A STUDY OF SEMEN PARAMETERS IN WELDERS AND NON-WELDERS IN THE SRI LANKA NAVY

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Degree of Master of Engineering

Department of Mechanical Engineering

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Thesis/Dissertation submitted in partial fulfillment of the requirements for the Degree Master of Engineering in Mechanical Engineering

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Declaration

This report contains no material which has been accepted for the award of any other degree or diploma in any University or equivalent institution in Sri Lanka or abroad, and that to the best of my knowledge and belief, contains no material previously published or written by any other person, except where due reference is made in the text of this report.

I carried out the work described in this report under the supervision of Dr. H.K.G. Punchihewa from the department of Mechanical Engineering, University of Moratuwa and Prof (Mrs.). D.M.S. Fernando from the Department of Health Science, Faculty of Medical Sciences, University of Sri Jayewardenepura

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Dedication

This thesis work is dedicated to my parents, who have always loved me unconditionally and whose good examples have taught me to work hard for the things that I aspire to achieve.

This work is also dedicated to my wife, Nayana, who has been a constant source of support and encouragement throughout this research. I am truly thankful for having you in my life.

Acknowledgements

I would first like to express my sincere gratitude to my advisors Dr. H.K.G. Punchihewa at the Department of Mechanical Engineering, University of Moratuwa and Prof (Mrs.). D.M.S. Fernando at the Department of Health Science, Faculty of Medical Sciences, University of Sri Jayewardenepura, for their continuous support for my M.Eng, study and related research, for their patience, motivation, and immense knowledge. Their insightful comments and encouragement throughout the research study stimulated me to direct my research from various perspectives. I could not have imagined having a better advisors and mentors for my M.Eng, study than them.

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Last but not the least; I would like to thank my wife Nayana for supporting me spiritually throughout writing this thesis and my life in general.

Abstract

Introduction: Welding is a metal joining process widely used in fabrication industry worldwide. Welding emissions are known to cause adverse effects on male reproductive system. The degree of hazard depends on the composition, concentration, and the length of exposure to emissions. Sri Lanka Navy has more than 300 welders at key establishments but their fertility status has not been assessed.

Objectives: The objective of this study was to describe the socio-demographic and lifestyle factors of welders and non-welders, and to describe the occupational exposures of welders of Sri Lanka Navy working in Colombo. The lifestyle factors, occupational factors and sperm parameters of welders and non-welders were compared.

Methodology: A descriptive study was done with welders (n=44) and non-welders (n=44) of Sri Lanka Navy base in Colombo. Socio-demographic and lifestyle factors of both groups and occupational factors of welders were studied. Semen samples were obtained from welders and non-welders after informed consent. Semen fluid analysis (SFA) was performed according to guidelines of WHO (2010), at Naval General Hospital Colombo and sperm parameters were compared in welders and non-welders. Correlation between lifestyle and occupational factors, and sperm parameters of welders were assessed. Ethical clearance was obtained from the Faculty of Medicine, Kothelawela defense University.

Results: The socio-demographic characters and lifestyle factors of both welders and non-welders were similar. Welders working in shipyard /on board ships were more exposed to welding emissions than those welders in fabrication workshop. The sperm parameters were normal in 70% of welders when compared to 86% for non-welders. Among welders sperm concentration was abnormal in 16% and sperm motility was abnormal in 11%. In contrast only 7% of non-welders had abnormal sperm concentration and motility was normal in all of them. Although the dose of exposure (hours/day) to welding emissions did not have a significant effect on sperm parameters of welders, the total duration of exposure (number of years of exposure) had a significant effect on sperm concentration of welders ($r = -0.4$ $p = 0.007$). Squatting position and wearing synthetic underpants had a significant association with sperm concentration of welders.

Conclusion: In this study the socio demographic and life style factors among welders and non-welders of the SLN base in Colombo were similar. Long term exposure to welding emission had a significant effect on sperm concentration but there were no effects with short duration of exposure. Welding in squatting position and wearing of dark coloured synthetic underpants was associated with a lower sperm concentration in welders.

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LIST OF ABBREVIATIONS

Abbreviations		Description
BDCP	-	Deibromochloropropane
BMI	-	Body Mass Index
BTB	-	Blood Testis Barrier
CAVID	-	Congenital Absence of Vas Deferens
EDB	-	Ethylenedibromide
EMF	-	Electromagnetic field
FSH	-	Follicle Stimulating Hormone
GnRH	-	Gonadotropin Hormone-Releasing Hormone
GMAW	-	Gas Metal Arc Welding
IM	-	Immortality
LH	-	Luteinizing hormone
MIG	-	Metal Inert Gas Welding
NP	-	Non-progressive
SLN	-	Sri Lanka Navy
SLNS	-	Sri Lanka Naval Ship
SMAW	-	Shielded Metal Arc Welding
TCE	-	Trichloroethylene
THC	-	Tetrahydrocannabinol
TIG	-	Tungsten Inert Gas Welding
PCE	-	Perchloroethylene
PER	-	Tetrachloroethylene
PPE	-	Personal Protective Equipment

PR	-	Progressive
SAR	-	Specific Absorption Rate
SFA	-	Semen Fluid Analysis
SMAW	-	Shielded Metal Arc Welding
WHO	-	World Health Organization

LIST OF APPENDICES

1. INTRODUCTION

It is reported that there has been a significant decline in the mean sperm density of men from 113 million/ml in 1940 to 66 million / ml in 1990[1]. Semen volume has decreased from an average of 3.40 ml to 2.75 ml. This demonstrates a 20% drop in volume and a substantial 58% decline in sperm production during last 50 years [1][2]. During the last two decades more rapid decline in sperm count and quality has been reported. It is reported that sperm count has been falling at an alarming rate of 2% per annum. [3]. Further there has been an annual decline of 2.6% in sperm concentration, 0.3% sperm with normal motility, and 0.7% sperm with normal morphology [3]. A study conducted in France between 1988 and 2007concluded that annual decline rate of total sperm count by 1.6%, total motility by 0.4%, rapid motility by 5.5% and normal morphology by 2.2% [4]. This is believed to be due to a combination of factors that might be interfering with spermatogenesis [1]. The changes in food habits, lifestyle, increase of global temperature and environmental pollution during the last few decades are thought to be contributing to the change in sperm quality worldwide.

Infertility is defined as the inability to achieve a pregnancy after one year of unprotected intercourse [1][2]. Conception is normally achieved within 12 months in 80-85 percent of couples not using contraceptives, thus an estimated 15% of couples attempting their first pregnancy have difficulty in conceiving [1]. Infertility is a widespread problem; evaluations have traditionally focused on women, because women tend to seek gynecological assistance but men are often reluctant to seek advice [5]. A variety of disorders ranging from physiological disturbances to structural abnormalities, to psychological problems can cause male infertility. Male factors contribute approximately 40-50% of all infertility cases [4], although some have reported a lesser percentage as 30% [6]. In Sri Lanka too a similar rise in male infertility has been reported. The pattern of occupational distribution in a sub-fertile population attending urology and andrology clinics at Teaching Hospital Peradeniya over a 6 years period has been studied. In this it is reported that the highest percentage of man were from armed forces (16.7%) followed by skilled agricultural, forestry and fishery workers (15%) and craft and related trade workers

(15%). Technicians and associate professionals was 5.8% [7]. Further the identified reasons of primary sub-fertility among men in this study were sperm quality problems, post testicular causes such as sexual dysfunction and testicular causes such as varicocele [8]. In addition, health related factors such as reproductive system related problems, usage of long term drugs, high body mass index, genetic factors and mental illnesses have affected fertility. Furthermore, socio economic factors such as education, occupation, daily working hours, and location of work place, income and expenditure status are shown as significant determinants of subfertility in Sri Lanka [9]. In Sri Lanka, it was found that the total fertility rate decreased from 5.32 children per woman in 1953 to 1.96 between 1995-2000 periods. Proportion married, contraception, postpartum infecundability, and induced abortions are the main four factors identified as important determinants in falling fertility rate [10]. There are only a few epidemiological studies evaluating the male infertility and occupations in Sri Lanka [7]. They too have not categorically identified occupational factors on male infertility. Therefore the status of male infertility in Sri Lankan is still mostly unknown.

Welding is an occupation known to have many harmful effects on spermatogenesis and sperm quality due to many reasons [1][2]. A considerable amount of heat is dissipated to the environment during welding operations. When manually performed, the welders get directly exposed to elevated temperatures, fumes and other emissions. This could reduce their fertility and thus need to seek solutions to protect welders. .

Irrespective of the welding process, the welders are constantly exposed to welding emissions such as heat, radiation and fumes & gases, despite advances in control and mitigation technologies [7]. The level of emissions in welding process depends on a number of different factors such as; process of welding used, welding parameters, filler metal and surface coatings or contaminants on the base metal surface [11].

Although the types of welding are many, Sri Lanka Navy (SLN) welders perform three popular welding processes on marine quality mild steel, stainless steel and aluminum. The types of welding processes commonly deployed in SLN are:

- Shielded metal arc welding (SMAW)
- Metal inert gas (MIG)
- Tungsten inert gas welding (TIG)

Currently SLN is strengthening her ship repair team with more than 300 numbers of multi welders at the key establishments (Colombo, Trincomalee, Galle and Kankasanthurai). According to unpublished data approximately 5% of the sailors are reported to be infertile. Exposure to welding heat, radiation, fumes and other factors or combinations of factors may be affecting the fertility of welders. However, evidence for this needs to be explored in order to propose engineering interventions for mitigation. Effects of welding emission on semen quality of welders have not been studied in Sri Lanka. Hence this study was planned to describe the association between seminal fluid parameters and exposure to welding emissions and other life style factors among welders and non-welders in the SLN. The results of this study will be of use to propose mechanical and other interventions to limit exposure.

Objectives

To describe the socio demographic and life style factors of welders and non-welders of Sri Lanka Navy sailors based in Colombo.

To describe the occupational exposures of the welders of the Sri Lanka Navy sailors based in Colombo.

To describe the sperm parameters of the welders and non-welders of Sri Lanka Navy sailors based in Colombo.

To identify associations between the socio demographic, life style and occupational factors and the sperm parameters of welders and non-welders of Sri Lanka Navy sailors based in Colombo

2. LITERATURE REVIEW

2.1 Male reproductive system

The function of the male reproductive system is mainly production of semen and transferring the gametes or the sperm into the female reproductive tract. This system primarily consists of the testes and a series of ducts and glands. Sperms are produced in the testes and are transported through the reproductive ducts. Reproductive ducts include the epididymis, vas deferens, ejaculatory duct which opens in to the urethra. The reproductive glands produce secretions which form semen. These glands include the seminal vesicles, prostate gland, and bulbourethral glands (also called a Cowper's gland).

