observed in male infertility.
(Mieusset R, Bujan L, Mondinat C, et al. "Association of scrotal hyperthermia with impaired spermatogenesis in infertile men." Fertility and Sterility (1987); 48:1006–1011)

X. Hyperthermia and Human Spermatogenesis: Enhancement of the Inhibitory Effect Obtained by 'Artificial Cryptorchidism'

After inducing local testicular hyperthermia by raising the testicles of adult volunteers into the inguinal canal, a decrease in both sperm count and motility were observed, with variations in the procedure resulting in a more marked suppression of spermatogenesis. After 2 months of this technique, the mean inhibitory effects of hyperthermia was at least 97%. The study concluded that the effects of 'artificial cryptorchidism' may be of practical interest in decreasing sperm production and motility.

(Mieusset, Roger, et al. "Hyperthermia and human spermatogenesis: enhancement of the inhibitory effect obtained by 'artificial cryptorchidism'." International Journal of Andrology 10.4 (1987): 571-580.)

XI. Influence of Occupation and Living Habits on Semen Quality in Men (Scrotal Insulation and Semen Quality)

The study examined the semen quality of 56 males from infertile couples. Patients were categorized into two groups of "cool workers/ cool sleepers" or "warm workers/ warm sleepers" based on whether or not there was interference with normal testicular thermoregulation (warm) or not (cool). A higher concentration of good moving spermatozoa in the "cool workers/ cool sleepers" group was found, indicating the advisability of a comprehensive patient history when evaluating infertility problems, especially the possibility of living habits influencing male infertility and treatment.

(Laven, Joop SE, Michiel J. Haverkorn, and Rob SGM Bots. "Influence of occupation and living habits on semen quality in men (scrotal insulation and semen quality)." European Journal of Obstetrics & Gynecology and Reproductive Biology 29.2 (1988): 137-141.)

XII. Effects of Local Heating of the Testis on Testicular Blood Flow and Testosterone Secretion in the Rat

Using microspheres to measure the blood flow to rat testes after exposing one or both to heating at 43 °C for 30 minutes, effects showed a significant reduction in both blood flow and testicular weight beginning within 2–4 days. Further reductions in blow flow were noted 14 and 21 days after heating and showed a decrease in the concentration of testosterone in testicular venous blood.

(Galil, K. A. A., and B. P. Setchell. "Effects of local heating of the testis on testicular blood flow and testosterone secretion in the rat." International Journal of Andrology 11.1 (1988): 73-85.)

1990's

XIII. Diurnal Variations in Scrotal Temperature of Normal Men and Patients with Varicocele Before and After Treatment

Measuring the scrotal temperature of 6 normally fertile volunteers and 48 infertile patients, researchers used a portable data recorder for 24-hour periods while the patients carried out their regular daily activities. The experiment found that temperatures during sleep were typically higher and that diurnal variations were less dramatic in the infertile patients than in the normal volunteers. Scrotal temperatures at night were similar between groups but statistically varied during the daytime hours. After successful embolization of the spermatic vein in 16 patients, there was no observed change in scrotal temperature, and although sperm counts were higher after treatment, the difference was not significant. It concluded that varicocele-related damage to the testis results from a lack of adequate cooling and that existing treatment does not normalize the temperature pattern.

(Lerchl A, Keck C, Spiteri-Grech J and Nieschlag E (1993) "Diurnal variations in scrotal temperature of normal men and patients with varicocele before and after treatment." International Journal of Andrology 16, 195-200.)

2000's

XIV. Diurnal scrotal skin temperature and semen quality

Studying diurnal scrotal temperature and markers of male infertility in humans, 60 men from couples planning their first pregnancy were recruited. Their scrotal skin temperature was measured for 3 days using a portable data recorder. They were questioned about their working hours and activities, and also provided a fresh semen sample. Couples were then followed for 6 menstrual cycles or until a clinical pregnancy was consummated. Results showed that sedentary work position increases scrotal temperature, and that even a moderate elevation in scrotal skin temperature is associated with a substantial reduction of sperm concentration.

(Hjollund, Niels Henrik I., et al. "Diurnal scrotal skin temperature and semen quality." International Journal of Andrology 23.5 (2000): 309-318.)