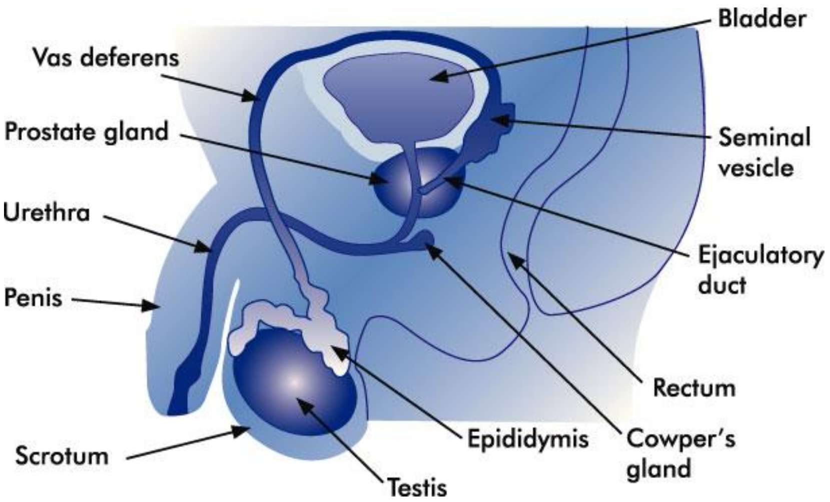

Figure 2.1: Parts of the male reproductive system

Source: Andrology Australia, School of Public Health & Preventive Medicine,

2.2 Process of spermatogenesis

Spermatogenesis is the process of the production of spermatozoa (sperm) from the immature germ cells lining tubules. During spermatogenesis, a diploid spermatogonium (male germ cell) increases its size to form a diploid primary spermatocyte. This diploid primary spermatocyte undergoes first meiotic division (meiosis I), which is a reduction division to form two equal haploid secondary spermatocytes. Each secondary spermatocyte then undergoes second meiotic division (meiosis II) to form two equal haploid spermatids. Hence, a diploid spermatogonium produces four haploid spermatids. These spermatids are transformed into sperm by the process called spermatogenesis [12].

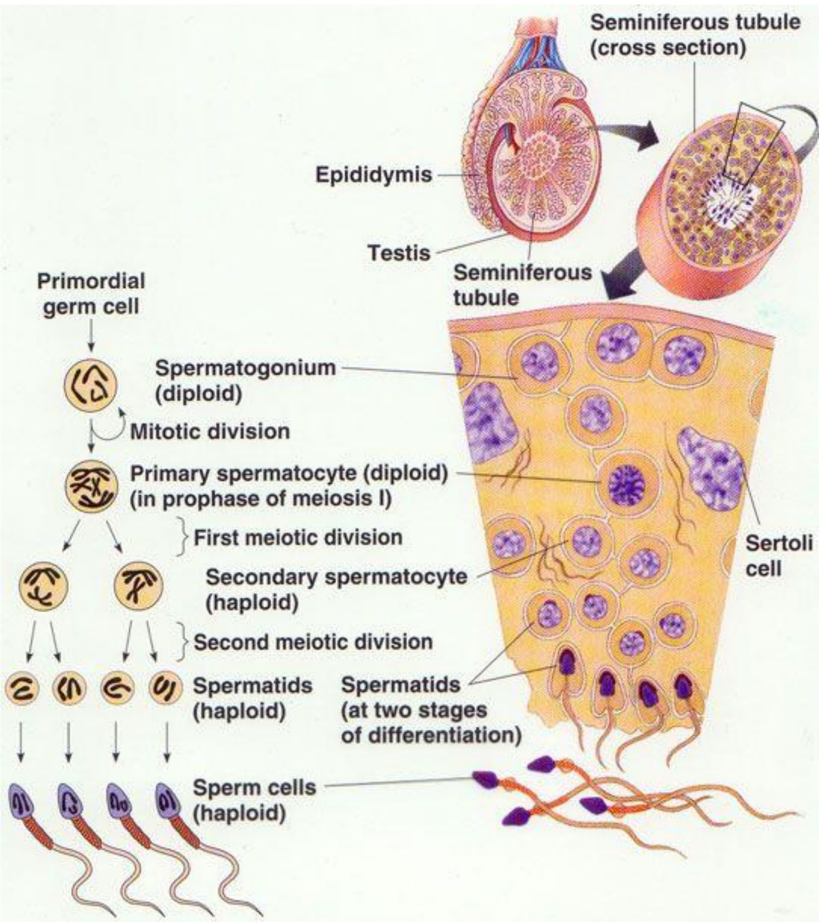

Figure 2.2: Graphical presentation of spermatogenesis

This is a continuous process with millions of sperm being produced each day after puberty. It normally takes about 70 days for a sperm to be matured, and be able to fertilize an egg. Sperm developing in the lining of the seminiferous tubules are supported by larger cells called Sertoli cells. When mature, sperm are released from the Sertoli cells into the lumen (the space in the middle) of the seminiferous tubules to pass out of the testes [12]. Sertoli cells provide support for developing germ cells within the seminiferous epithelium. The blood-testis barrier (BTB) is found between adjacent

Sertoli cells in the testis where it creates a unique microenvironment for the development and maturation of meiotic and postmeiotic germ cells in seminiferous tubes. The BTB divides the seminiferous tubules into the basal and apical (adluminal) compartments. Meiosis, spermatogenesis and spermiation take place in the apical compartment; whereas, spermatogonial cell division and differentiation to preleptotene spermatocytes occur in the basal compartment. Thus, the BTB creates a unique microenvironment for meiotic and postmeiotic cells by forming an immunological barrier that separates meiotic and postmeiotic germ cells from blood circulation [13].

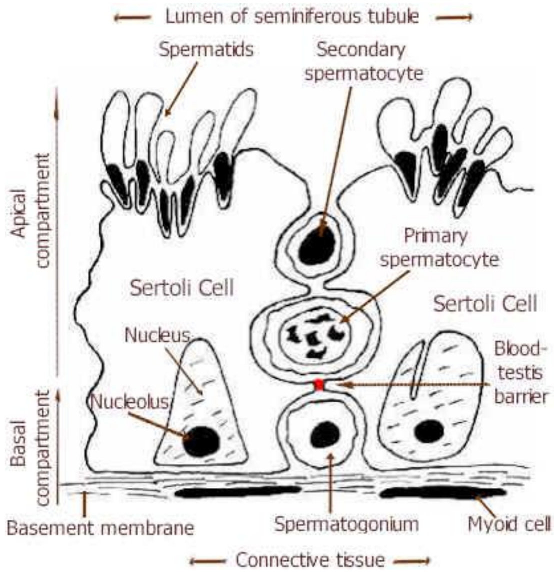

Figure 2.3: Blood testis barrier

2.3 Process of sperm maturation and ejaculation

Sperm maturation is defined as the developments of the ability of spermatozoa fertilize the ovum. Though, development of germ cells occurs in the testis in a process called spermatogenesis, the testicular sperm are nonfunctional and lack the ability to naturally fertilize an egg. Maturation process of sperm occurs when it is travel through the epididymis by acquiring progressive motility and the ability to fertilize. The epididymis is a highly coiled tube (duct) that lies at the back of each testis and connects the seminiferous tubules to the vas deferens. Sperm normally spend 2 to 10 days passing through the epididymis where they gain the vital ability to swim strongly (become 'motile'), and to attach to and penetrate an egg. Sperm move up the epididymis with a small amount of fluid and then mix with large amounts of fluid from the seminal vesicles (60%), prostate (30%) and other smaller glands that make up the seminal fluid [14][15]It takes about 70 days for a sperm to be matured [16]. When a man is sexually stimulated, the brain sends signals to the genital area through nerves in the spinal cord to make the pelvic muscles contract. At orgasm, waves of muscle contractions transport the sperm, with a small amount of fluid, from the testes through to the vas deferens. The seminal vesicles and prostate contribute extra fluid to protect the sperm. The passage of fluid along the urethra is further facilitated by secretions of the Cowper's glands. This mixture of sperms and fluid (the semen) travels along the urethra to the tip of the penis where it is ejaculated. During ejaculation, usually the sperms and the prostatic fluid come out first and the seminal vesicle fluid follows [14][15].

2.4 Hormonal regulation of spermatogenesis

The brain plays an important role in the control of the male reproductive system. The pituitary gland and the hypothalamus, located at the base of the brain, control the production of male sex hormones. Luteinizing hormone (LH) and Follicle Stimulating Hormone (FSH) are the two important messenger hormones produced in the pituitary gland that act on the testes [14].LH enters the testes and stimulates the Leydig to produce and release testosterone within the testes and in to the blood. Testosterone controls the male sexual characteristics and behavior and stimulates spermatogenesis. FSH from the pituitary gland enters the testes and stimulates the Sertoli cells to facilitate spermatogenesis. Then testosterone and FSH are act together on the seminiferous tubules (sperm-producing tubes) in the testes to produce sperm. A negative feedback system occurs in the male with rising levels of testosterone acting on the hypothalamus and anterior pituitary to inhibit the release of GnRH, FSH, and LH. The Sertoli cells produce the hormone inhibin. This inhibits the release of GnRH and FSH, which will cause spermatogenesis to slow down. If the sperm count reaches 20million/ml, the Sertoli cells cease the release of inhibin, and the sperm count increases [17].

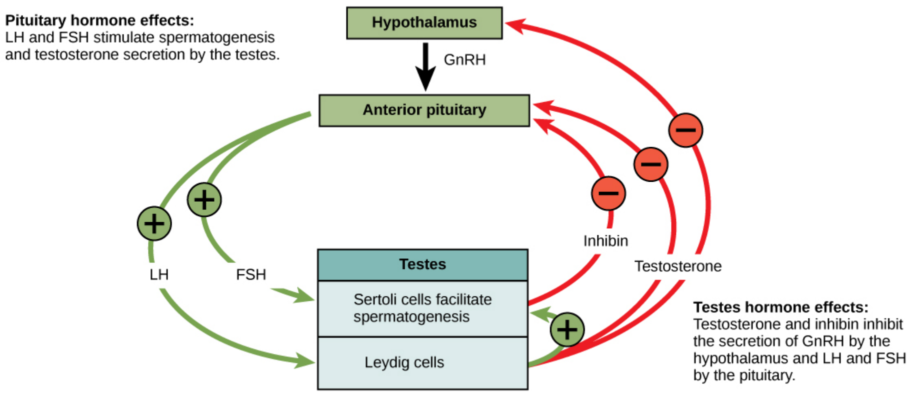

Figure 2.4: Hormonal regulation of sperm production

Normal testicular function is dependent upon hormones acting through hypothalamo pituitary testicular axis. Hormones such as Follicular Stimulating Hormone (FSH), Luteinizing Hormone (LH) and testosterone are known to influence the germ cell production. Activin A, follistatin and FSH play a role in germ cell maturation during the period when gonocytes resume mitosis to form the spermatogonial stem cells and differentiating germ cell populations [18][13].