XV. Improvement of Semen Quality by Nocturnal Scrotal Cooling and Moderate Behavioural Change to Reduce Genital Heat Stress in Men with Oligoasthenoteratozoospermia

This study measured whether poor semen quality could be improved by lowering scrotal temperature using a nocturnal cooling device, and also assessed behavioral factors (daily time spent sitting, standing or lying, and use of tight pants, tight underwear, pajamas, duvets, electric blankets, saunas, hot baths, solariums, or heated car seats) contributing to increased scrotal temperatures. Results favored this method of nocturnal scrotal cooling, as well as changes in patient behavior toward reducing moderate heat stress, providing evidence of an improvement in both sperm concentration and total sperm output.

(Jung A, Eberl M, Schill WB: "Improvement of semen quality by nocturnal scrotal cooling and moderate behavioural change to reduce genital heat stress in men with oligoasthenoteratozoospermia." Reproduction (2001), 121:595-603.)

XVI. Impact of Diurnal Scrotal Temperature on Semen Quality

Assessing the common occurrence of high scrotal temperatures in infertile patients, researchers designed an experimental study to investigate the impact sedentary work positions have on increasing scrotal temperature. Semen and blood samples from 99 healthy men were analyzed in relation to scrotal skin temperature with 24-hour continuous monitoring, along with a questionnaire about sedentary work environments. Finding a negative correlation between high scrotal temperature and sperm output, results showed that sperm concentration decreased 40% per 1°C increase of median daytime scrotal temperature.

(Hjollund NHI, Storgaard L, Ernst E, Bonde JP and Olsen J (2002b) "Impact of diurnal scrotal temperature and semen quality." Reprod Toxicol 16, 215-221.)

XVII. Long-Term Protective Effects of Hypothermia on Reperfusion Injury Post-Testicular Torsion

In an effort to salvage post-torsion testicular function, this research investigates the benefits of hypothermic application to the area of damage. Recognizing that as many as two-thirds of testes will atrophy within 2 years post-torsion and subsequent testicular damage is due in some part to an ischemia/reperfusion injury, the authors analyzed the long-term protective effects of subjecting twenty male rats to hypothermic 'ice baths' after removing the left testicle (twenty more were used as the control group), kept at a temperature of 2–4°C for the final hour prior to detorsion. Using a single blind pathologist, testes were retrieved at 1 and 12 weeks. At 12 weeks of reperfusion there was a marked benefit seen in the testis subjected to hypothermia. The authors concluded that hypothermia decreases long-term testicular damage in post-torsion testes, and has the potential to aid in long-term salvation.

(Power RE, Scanlon R, Kay EW, Creagh TA, Bouchier-Hayes DJ. "Long-term protective effects of hypothermia on reperfusion injury post-testicular torsion." Scand J Urol Nephrol (2003); 37:456–460.)

XVIII. Influence of the Type of Undertrousers and Physical Activity on Scrotal Temperature
Investigated the correlation between high testicular temperature and the choice of undertrouser, while walking or sitting. 50 volunteers without a history of male infertility were selected to have scrotal temperatures measured every minute with a portable data recorder connected to two thermistor recorders attached on either side of the scrotum. With all volunteers under the same environmental conditions, they performed 6 sequences of 45 minutes either walking on a treadmill or sitting, wearing either tight or loose-fitting undertrousers. Scrotal temperatures were significantly higher for tight versus loose-fitting versus no undertrousers. Significantly lower scrotal temperatures were also seen for walking versus sitting.
(Jung, A., et al. "Influence of the type of undertrousers and physical activity on scrotal temperature." Human Reproduction 20.4 (2005): 1022-1027.)

XIX. Improvement of Semen Quality by Nocturnal Scrotal Cooling in Oligozoospermic Men with a History of Testicular Maldescent
This study intended to evaluate the influence of nocturnal scrotal cooling on semen quality in patients with oligozoospermia. Over a 12 week period, 20 male participants received a scrotal cooling treatment, in which a membrane pump connected by tubes to cooling receptacles was placed on the groin every evening. In contrast to a control group, results favored the nocturnal procedure of scrotal cooling as a treatment for infertility, producing a 0.8 °C (median) drop in scrotal temperature and resulting in a significant increase in sperm concentration and total sperm count after 8 weeks ($p < 0.01$; $p < 0.05$, respectively) and 12 weeks ($p < 0.01$; $p < 0.01$, respectively). The study suggests nocturnal scrotal cooling as a therapeutic option to improve semen quality.
(Jung A, Schill WB, Schuppe HC: "Improvement of semen quality by nocturnal scrotal cooling in oligozoospermic men with a history of testicular maldescent." International Journal of Andrology (2005), 28:92-98.)