2.5 Factors affecting to sperm quality

There are many factors affecting male fertility ranging from structural abnormalities, hormonal abnormalities, lifestyle & occupational factors.

2.5.1 Structural abnormalities

The structural abnormalities might damage the testes or block the epididymis, seminal ducts or other reproductive structures and can ultimately affect male fertility. Structural abnormalities affecting spermatogenesis can be deliberated under three main categories as testes, ducts system and reproductive glands.

Common abnormalities that affect the proper testicles functions and infertility are orchitis specially due to mumps, testicular trauma, testicular torsion, cancer, vericocele and hypogonadism.

Mumps affects the testes and causes an inflammatory condition called orchitis. The disease ultimately causes a reduction in sperm production. Although the reason for this is not thoroughly understood, it might involve changes in male hormones during the early stages of orchitis. The researchers also indicate that the viral infection causes swelling of testis which can increase the pressure on the sperm-producing parts of the testis. Prolonged pressure may permanently damage the tissue, leaving it incapable of sperm production, however complete infertility is extremely rare [19], but it may contribute to sub-fertility. It can also lead to oligospermia, azoospermia, and asthenospermia (defects in sperm movement).Mumps virus damage to sperm production particularly if the infection is in post-pubertal which is when the sperm producing cells are starting to grow[20][21].

Testicular trauma is a frequent acquired cause of infertility; accidents, work injuries and sports injuries are common causes of testicular trauma. Studies have shown definite evidence of subfertility as assessed by abnormal semen analyses and atrophic testes following testicular trauma [22].

Testicular torsion is twisting of the spermatic cord resulting in progressive impairment of testicular venous drainage ultimately culminating in arterial ischemia and testicular infarction. Torsion is one of the leading causes of male factor infertility. However, it is more likely that infertile men will present with the long-term complications of a torsion that occurred when they were younger, than present with acute testicular torsion itself [23]. Possibilities of decreasing in semen quality and increasing in the rate of testicular cancer have been reported in many populations over the recent decades. Men with testicular cancer often have abnormal semen characteristics, but the association between abnormal semen characteristics and testicular cancer has not been investigated prospectively. Analysis of specific semen characteristics showed that low semen concentration, poor motility of the spermatozoa, and high proportion of morphologically abnormal spermatozoa were all associated with an increased risk of testicular cancer. [24]. Further it is reported that infertile men with abnormal semen parameters has a 20-fold greater incidence of testicular cancer compared to the general population [25].

Varicocele is the most common correctable cause of male infertility, defined as abnormal dilatation and elongation of the internal spermatic veins and pampiniform plexus of the spermatic cord. Existence of disease is normally present in 40% of men with primary infertility and in up to 70% of men with secondary infertility [14].This difference in the incidence of varicocele was highly significant. A study has shown that men with secondary infertility and varicocele had a lower mean sperm concentration (30.2 versus 46.1×10^6/mL), more abnormally shaped sperm (72% versus 40 %,), and higher mean serum follicle-stimulating hormone levels (17.6 versus 7.9 mIU/mL,) compared with men with primary infertility and varicocele. These findings suggest that varicocele causes a progressive decline in fertility and that prior fertility in men with varicocele does not predict resistance to varicocele induced impairment of spermatogenesis [26]. Men with varicoceles often have a lower than average number of sperm, poorer sperm movement and an increase in the number of abnormally shaped sperm [15]. However, a recent meta-analysis showed that semen improvement is usually observed after surgical correction. Although many mechanisms by which varicoceles affect testicular function has been postulated, the most commonly accepted hypothesis is that varicoceles result in an increase in testicular temperature that suppresses spermatogenesis [27].

Male hypogonadism is a condition in which the body does not produce enough testosterone hormones that plays a key role in masculine growth and development during puberty. Primary type of hypogonadism is also known as primary testicular failure. Secondary type indicates a problem in the hypothalamus or the pituitary gland that signal the testicles to produce testosterone. Both these leads to reduced testosterone production with defective spermatogenesis, reduced libido, and erectile dysfunction [28].

The epididymis is a narrow tightly coiled tubule (3–4m in length) that connects the efferent ductules of the testis to the vas deferens; and is attached to the testis. The epididymis is responsible for sperm maturation, transport and storage, and is a target for inflammation (acute or chronic) and neoplastic diseases (benign or malignant) [23]. The epididymal environment is required for the final maturation of spermatozoa and the acquisition of normal motility and fertilizing ability. Appearance of sperm tail abnormalities in conjunction with normal or high sperm concentrations suggests a disturbance of epididymal physiology [29].

The vas deferens is a paired tubular structure that extends from the tail of the epididymis into the pelvis through the inguinal canal toward the base of the bladder. At the internal ring, the vasa deferentia curve laterally and then pass medially and downward into the pelvis to join seminal vesicles to form ejaculatory ducts [23]. Malfunction of vas deferens are associated with poor fertility. Generic or acquired causes can lead to vas deferens diseases. One genetic disorder is called CAVID, which is a short form of congenital absence of vas deferens. This condition can develop even before the birth. Men who have this type of vas deferens are able to produce sperm, but no possibility to transmit sperm in a proper manner. This type of the disorder causes azoospermia.

Success of fertilization is dependent upon both quality and quantity of semen delivered to the female reproductive system. There is a minimum number of sperm per inseminate required to reach maximum fertility. Inability of sperm to reach the site of fertilization due to the block of transportation duct may have less or no chances to penetrate the ovum [30]. Main causes for transport disorders of the duct system are congenital disorders or acquired disorders. Scarring of the ducts due to infections or functional obstruction due to nerve damages are acquired causes of obstruction. Obstruction of the ejaculatory ducts is commonly associated with low semen volume, decreased or absent seminal fructose, and acid pH [31].

2.5.2 Hormonal abnormalities

Hormonal imbalance as a result of disturbances to hormonal regulation of male spermatogenesis is one of the leading causes of abnormal sperm production. There are a variety of hormonal abnormalities that can lead to infertility. Disorders of hypothalamus and pituitary are key factor to make hormonal imbalance. The hypothalamus plays a significant role in the endocrine system. It is responsible for maintaining body’s internal balance, which is known as homeostasis. Hypothalamus helps stimulate or inhibit many of your body's key processes, including Production of substances that influence the pituitary gland to release hormones of Gonadotropin-releasing hormone (GnRH). GnRH stimulates the anterior pituitary to release follicle stimulating hormone (FSH) and luteinizing hormone (LH), which work together to ensure normal functioning of the testes. The function of the testicles is directed by the central nervous system and pituitary gland. Precise regulation of testicular function is conferred by an elegant feedback loop in which the secretion of pituitary gonadotropins is stimulated by gonadotropin hormone-releasing hormone (GnRH) from the hypothalamus and modulated by testicular hormones [32][33][34]. Common signs of hormonal imbalance in men are low libido, abnormal hair growth, and erectile dysfunction.

2.5.3 Abnormalities in heat regulation

Temperature influences the development of germ cells as well as reproductive cycle of human beings. The scrotum is kept outside the body so that the temperature of testes remains lower than the core body temperature. Testicular temperature is kept at 2-4^{0}C below the core body temperature to make it compatible with spermatogenesis [35][36]. Optimum temperature for human spermatogenesis is considered to be 35^{0}C [37]. Testicular descent into the scrotum normally occurs at birth in boys and failure to do so, which extends into puberty and adulthood, results in absence of spermatogenesis [35].

Testicular temperature is regulated by two mechanisms. First level of regulation is by changing the distance between the testicles and the abdomen. When the room temperature is warm, the scrotum moves the testes further away from the abdomen. This helps to increase the total surface area of its skin and dissipate heat faster. The scrotum will move the testicles closer to a person's abdomen with lower room temperatures. The second thermoregulatory system is located in the spermatic cord where there is a countercurrent heat exchange mechanism between incoming arterial blood and outgoing venous blood [37][38].

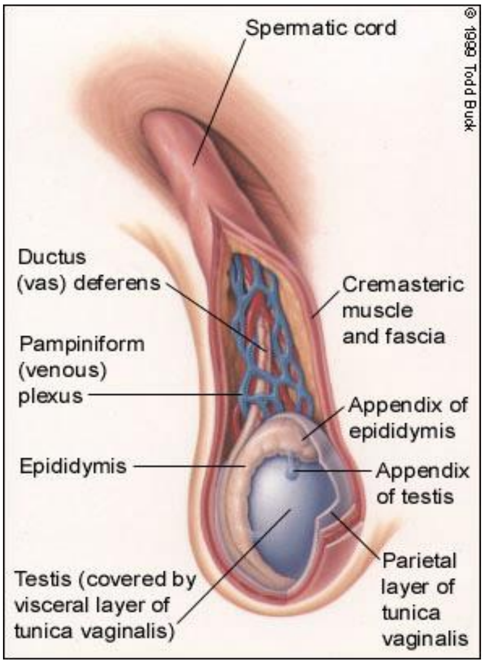

Figure 2.5: Spermatic cord

Abnormalities of thermoregulatory mechanisms discussed may elevate the testicular temperature and is associated with a substantially reduced sperm concentration, resulting in poor semen quality. Furthermore elevation of testicular temperature by 1^0C above the base line depresses spermatogenesis by 14% and there by decrease the sperm output. Moreover the exposure to high temperatures results in modification of sperm morphology. The mean value of sperm with abnormal morphology rises from 30-60% within 6-8 months of exposure to high temperature [35]. An experimental study has shown that rambling effect of heat on spermatogenesis in men with normal spermatogenesis, with increases testicular or scrotal temperature, induces a decrease in sperm count, percentage motility and normal sperm morphology [37].