XX. Effect of Posture and Clothing on Scrotal Temperature in Fertile Men
Investigated the effects of both body position and clothing choice on the temperature of the scrotum in 13 fertile men. By assuming successive positions for 15 minutes each, first naked and then clothed, each volunteer's scrotal temperature was measured in supine, standing, seated with legs apart, and seated with legs crossed. Results showed standing naked yields the lowest scrotal temperature, and that in any position there is an increase in scrotal temperature when clothing is worn. Sitting with legs crossed produced the highest scrotal temperatures and appeared to affect the temperature in the posture succeeding it as well.
(Mieusset, Roger, Bourras Bengoudifa, and Louis Bujan. "Effect of posture and clothing on scrotal temperature in fertile men." Journal of Andrology 28.1 (2007): 170-175.)

XXI. Effect of External Scrotal Cooling on the Viability of the Testis with Torsion in Rats
Testing the previous successful use (X) of hypothermia as a treatment to preserve the viability of ischemic organs for prolonged periods, the research aimed to evaluate the effectiveness of external scrotal cooling in preserving testicular viability after spermatic cord torsion in rats. Using 100 adult rats divided into 10 groups, 8 of which were exposed to scrotal cooling of the right testicle for 4 or 8 hours, and 4 of which were exposed to scrotal cooling during the torsion. Histological results favored hypothermia, showing that external scrotal cooling decreased both immediate and late damage to the testis cause by torsion. It can be concluded that external scrotal cooling is effective in preserving the viability of the torsed testis in rats, although periods of exposure lasting greater than 4 hours can pose a threat to the contralateral testis. Application of this treatment may be useful in humans awaiting surgery.
(Haj, M., et al. "Effect of external scrotal cooling on the viability of the testis with torsion in rats." European Surgical Research 39.3 (2007): 160-169.)

XXII. Heat Shock Protein and Heat Shock Factor Expression in Sperm: Relation to Oligozoospermia and Varicocele
To investigate the correlation of increased temperature and alternations in spermatogenesis associated with varicoceles, the study was performed with 117 consecutive patients with varicoceles and 68 controls without. Dividing subjects into 4 groups based on the absence or presence of varicocele and normozoospermia/oligozoospermia, they were studied by history, physical examination, scrotal Doppler ultrasound, semen analysis, reproductive hormone plasma levels, and quantitative real-time polymerase chain reaction in RNA extracted from ejaculated sperm samples. Examining the different heat shock proteins and heat shock factors in ejaculated sperm, the results showed that there may be a molecular marker of an adequate or inadequate response to the damaging effect of a varicocele on spermatogenesis. *(Ferlin, Alberto, et al. "Heat shock protein and heat shock factor expression in sperm: relation to oligozoospermia and varicocele." The Journal of Urology 183.3 (2010): 1248-1252)*

XXIII. Protection from Scrotal Hyperthermia in Laptop Computer Users
Evaluated methods of protection from scrotal hyperthermia caused by the laptop use of portable computers by measuring right and left scrotal temperatures during 60-minute sessions using a working Laptop Computer (LC) in a laptop position in three separate sessions (sitting with legs close together, sitting with legs closely together with a lap pad below the working LC, sitting with legs apart at a 70 degree angle with a lap pad below the working LC. Scrotal temperature increased significantly regardless of leg position or use of laptop pad, although session 3 provided the lowest temperature and most promising results. Results prove that sitting with legs close together contributes to scrotal hyperthermia and that scrotal shielding with a lap pad does not protect from elevated scrotal temperature. The best method of reducing scrotal hyperthermia is to sit in a position with legs apart and significantly reduce the duration of LC use.
(Sheynkin, Yefim, et al. "Protection from scrotal hyperthermia in laptop computer users." Fertility and Sterility 95.2 (2011): 647-651.)

PAPERS

I. Specific Nonsurgical Therapy in Male Infertility
The authors presented promising information on various new treatments for male infertility, recognizing male scrotal cooling devices as an overlooked nonsurgical method of therapy for varicoceles. They encouraged future investigation of these preventative devices for their beneficial possibilities.
(Kaufman, D. G., and H. M. Nagler. "Specific nonsurgical therapy in male infertility." The Urologic Clinics of North America 14.3 (1987): 489-498.)