2.5.4 Chemical influences

There is possible health threat posed by endocrine-disrupting chemicals, which are substances in our environment, food, and consumer products that interfere with hormone biosynthesis, metabolism, or action resulting in a deviation from normal homeostatic control of reproduction [39].

Chemicals which may be used in different contexts, combinations and concentrations enter the body via inhalation, ingestion or absorption through the skin, can affect sperm development and sexual function in males. In men, solvent exposure has been associated with reduced semen quality and altered hormone levels [40]. Potential risk of environmental chemicals to male reproductive health seen as descending trends in semen quality, as well as increased rates of developmental urogenital tract anomalies and testicular cancer has been reported.

2.5.5 Occupational factors

The effects of exposure to occupational hazards on male reproductive system in humans have been reported in many studies [41]. Exposure to occupational emissions and hazards is one of recognized causes for the tendency to decline in sperm parameters of men. Although many occupational risks have been reported as harmful for male reproduction, these can be largely discussed under the divisions of heat, chemical toxins, and heavy metals.

Occupational exposure to heat

Heat is one of the main occupational factors that adversely effect on male fertility. It has been reported that the effect of exposure to heat which increases testicular or scrotal temperature in men with normal spermatogenesis, induces a decrease in sperm count, percentage motility and normal sperm morphology [37]. Further, altered spermatogenesis is seen in men who are continually exposed to high temperatures. Further low birth weight, preterm delivery, and spontaneous abortion has been reported as related directly to elevated heat exposure of the male partner, which could be due to genetic mutations in sperms [42]. Semen characteristics of healthy ceramic oven operators with long term exposure to high temperature were compared with non-exposed workers of the same company and observed a significant difference of sperm parameters between the exposed and non-exposed groups. Many of the workers exposed to heat reported difficulties their partners conceiving though, semen analysis did not indicate a difference in mean sperm concentration and morphology, but showed a lower percentage of normal sperm motility for the exposed workers [43].

In men spending long hours in sedentary position it has been observed that air does not circulate easily around the scrotum resulting less efficient cooling. This effect is likely to be worsened if wearing tight underpants. In studies of men in whom scrotal temperature was measured continuously in relation to position and activity, scrotal temperature increased progressively with duration of sedentary position and this was associated with lower sperm count. Further lorry and taxi drivers, who spend a long time in seated position, have also produced evidence for detrimental effects on sperm quality [44]. The effect of long-term driving upon spermatogenesis was investigated with professional drivers and found incidence of pathospermia was significantly increased among occupational drivers as compared to other professionals. The ratio of severe pathospermia increased in proportion to the number of years of driving. The deterioration of spermatogenesis was mild among car drivers, but was severe in hard machinery and farm equipment drivers [45]. In a study conducted with continuous monitoring of scrotal temperature in real conditions, in men driving a car for a prolonged period it was found that scrotal temperature was increased significantly in driving posture after 2 hours of driving, reaching a value 1.7-2.2 ^{0}C higher than that recorded while walking. This link between driving position and increased scrotal temperature indicates a potential exposure of male reproductive function to occupational factors [46]. Taxi drivers in the city of Rome, have showed significantly lower prevalence of normal sperm forms (45.8% vs. 64.0%); and that this association was enhanced for those who had been driving for a longer duration of time [47].

Clothing / tight fitting undergarments increase scrotal temperature in whatever the position [48]. Moreover, seated with legs crossed position is observed as that scrotal temperature reaches its highest value [49]. The germ cells and sertoli cells are highly sensitive to elevated temperature which causes partial or complete spermatogenic arrest. Even in normal fertile males fever, high summer temperatures and frequent hot baths are known to result in destruction of germinal epithelium and also induce transient oligozoospermia [50].

Cyclists are more likely to show signs of abnormal and low sperm count compared to other athletes, especially who regularly ride longer distances. The main reason for the apparent connection between cycling and infertility is temperature elevation due to tight clothing. Road cyclists who travel short distances may not be at a great risk. It may be only those elite cyclists who ride more than 180 miles per week that are at most risk of developing infertility [51]. Men who cycle as their primary form of exercise had a lower sperm concentration and lower levels of total motile sperms [52].

Laptops can reach an internal operating temperature over 70°C. They are frequently positioned on thighs close to the scrotum, and the user is required to be seated with his thighs close together to balance the machine, which traps the scrotum between the thighs. In 29 healthy male volunteers aged between 21 - 35 years, who took part in an experiment and their scrotal temperature changes caused by laptop use was recorded at different seating positions over one hour time periods. Just sitting with the thighs together, a posture needed to balance a laptop, caused scrotal temperatures to rise by 2.1^0C. Another study has found that men who sat with laptops on their laps for an hour had an average increase in scrotal temperature of about 2.7^0C [53]. Previous studies have suggested that rise of scrotal temperature by 1°C above the baseline is the possible minimal thermal gradient which can affect the production of healthy sperms. Although changes in sperm quality might be reversible, repetitive use of a laptop in the same posture might cause permanent damage [54][55].

Occupational exposure to chemical toxins is of two types: exposure to industrial chemicals and exposure to agricultural chemicals.

Exposure to industrial chemicals

Different types of chemicals are used in industrial applications and, many new chemicals are introduced annually. Chemicals which may be used in different contexts, combinations and concentrations enter the body via inhalation, ingestion or absorption through the skin, but a comprehensive list of chemicals causing reproductive hazards does not exist at present. Individuals are affected differently, depending on the time of exposure, dosage or frequency of exposure to chemicals.

Chemicals can affect sperm development and sexual function in males. In men, solvent exposure has been associated with reduced semen quality and altered hormone levels [40].The range of chemical effects may have on male reproductive health can be briefly summarized in table 1.1

Table 2.1: Summary of application and effect on male fertility of commonly used chemicals

Chemical	**Application**	**Effects on sperm parameters**
Glycol ethers	Manufacturing paints, glue, dyes and thinners and printing ink	Decrease in semen quality[56][57][58]
Acetone	Manufacturing glues, rubber cement and varnishes, reinforced plastic	Reduced sperm morphology and motility [59], alteration in DNA integrity in germ cells [60], decline in sperm density and sperm count [61].
Trichloroethylene (TCE) and tetrachloroethylene (PER)	Used as degreasers, dry-cleaning industry	Effect on sperm motility and morphology [62]
Perchloroethylene (PCE)	Dry clean and laundry industries	Affect male reproductive function [63].
Ethylenedibromide {EDB)	Papaya plantation	Decreased semen volume sperm count, motility and morphologically normal sperm cells.[64][65] [66], increase in the number of abnormal sperm and decreased sperm concentration [40][67]
Deibromochloropropane '(BDCP) and nematocide	used on crops such as bananas and pineapple	Reduce concentration of ejaculated[67] [68][69][70][71] [72]

Exposure to agricultural chemicals

Men working in the agriculture industry showed more than a ten-fold increased risk of having infertility in comparison to other job occupations [73][74]. A study was recently carried out in Argentina, where this area, is one of the most fertile farmland zones in the world, is characterized by intensive agricultural and industrial activity. The study disclosed that exposure to pesticides significantly increased the risk of having a sperm concentration of below 1 million/ml, a total number of sperm per ejaculate below 3 million, less than 50% motile spermatozoa, and less than 30% of spermatozoa with normal morphology. These associations were higher in men who were frequently exposed than in men who were only occasionally exposed. Exposure to solvents also increased the risk of having poor sperm characteristics, particularly poor sperm motility [75]. Men using Ethylenedibromide {EDB) in a papaya plantation had decreased sperm count, motility and morphologically normal sperm cells. In addition, reduced fertility was observed among workers in one plant manufacturing EDB [64] [76]. Men exposure to pesticide 'deibromochloropropane'(BDCP) and 'nematocide' which are used on crops such as bananas and pineapple, during manufacture or application cause severe impairment of spermatogenesis and resulting infertility in high proportion of highly exposed men and recovery after stopping exposure did not always occur [72][72].

Exposure to ionizing radiation: Spermatogenesis is a long complex process and during this process the developing germ cells are highly sensitive to ionizing radiation [77]. A radiation dose of 0.15 Gy (Gray is SI unit for radiation absorbed by a person) may temporarily reduce sperm counts, while 2 Gy may result in long lasting or permanent azoospermia. At higher radiation doses (> 15 Gy), Leydig cell function will also be affected [78][79].

Exposure to Electromagnetic field (EMF): The health risk caused by EMF exposure remains an open question. Some studies have concluded that there is no strong evidence that EMF exposures pose a health risk. However, some studies have shown low level of health risk. The working voltage used in arc welding is low compared to the voltage levels which can cause biological effects inside the human body. At frequencies above 100 kHz energy of an electromagnetic field will be partially absorbed by body tissues, which can lead to dielectric whole-body or local heating effects. Typically the amplitudes of relevant frequency components of fields generated during welding are low. The presently available information does not suggest excessive thermal effects due to the electromagnetic fields produced by the welding [77][80].

Exposure to heavy metals

Men are inevitably exposed to metals due to their availability and persistence in environment and as well as wide use in industry. Metals can penetrate the body through dietary supplements, water, air, alcoholic drinks, and tobacco [81]. Heavy metals like lead, mercury, cadmium, chromium and copper that are routinely used in work processes are capable of causing male infertility are discussed below.

Lead (Pb):- People are extensively exposed to leads via paints & gasoline, consuming of certain food and drinks, strongly acidic beverages (such as wine, fruit juices, and soft drinks) and certain fish as tuna in which these metals may be concentrated [81][68]. Analysis of sperm count in lead workers showed a decrease in sperm count as well as decreased motility and life span of sperm. This was directly related to the level of lead in blood; it is reported that even moderate exposure to lead can significantly reduce human semen quality [72]. Series of studies conducted has described the possible links between low level lead exposure and the adverse effects on male reproductive system. Male workers who were exposed with Pb-B over 40 micrograms have been reported to have decreased volume of ejaculation, prolonged latency of semen liquefaction , reduced total sperm count and alive spermatozoa, retarded sperm activity as well as lowered density of semen fluid [82]. It is also shown that the median sperm concentration was reduced by 49% in men with blood lead concentration above50 microg/dl. Some studies have reported that there was no linear trend of lower sperm concentration with increasing blood lead values, but no adverse effects were observed at blood lead concentration below 44 micro g/dl. It is also reported that there was no association between occupational exposure to lead and lower fertility rates when blood lead concentrations ranged from 29 to 37μg/dl [83]. A study done among paint factory workers in Bangalore, India show that low sperm velocity and motility with high non-progressive motile spermatozoa indicating lowering of cellular activity after lead exposure. Deterioration of sperm count, structural abnormality of spermatozoa and sperm head DNA hyploidy was also associated with high blood and semen lead levels in the paint factory workers without interfering with FSH, LH and testosterone level [84]. The sperm analysis of men who were exposed to lead over a period of six years (average) and six hours daily has been revealed to have morphological abnormalities of sperms (mainly, the tail abnormality) and significant decrease in certain key seminal constituents like, fructose and succinic dehydrogenase which indicate male reproductive functional impairment with exposure to lead [85].