II. Male Infertility: Diagnosis and Treatment
The author presented an evaluation of the sub-fertile male, covering everything from basic history to known forms of treatment. Discussing important information regarding precursors to infertility, he presented possible solutions to various forms of male sub-fertility, underscoring the evidence that hypothermia treatment can alleviate the dangers of increased scrotal temperature, especially when associated with a varicocele's irregular spermatogenesis. He discussed the inconveniences of testicular cooling devices, including discomfort and occasional water leakage.
(Chan, S. L. "Male Infertility: Diagnosis and Treatment." Canadian Family Physician 34 (1988): 1735.)

III. Effects of Elevated Temperature on the Epididymis and Testis: Experimental Studies
Discussing various studies looking at temperature effects on the male reproductive system in animals, this paper shows that a small increase in the temperature of the testes does not destroy the germinal epithelium (necessary for sperm production), but that it does reduce testis weight and produces a greater likelihood of abnormal spermatids and spermatozoa. It argues that the testes can withstand a moderate

rise in ambient temperature, but that deep body temperature changes can greatly influence the ionic and protein composition of the cauda fluid, as well as effecting the cauda epithelium and its ability to store and prolong the life of spermatozoa. In addition, deep body temperature increases curtail the storage capacity of the cauda epididymis, reducing the diameter and length of the cauda and vas deferens, which contract during orgasm to produce the bulk of the ejaculate. This results in a significant reduction in the number of spermatozoa in the first ejaculate and a continual decrease in those following.
(Bedford, J. Michael. "Effects of elevated temperature on the epididymis and testis: experimental studies." "Temperature and environmental effects on the testis." Springer US (1991). 19-32.)

IV. Testicular Heating and its Possible Contributions to Male Infertility: a Review
Outlining the evolutionary adaptation of the scrotum and its biological functions, this study emphasizes the valuable role of the scrotum in promoting heat loss and protecting the sensitive temperature-dependent environment necessary for the healthy production of male semen. Discussing the two thermoregulatory systems necessary to maintain a physiologically low testicular temperature, the authors provided a descriptive biological presentation of the scrotum and its functional design for reducing temperature through the evaporation of sweat secreted by the acuminous apocrine glands found in mammalian scrotal skin. The second necessary thermoregulatory system vital to maintaining low testicular temperature is something called the pampiniform plexus located in the spermatic control system. The plexus enables counter current heat exchange between incoming arterial blood and outgoing venous blood via the interconnecting system of multiple large veins surrounding the tortous testicular artery. Reporting the negative effects of failures in these two systems, the study underscores the necessary role of the scrotum in maintaining low testicular temperature necessary for healthy male reproduction and fertility.
(Mieusset R, Bujan L. Testicular heating and its possible contributions to male infertility: a review. International Journal of Andrology (1995); 18:169-184.)

V. Influence of Genital Heat Stress on Semen Quality in Humans
Reviewing the current knowledge of genital heat stress and its consequences on male heath, this study assesses the widely accepted correlation between elevated testicular temperature and the impairment of spermatogenesis. A strong correlation was found between degraded spermatogenesis and professional drivers who sit for long periods of time, especially those who wear tight-fitting underwear. It was noted that while using genital heat stress as a form of contraception is both inconsistent and unsafe, testicular cooling can improve semen quality.
(Jung, A., and H-C. Schuppe. "Influence of genital heat stress on semen quality in humans." Andrologia 39.6 (2007): 203-215.)

VI. Lifestyle Impact and the Biology of the Human Scrotum
Describing the evolutionary function of the male gonads of mammals and their function in allowing the testes and epididymis to exist in an environment a few degrees below the core body temperature, the study suggests that those with varicocele show mild scrotum warming and the detrimental effects this has on sperm production, stem cell population, spermatogenesis, and sperm maturation. It also discusses the present research on lifestyle factors and environmental threats to healthy male fertility.
(Ivell, Richard. "Lifestyle impact and the biology of the human scrotum." Reprod Biol Endocrinol 5.15 (2007): 1477-1482.)

VII. Effects of Heat Stress on Mammalian Reproduction
Focusing on the effects of heat stress on the reproductive functioning of mammals, this paper outlines the damaging results of either hyperthermia or physiological adjustments made by the heat-stressed animal to regulate body temperature. Discussing the various forms of the male scrotum, it presents the idea that a rise in testicular temperature in mammals, even with external testes, leads to reduced sperm output,

decreased sperm motility, and an increased proportion of morphologically abnormal spermatozoa in the ejaculate.
(Hansen, Peter J. "Effects of heat stress on mammalian reproduction." Philosophical Transactions of the Royal Society B: Biological Sciences 364.1534 (2009): 3341-3350.)