Mercury: - The most common organic compound of mercury is methylmercury (MeHg). The major route of human exposure to methyl mercury (MeHg) is largely through diet, especially through freshwater, contaminated fish, seafood (e.g. shark, sword fish, barracuda, large tuna)[86]. In Hong Kong, blood mercury concentrations of infertile couples were compared with those of fertile couples, to examine the relationship between blood mercury concentrations and seafood consumption. The study found that higher blood mercury concentration is associated with male and female infertility. Higher seafood consumption is associated with elevated blood mercury concentrations in infertile population. [87]. Mercury may affect reproductive function by altering the circulating levels of follicle-stimulating hormone (FSH), luteinizing hormone (LH), estrogen, progesterone, and the androgens. Studies in Hong Kong demonstrated that increased mercury levels were associated with infertility in both men and women. In males, mercury can have adverse effects on spermatogenesis, sperm count, and testicular weight [86].

Cadmium: - Cadmium is used in the production of nickel-cadmium batteries, pigments (bright yellow, orange, red, and maroon dyes), ceramics, plastic stabilizers, electroplating and fertilizers. Environmental exposure can occur through inhalation of cadmium fumes and ingestion of foods particularly cereals such as rice and wheat, green leafy vegetables, potato, and organ products such as liver and kidney. Cigarette smoke is one of the most important sources of cadmium [81]. Several studies have found evidence that low-level cadmium affects semen quality and/or reproductive hormone levels. The effects reported in men with blood cadmium level <1.5 μg /L were decreased sperm density and number of sperm per ejaculate, decreased semen volume and increased sperm mid-piece defects and immature sperm forms [81].

Chromium: - Chromium is widely used in refractory, pigment and stainless steel factory, tannery, welding, engraving and photo processing industries. It is known to cause severe reproductive injury among the exposed persons. Industrial workers exposed to chromium over 25 months for 6hrs daily showed high metal levels in blood and semen. The welding fumes contain high percentage of chromium and so the welders exposed to smoke generated by welding, suffered from an increased risk of reduced semen quality leading to infertility [85]. Experimental observations indicated that different doses of chromium treatment, in rats has indicated visible disruption in germ cell arrangements near the wall of seminiferous tubules and a decrease in the diameter of the seminiferous tubules. Thereby, steroidogenic processes in the testis may get impaired, leading to infertility. The degree of damage is directly proportional to the dose applied [88].

Copper: - Copper is a trace element that is essential for human health. The role of copper in male reproductive capacity appears to be largely unknown. Occupational exposure to copper often occurs, and very few studies have been shown the effects of copper on human spermatogenesis. The effect of copper on normospermic, oligozospermic, asthenozospermic and azospermic groups was studied according to their spermiogrames and suggested that excess copper in seminal plasma was detrimental for male reproductive capacity by reducing sperm count, motility, vitality and morphology [89].

2.5.6 Life style factors

Lifestyle factors are the changing habits and ways of life that can greatly impact overall health and well-being, including fertility. Lifestyle risk factors such as alcohol consumption, cigarette smoking, other addictions, other beverages, use of mobile phone, emotional stress, poor dietary habits causing obesity, are known to cause significant alterations in spermatogenesis and decrease semen quality [1][2][90].

Alcohol consumption

Alcoholic beverages are known to cause harmful effects on different systems of human body including reproductive system. It has been observed that chronic ethanol consumption cause sexual dysfunction and is often associated with impotence, loss of libido, and infertility. Impaired sperm motility has been reported in chronic ethanol users [2]. Alcohol is a direct testicular toxin, causes atrophy of seminiferous tubules, loss of sperm cells, and an increase in abnormal morphology of sperms. It can also adversely affect the leydig cells, which produce and secrete the hormone testosterone, and can cause significant deterioration in sperm concentration, sperm output and motility. Alcohol further impairs the function of the testicular Sertoli cells that play an important role in sperm maturation. Semen samples of men consuming excessive amounts of alcohol have shown distinct morphological abnormalities. It has been also reported that approximately 80% of chronic alcoholic men are sterile. Furthermore, alcohol is one of the most common causes of male impotence [91] [92]. Alcohol consumption may alter both testosterone secretion and spermatogenesis. In fact, it is well known that alcohol consumption produces significant morphological changes of sperms which include breakage of the sperm head, distension of the midsection, and tail curling. In addition, seminiferous tubules in alcohol users mostly contain degenerated spermatids with a consequent azoospermia [92].

Cigarette smoking

Cigarette smoking is significantly associated with decreasing sperm count, alteration of motility and an overall increase in the number of morphologically abnormal sperm [1]. A number of studies have shown that men, who smoked have higher rate of abnormal morphology of sperms, decrease sperm motility and density, damaged DNA and reduced testosterone production. Higher percentage of abnormal sperm morphology may be related to greater incidence of miscarriages or birth defects [2] [93]. Some reports have shown that the tobacco smoking significantly lower the zinc levels, which is necessary for the stability of the sperm chromatin [94]. Additionally seminal cadmium levels were significantly high, especially in those smoking more than one packet / 20 cigarettes per day [1]. Level of cotinine (a byproduct of nicotine) and trans-3-hydroxycotinine are found in similar concentrations in semen and blood of smokers. Level of nicotine found in smoker's semen is reported even higher than the level found in their blood, indicating that once absorbed in to the bloodstream nicotine accumulate in seminal fluid affecting the male reproduction system. There is some evidence that smoking may increase the level of prolactin, a hormone causing decrease in the size of testes and motility. Male smokers have lower level of testosterone and higher level of follicle stimulating hormone than nonsmokers, which indicates that cigarette smoking may decrease male fertility. Decreased testosterone level can caused decreased stimulation of the seminal vesicles resulting lower ejaculate volume. The intensity of cigarette smoke causes decrease in semen volume which may be nicotine's effect on the nervous system [93]. Smoking increases the number of white blood cells in the semen, result in the sperms of a smokers having less ability to penetrate the egg (ovum) thus adversely affecting the ability to fertilize. Smoking further directly inhibits the ability to produce normal quantity of sperm which is one of the risk factor for infertility. It is further associated with an increased risk of impotence or inability to have an erection of penis due to impairment of blood flow to penis [93]. Tobacco chewing has widely spread in South – East Asian region compared to western countries. It was observed that men with habit of tobacco chewing had reduced sperm count and motility than non-chewers [94].

Other addictions

Tetrahydrocannabinol (THC), the active ingredient in marijuana, decreases sperm production and weakens sexual drive by interfering with the production of testosterone. THC also has a direct harmful effect on the movement of sperm by binding active components and metabolites of marijuana to receptors on sperm which, impairs the sperm's ability to move properly through the female reproductive tract and fertilize an egg [95]**[**96**].** Cannabis can affect the production of healthy sperms, which may lead to a lower sperm count, also change the size, shape and movement of sperm. Deformed sperm are less able to swim in a straight line, so are less likely to reach and fertilize an egg [97]. Cocaine can lead to erectile dysfunction because the drug narrows the blood vessels, a process known as vasoconstriction.

But studies on the effects of cocaine by itself are limited because users tend to use cocaine with a cocktail of other drugs. Most of the time cocaine is used along with alcohol, cigarettes and other drugs, hence single cocaine users are almost a rarity. However, animal studies have concluded that there are receptors for cocaine in the testicles and sperm, and the drug can degenerate the testicular tissue. It is further found that cocaine could be transferred from the sperm to an egg, which can lead to early miscarriage [95]. Opiates (narcotics) are found in both prescribed medications (for treating pain and addiction) and illegal street drugs. Long-term use of opiates can disrupt the signals that control testosterone production, which can cause low testosterone and decrease the quantity and quality of the sperm. The extent of the impact depends on the types of opiates, the dosage, and the duration of using the opiates [96]. Opiates can fragment DNA within sperm, leading to lower fertilization rates and miscarriages [95].

Other beverages

Consumption of soft drinks especially cola based drinks has increased worldwide. Cola soft drinks contain large amounts of glucose (up to 11 g of sugar/dL) and high-fructose corn syrup, which are often used to sweeten the carbonated soft drinks. Cola soft drinks and coffee are the main sources of caffeine intake. Cola contains amounts of caffeine ranging from 95 to 160 mg/L [98]. Sperm counts are lower in men who frequently drink cola of 1 L (estimated to contain 100-140 mg of caffeine) [99]. Heavy quantity consumers of cola or caffeine had an unhealthier lifestyle, which has previously been associated with poorer semen quality [100][101]. Caffeine is probably the most frequently found in common beverages (coffee, tea, soft drinks), in products containing cocoa or chocolate, and in medications. Coffee drinking was correlated with increase in sperm count and percentage of abnormal forms. Men who drink one to two cups of coffee per day had increased sperm motility and density compared with subjects who drink no coffee. However, men who drink more than two cups per day had decreased sperm motility and density. The combination of drinking more than four cups of coffee per day (>400 mg caffeine day_1) and smoking >20 cigarettes per day diminished sperm motility and increased the percentage of dead sperm [102].

Use of mobile phones

Radio frequency energy is emitted from cell phones in a form of non-ionizing electromagnetic radiation, which can be absorbed by tissues closer to where the phone is held, but does not make a risk of damaging cells [103]. Many studies have pointed toward a negative correlation between cell phone & male reproduction. There have been further several studies which have disclosed over the detrimental effects of cell phones use on the reproductive characteristics of men. However a retrospective study performed was noted that there was a significant decrease in the percentage of progressive motile sperm and correlated with the frequency of cell phone handling (persons who frequently use phone for more than 2 years) [104][105]. Furthermore, the duration of cell phone usage and the daily transmission time correlated negatively with the proportion of rapid progressive motile sperm and shared a significantly positive correlation with the proportion of slowly progressive motile sperm [106]. Also, it has been found that sperm samples exposed to high intensity electromagnetic radiation (1.8GHz x 0.4 W/kg – 27.5 W/kg SAR) experienced a statistically significant decline in both motility and viability and showed that potential to cause damage not only at the morphological level but also at the molecular DNA level [107 - 110].

Emotional Stress

Emotional and physical changes in domestic and working place may lead to stress. Stress affects biological systems and by the effects on hormonal regulation may affect reproductive health. Emotions can decrease sperm count & quality which may affect the sperm motility and morphology leading to reduced fertilizability and problems of conception [111]. Stress is known to influence the hormones which, are needed to produce healthy sperm and by damaging cells that produce sperm. Further excessive anxiety may increase the levels of “reactive oxygen species” in a man’s semen, leading to oxidative stress, which has been shown to affect semen quality and fertility [112].

Obesity

Over the past few decades many changes have occurred in the dietary and life style habits. Obesity is a lifestyle dependent factor, associated with unhealthy eating habits and reduced physical activity. Intake of high calorie foods, sedentary work, reduced exercise, convenient transportation, and use of modern technology which reduce the physical activities are the reasons for increased obesity around the world. Men with above normal body mass index (BMI $\geq$ 25) have an average of 25% lower sperm count and motility compared to men with a normal BMI [2][94][113]. Obese men have compromised testicular thermoregulation owing to several factors: decreased physical activity and prolonged sedentary periods, increase fat deposition in abdominal, suprapubic, and upper thigh areas and around the spermatic cord which leads to suppressed spermatogenesis [114]. Further, deposition of fat around the scrotal blood vessels, leading to impaired blood cooling and elevated testicular temperature can reduce spermatogenesis in obese men [2].

2.6 Effects of welding on male semen quality

Welding is a technology indispensable with modern industries carried out worldwide. Welders comprise a major occupational group exposed to intense heat, fumes & gas, toxic metals and their oxides during the process of welding. Many have reported that effects on semen quality may be due to exposure to some of these substances or combinations of them, but the exact mechanisms are not clear [115]. The fume generated by welding and hot cutting processes is a varying mixture of airborne gases and very fine particles which, if inhaled can cause health hazards. It has been shown that the fume composition is reasonably independent of the substrate material itself and that the welding fume is mainly composed of elements from the electrode material [116]. Marine quality mild steel, aluminum alloys and stainless steel are the main type of welding materials used in Sri Lanka Navy. However in the industries mild steel is the most commonly used welding material, but welding of stainless steel and high performance alloyed steel is also widely practiced.

Many studies have reported varying results regarding the effects of welding on semen parameters. Among welders, who are exposed to mixture of pollutant air while performing arc and gas welding, adverse effects on sperm motility and morphology were found even though sperm concentration was in the normal range [115]. Semen quality and sex hormone concentrations of manual metal arc alloy steel welders with moderate exposure to radiant heat (skin temperature in the groin increased on average by 1.4^{0}C) without substantially exposed to welding fumes were investigated by another group. They found that sperm count and percentage of motile sperm were not-significantly reduced among welders. Proportion of sperms with normal shape declined significantly after six weeks of exposure to heat and increased after a break in exposure. The changes of sperm count and concentrations were not statistically significant and no consistent changes in concentrations of sex hormones were found [117]. Moderate deterioration of semen quality in mild steel welders and less reliable changes in semen quality in low exposed stainless steel welders were established in a cross sectional field study in metal workers [117]. In a recent study it was found that welding of mild steel is related to a moderate decrease in sperm count per ejaculate, proportion of normal sperm forms, motility, and linear penetration rate, and to an average significant increase in concentration of FSH in serum with increasing exposure to welding fumes [118].

Aluminum is metal that can enter to the human body through inhalation, ingestion and dermal contact during welding. When the amount of aluminum consumed exceeds the body's capacity to excrete it, aluminums is then deposited in the different parts of the body. High levels of aluminum in the body possibly have effects on reproduction [119]. Research conducted by scientists in the UK and France suggests that human exposure to aluminum may be a significant factor to lower sperm count and reduced male fertility [120]. However inclusive evidence is not found on the effects of aluminum on welders.

Chromium and nickel are primarily associated with stainless steel [121]. The stainless steel welders had significantly decreased semen volume, total sperm count, proportion of motile sperm, motility, and concentration of testosterone in serum [118]. A study was conducted to examine the relationship between semen quality and chromium level in the urine and blood of a population of 30 tungsten inert gas (TIG) stainless steel welders, and 30 mild steel welders. It was found that low-level exposure to hexavalent chromium does not emerge a major hazard for human spermatogenesis [122]. However, in another study conducted by J. P. Bonde has found that the sperm concentration was not reduced in either mild steel or stainless steel welders. But, the sperm count per ejaculate, the proportion of normal sperm forms, the degree of sperm motility, and the linear penetration rate of the sperm were significantly decreased [118]. The semen quality and blood nickel & chromium concentration of workers who were occupationally exposed to Nickel & Chromium in a South Indian welding plant was observed and found that the level of nickel and chromium in blood of the exposed group was significantly higher than that of control group. Sperm concentration and rapid linear sperm motility of exposed group was considerably reduced [123]. There was a significant positive correlation between the percentage of tail defects and blood nickel concentration in the exposed workers. The sperm concentration showed a negative correlation with blood chromium content in workers. However, it is concluded that it takes a number of years of exposure to welding fumes containing nickel and chromium to have semen abnormalities [123].

2.7 Welding in Sri Lanka Navy

Shielded Metal Arc Welding (called manual metal arc welding), Gas metal arc welding (Known as MIG) and Gas tungsten arc welding (Known as TIG) are the main welding process use in Sri Lanka Navy for ship repairs. These welding processes generate a huge amount of thermal energy and a considerable amount of heat is dissipated to the environment. The welder performs very close to the welding pool thereby the impact of heat is felt more than the other occupations. Effect of heat to genital area is higher in the seated position rather than the standing position during welding. The temperature of the arc in shielded metal arc welding (SMAW) can be over 9000°F (5000°C), with the correct diameter electrode; the heat created by the arc is enough to melt any wieldable metal. Mild carbon steel melts at slightly above 2800°F (1540°C) [124]. Shielded metal arc welding is the main type of process use in Sri Lanka Navy. Arc efficiency of shielded metal arc welding of mild steel range from 66-68%, while the range for coated electrode welding is 75-85% [125], (Arc efficiency provides quantitative measure of fraction of total arc energy delivered to the substrate). The arc temperature of MIG welding range from 6000-

8000^{0}C [126]. Arc efficiency for gas metal arc welding (MIG) range from 66-70% in deposition of mild steel and 70-85% in aluminum. The arc temperature of tungsten inert gas welding is around 11,000° F (6093^{0}C). Generally non-consumable electrode process is slightly lower of arc efficiency than the consumable electrode process. This may be the cause of substantial part of heat generated at electrode tip dissipating into electrode holder [125].

SMAW is very flexible in terms of the material thicknesses that can be welded (materials from 1/16" thick to several inches thick can be welded with the same machine and different settings). It's quite versatile because it can weld many different types of metals; generally base metals include steels, stainless steels, cast irons, and certain nonferrous alloys. It is not used or seldom used for aluminum and its alloys, copper alloys, and titanium. However some of the biggest drawbacks to SMAW are that, it produces a lot of smoke & sparks. This process is commonly used for welding of the metals particularly for short welds in production, maintenance and repair work, and for field construction, which are comparatively less sensitive to the atmospheric gases. Common applications include construction, pipelines, machinery structures, shipbuilding, job shop fabrication, and repair work. Gas Metal Arc Welding (GMAW) is commonly known as MIG (*metal inert gas*) welding, that produced sound, free of contaminants, and as corrosion-resistant as the parent metal. The filler material is usually the same composition (or alloy) as the base metal. This process is easily used for welding on thin-gauge metal as well as on heavy plate. It is most commonly performed on steel (and its alloys), aluminum and magnesium, but can be used with other metals as well. MIG welding has been used widely to join pieces of aluminum alloys in construction of rail, vehicles, ships, steel bridges, and pressure vessels. Sri Lanka Navy use MIG for aluminum welding. Tungsten inert gas (TIG) welding is easily performed on a variety of materials, from steel and its alloys to aluminum, magnesium, copper, brass, nickel, titanium, etc. Sri Lanka Navy use TIG welding commonly for fabrication of stainless steel parts.

3. METHODOLOGY

3.1 Introduction: This was a cross sectional descriptive study conducted among Navy personnel in Colombo district to study the socio demographic, occupational and lifestyle factors affecting semen parameters. The semen parameters were compared in two groups, the experiment group being the men regularly exposed to welding in Sri Lanka Navy workshops & ship yard based in Colombo, and the control group being the desk job holders of same base.

Study setting

Semen samples were obtained from each participant at the Naval General Hospital – Colombo, according to the WHO laboratory manual for the examination and processing of human semen (2010).

3.2. Sample selection: Welders, who were actively participating in welding operation during the study period, were selected as the experiment group. Sailors, at office and engineering workshops were selected as the control group.

Inclusion criteria:

i. All participants between 24 to 36 years
ii. Welders with more than one year of exposure to welding
iii. Non - welders with no occupational exposure to welding.

Exclusion criteria:

i. Men who were on medical treatment for any other condition which will influence sperm parameters
ii. Men who have undergone genitourinary surgery
iii. Other causes such as varicolele which may affect spermatogenesis

Past medical records of all participants were pursued and subjected to a medical examination which was conducted by a qualified medical officer at Naval General Hospital – Colombo in order to select the sample as per said criteria. Subjects who satisfied the above inclusion and exclusion criteria were recruited as study participants.

3.3 Sample size

Those who fulfilled the above inclusion and exclusion criteria were recruited until the sample size of 44 welders and non-welders were achieved.

Welders and non-welders were selected from SLNS Rangala situated in port of Colombo. The population of welders was 45. The sample size was calculated by using following formula with 95% confidence level and 5% confidence interval (marginal error).

Sample size (n) is given by following formula

$$n = \frac{t^2 \times p(1-p)}{m^2}$$

Where

n is required sample size

t is confidence level at 95% (standard value of 1.96)

p is estimated prevalence of malnutrition in the project area. It has been estimated that roughly 5% of welders are infertile.

m is margin of error at 5% (standard value of 0.05)

$$n = \frac{1.96^2 \times 0.05(1-0.05)}{0.05^2}$$

$$n = 73$$

Though the computed sample size is 73, population of welders in the workshop was 45, in them 44 welders were voluntarily participated for the research study. Therefore the research study was conducted with 44 sample size.

3.4 Data collection

3.4.1 Socio Demographic data

Questionnaire: - At the enrollment, a pre tested interviewer administered questionnaire was administered to both welders and non-welders. The questionnaire was designed to obtain the demographic data, occupational data and lifestyle factors of the participants (Appendix–I).

Occupational data; - Participants were interviewed duration exposed to welding per day (approximate collective time actually exposed to welding emission), type of welding commonly practiced and the common posture in which welding was performed (standing position or sitting position), total duration of exposure to welding emissions in years (numbers of years practiced in welding profession and not the calculation based on numbers of hours actually exposed to welding).

Lifestyle factors; - Factors which are known to influence sperm production such as tobacco smoking & chewing, addiction to alcohol & caffeine containing drinks and exposure to chemicals, heat & welding fumes , were recorded through questionnaire .

Physiological parameters; - Age, height and weight of participant were recorded and BMI was calculated. .

The occupational factors, life style factors, age and BMI were compared in the welders and non-welders to find the associations.

3.4.2 Semen collection: The fresh semen samples were collected into sterile containers by masturbation at the laboratory of the Naval General Hospital-Colombo. Participants were instructed to abstain from ejaculation for 2-3 days before providing the semen samples. However, each participant was interviewed by the lab technician prior to taking semen sample and information of age, date & time of collection, period of abstinence were recorded and reported.

3.4.3 Seminal fluid analysis

Fresh semen samples obtained from the participants were incubated for 30 minutes at 37°C before observing for liquefaction according to WHO guidelines (2010). After liquefaction, viscosity of sample was estimated by introducing a glass rod into the sample. Semen was allowed to drop by gravity and observed the length of thread. Normal sample leaves the glass rod in small discrete drops. Colour of the semen was assessed visually. Normal colour of the semen is grey-opalescent. The semen sample was mixed well and drop of semen was applied over a pH paper strip to assess the pH. The colour of the pH paper was compared with the calibrated strip and reading was recorded. The sample was transferred to a precisely graduated measuring cylinder after assessing the above parameters and volume of the semen sample was recorded.

Although a routine semen fluid analysis (**SFA**) according to WHO guidelines include macroscopic assessment of the above described parameters and the microscopic assessment of sperm count (concentration) , motility, vitality and morphology in this study only the sperm count and motility were assessed due to lack of facilities and trained staff.

Semen analysis was begun soon after liquefaction, preferably at 30 minutes. The sample was mixed well in the original container smoothly before aliquots were taken for assessment of sperm count and motility. Then an aliquot (a standard volume of semen of 10 µl) of semen was immediately taken, allowing no time for the spermatozoa to settle out of suspension and placed onto a clean glass slide. It was covered with a coverslip of 22 mm × 22 mm for 10 µl, to provide a counter chamber approximately 20 µm deep which allowed the spermatozoa to swim freely. The weight of the coverslip was supported to spread the sample homogeneously. Then the assessment of sperm count was carried out on the freshly made wet preparation under the × 400 magnifications as soon as the contents were no longer drifting. The motility of all spermatozoa was assessed within a defined area of the field on freshly made wet preparation, same as above. This was most easily achieved by using an eyepiece reticle. The grid section was scanned initially to score progressive motile (PR) cells. Next non-progressive motile (NP) spermatozoa were counted and finally immortality (IM) spermatozoa in the same grid section were counted. The number of motile spermatozoa was scanned and counted quickly to avoid overestimating, since the spermatozoa being swim between the grid sections during recording. Nearly 200 spermatozoa were evaluated in a total of at least five fields in each replicate, in order to achieve an acceptably low sampling error. The average percentage was calculated for the PR, NP or IM in the replicate wet preparations.

3.4.4 Quality assurance of laboratory procedures

Standardized laboratory procedures and strict quality control (QC) measures were followed according to Chapter 7 of WHO laboratory manual for the examination and processing of human semen (2010). The replicate assessments were performed in the same way by two technicians to assess sperm concentration and motility. In doing so procedures such as mixing the specimen before sampling were followed to minimize variation. The values of sperm concentration on five (5) quality control samples (Table 3.1) which was measured by the two lab technicians were considered in this study. Mean and standard deviation of each sample were calculated to determine the values for warning and action control limits for X_{bar} chart and S_{bar} chart. The factors used to compute the control limits of both charts were obtained from Table 7.1 of WHO laboratory manual. Quality control samples were plotted in the X_{bar} chart and S_{bar} chart are given in Figure 3.1 and Figure 3.2

Table 3.1: Sperm counts of five (5) QC Sample

Sample	1	2	3	4	5
	Sperm concentration(million per ml)				
Technician A	39.5	46	38	42	42
Technician B	35	40	45	38	35
Mean	37.2	43	41.5	40	38.5
SD	3.2	4.2	4.9	2.8	4.9

Calculating the X_{bar} chart control limits

For five (5) sample average of mean (X_{bar}) = 40.05

Average of the SDs for (S_{bar}) = 4.03

Warning control limits are given by (X_{bar}) ± 1.772 x (S_{bar})

= 40.05 + 1.772 x 4.03 and 40.05 - 1.772 x 4.03

= 47.19 and 32.90

Upper warning control limit = 47.19

Lower warning control limit = 32.90

Action control limits are given by (X_{bar}) ± 2.659 x (S_{bar})

= 40.05 + 2.659 x 4.03 and 40.05 -.2.659 x 4.03

= 50.76 and 29.33

Upper action control limit = 50.76

Lower action control limit = 29.33

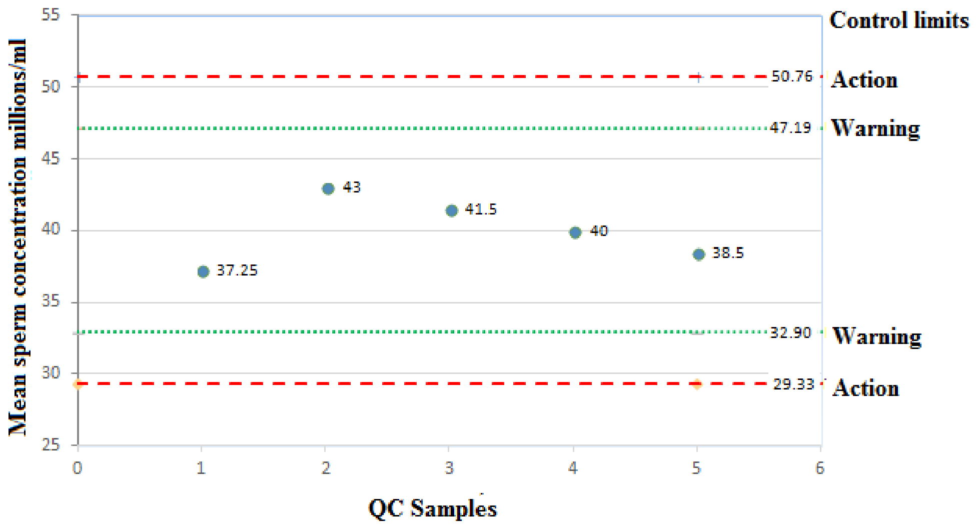

Figure 3.1: X_{bar} chart for sperm concentration

The S chart

This chart detects whether technicians are producing highly variable results, so any significant differences between technicians would suggest systematic bias in the assessment

Calculating the S chart control limits

The lower action limit = $S_{bar} \times S_{0.999,2}$

= 4.03 × 0.002 = 0.0081

The lower warning limit = $S_{bar} \times S_{0.975,2}$

= 4.03 × 0.039 = 0.157

The upper warning limit = $S_{bar} \times S_{0.025,2}$

= 4.03 × 2.809 = 11.320

The upper action limit = $S_{bar} \times S_{0.001,4}$

$$= 4.03 \times 4.124 \qquad = 16.62$$

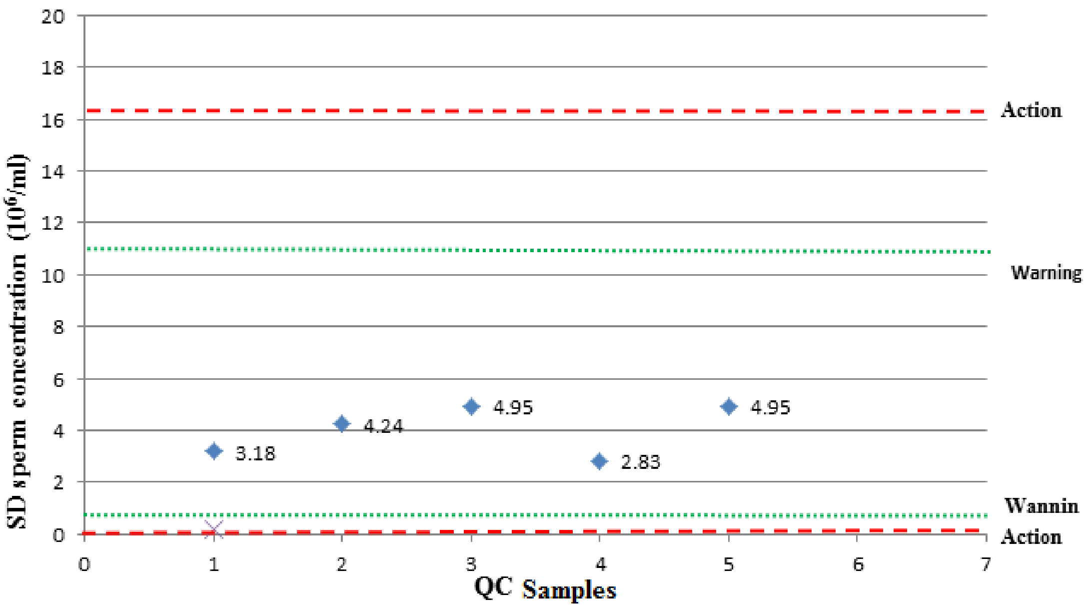

Figure 3.2: S_{bar} chart for sperm concentration

The calculations and Figure 3.1 and 3.2 have shown that less systematic errors and variations of the ultimate results evaluated by technicians are within the control limits and quality of sample analysis could be assured.

3.5 Data entry and analysis

3.5.1 Data entry

Independent variables and dependent variables were identified initially. The independent variables (Age, BMI, total exposure, dose exposure, colour and materials of underpants) were obtained from questionnaire and were recorded in a excel sheet. Dependent variables (Sperm parameters) were obtained on semen fluid analysis and were entered into a different excel sheet under respective headings. All variables were defined in SPSS and then, the data were imported from excel sheet to SPSS for analyzing. In the same way the data were defined and were imported to minitab14 to obtain appropriate figures which were presented the correlations between independent and dependent variables.

3.5.2 Statistical analysis

The data obtained from welders and non-welders in this study regarding associated factors (socio demographic, occupational and life style factors) and the sperm parameters were analyzed statistically by statistical package for the social sciences SPSS (version 16, SPSS). Mean values and standard deviation of semen parameters were computed and differences between welders and the reference group were tested with independent sample t-test. P value ≤ 0.05 was considered statistically significant.

Correlation between each sperm parameter with age, BMI, dose exposure (duration of exposure per day) and total duration of exposure were tested and coefficient of correlation (r) and p value was computed using statistical package for the social sciences SPSS (version 16, SPSS) and package Minitab14.

3.6 Ethical considerations

The ethical approval was obtained from the Ethical review committee of Kothalawala Defense University to conduct the study (Appendix II).

Approval from the commander of the navy was obtained to the participants from Sri Lanka Navy and also to utilize the laboratory facilities at the Navy General Hospital – Colombo (Appendix III).

The subjects who volunteered to participate in the study were educated on the purpose and the process of the study. Informed written consent was obtained after explaining their role in the study, prior to interviews and seminal fluid analysis. The information sheet to participants and consent form explained the purpose of study, procedure, the way of preparation for semen sample analysis and some other important matters such as risk, benefit and compensation (Appendix-IV).

In order to main confidentiality of information, the personal details of participants were not recorded, but identification number was issued with the questionnaire and same number was used to match the occupational data with the semen parameters.

The semen samples were not used for any other purpose and were discarded following recommended procedures.

3.7 Definitions of variables

Total exposure (years):-	The number of years in welding that the participant has performed occupation.
Dose exposure (hours):-	Numbers of welding hours per day that individuals were exposed to welding emission.
Normozoospermia: -	Semen shows normal characteristics in a seminogram. The volume of the sample must be over 1.5 ml, containing 15 million sperm/ml or more with a progressive motile sperm percentage of 32% or more and total motile percentage of 50% or more
Oligozoospermia: -	A sperm count, less than 15 million sperm/mL.
Asthenozoospermia: -	A progressive motile sperm percentage less than 32%
Oligoasthenozoospermia: -	A combination of asthenozoospermia and oligozoospermia.
Addiction to alcohol: -	Continue consumption of alcohol every day and no ability to control intake.
Addiction to smoke: -	Continue smoking with no ability to control the usage.
Addiction to beverages: -	Habit of taking caffeine contained drink every day than the routinely supplied tea from SLN.
Time to pregnancy: -	The number of menstrual cycles it takes to fertilize an ovum.
Mean duration of marriage: -	Mean time period from the date of marriage to the date the study was commenced.
Mean time taken to first child: -	Mean time period from the date of marriage to the date of birth of first child.
Multi welder: -	Welder who is capable of performing MIG, TIG, and Shielded mental arc welding processes

4 RESULTS

4.1 Socio demographic and life style factors

As per objective 1, socio-demographic and life style factors of active welders (44) and non-welders (44) were compared and results are given in Tables 4.1 and 4.2. Both groups of welders and non-welders were in reproductive age between 24-36 years. Mean age of the welders and non-welders was 30.7 (SD 3.9) and 27 (SD 2.2) years respectively. The welders had a longer mean duration of service, marriage and time to taken to have the first child when compared to the non-welders.

Table 4.1: Demographic characteristic of welders and non-welders

Characteristics	**Welders**	**Non welders**
Mean age (years)	31	27
Mean BMI(Kg/m^2)	22.5	22.2
Mean Duration of service(years)	9.5	5
Mean Duration of marriage(years)	7	1
Mean time taken to first child (months)	18.5	11

Out of the 44 welders, 36 were married. Of the married welders, 27 have had their first child within a mean duration of 18.5 months. However the spouses of other 9 welders have not been successful in achieving a pregnancy.

Further wives of 41.6 % of married welders were not successful in achieving a pregnancy within the period of 12 months of marriage which classify them as infertile according to the WHO classification.

Table 4.2 describes the life style factors of welders and non-welders are similar being in a structured organizational culture inherent to the SLN. Both groups are living in Colombo based establishment at SLNS Rangala where consumption of alcohol, smoking and other illicit drugs are prohibited within the establishment. Both welders and non-welders basically follow the same daily routine and food menu during the stay in naval premises and take 6-8 days leave once a month.

Table 4.2: Comparison of lifestyle factors of welders and non - welders.

Lifestyle factors	**Welders**	**Non-welders**
Smoking	None	None
Alcohol addiction	None	None
Illicit drugs	None	None
Addiction to beverages	None of participants were addicted to cola drinks or any other drinks containing caffeine. They drank tea routinely three times per day, supplied by SLN	None of participants were addicted to cola drinks or any other drinks containing caffeine. They drank tea routinely three times per day, supplied by SLN
Sauna/steam bath	None	None
Physical exercise	All participants engaged in the physical exercise in the morning during weekdays	All participants engaged in the physical exercise in the morning during weekdays
Food habits	consumed Meals supplied by SLN, containing rice or bread, vegetables, chicken or fish and fruits/sweet	consumed Meals supplied by SLN, containing rice or bread, vegetables, chicken or fish and fruits/sweet
Use of mobile phone	All welders used mobile phone. 22welders used to keep phone in trouser pocket and rest of them in shirt pocket. Maximum 2 calls during working hours-	All non-welders used mobile phone. 03 kept the phone in trouser pocket and rest of them in shirt pocket.
Use of laptop	None	None
Sleep deprivation	None	None
Contact with solvent/chemicals	None	None
Working dress	Blue coloured, cotton overall	Blue coloured, cotton overall
Underpants	04 welders reported wearing tight underpants Mix of colours and materials were worn.	None of the non-welders reported wearing tight underpants. Mix of colours and materials were worn

4.2 Occupational exposures of the welders

Prime duty of the welders attached to the workshop at SLNS Rangala is to maintain and repair the ships and crafts of the Sri Lanka Navy. They have to perform welding in two different environmental conditions which is in the workshop and onboard ships. The workshop is an environmental friendly place to work, but working onboard ships and crafts is somewhat difficult. Welders have to work in confined spaces in ships as well as in open air on the ship's deck where the environmental temperature is higher than that in the workshop. The welders perform all welding processes (SMAW, TIG and MIG) depending on the job assigned. The workshop is ventilated by natural air whereas ships are ventilated by local ventilation system when attending to welding in confined spaces. In addition, all welders use similar personal protective equipment (PPE) during welding process.

4.3 Sperm parameters of the welders and non-welders

According to Objective 3, sperm parameters of welders were analyzed and were compared with non-welders (control group) in Table 4.3. It was noted that there were no significant difference in sperm parameters between welders and non-welders. However sperm concentration was higher in welders than non-welders but as expected although the differences were not significant (p>0.05).

Table 4.3: Sperm parameters of welders and non-welders

Sperm parameters	**Welders (n=44)**		**Non-welders (n=44)**		**t-Test P value**	**Significance at 95% confidence interval**
	Mean	**SD**	**Mean**	**SD**		
Volume (ml)	2.3	1.1	2.8	1.1	0.6	NS
Concentration (millions/ml)	41.9	27.4	40.9	25.1	0.6	NS
Progressive motility (%)	64.0	22.3	70.9	13.9	0.8	NS
Total motility (%)	79.0	19.3	85.4	9.4	0.1	NS

Note: - NS - Not Significant (p> 0.05), S: - Significant (p<0.05)

When analyzing the sperm parameters of welders and non-welders (control group) the WHO classification (WHO, 2010) was used. In summary, the classification and the proportions of sperm abnormalities of welders and non-welders are given in Figure 4.1

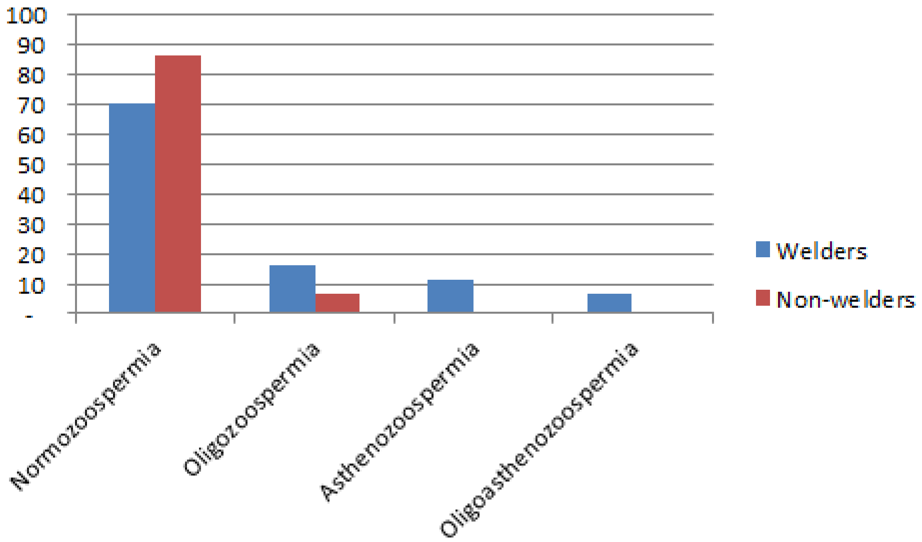

Figure.4.1: Proportion of sperm abnormalities of welders and non-welders

Percentage of welders and non-welders with normal sperm parameters was 70% and 86% respectively. Sperm count was abnormal (oligozoospermia) in 16% of welders and 7% of non-welders with a mean sperm count of 9.2 million/ml and 11.3 million/ml respectively. Sperm motility was abnormal (asthenozoospermia) in 11% of welders and the mean progressive motility was 15.4%. Asthenozoospermia was not found among the non-welders in this study. . It was further found that 7% of welders were oligoasthenozoospermic with both count and motility being below the normal whereas, it was not found among the non-welders.

4.4. Association of socio-demographic, lifestyle and occupational factor with sperm parameters

4.4.1 Socio-demographic factors and sperm parameters

On evaluating the association between, socio-demographic and occupational factors of welders and sperm parameters it was found that there was no significant correlation between age and sperm parameters. A correlation between age of welders and volume (ml) of semen per ejaculation was not found at all [Figure 4.2]. A decreasing trend of sperm concentration with age of welders (r = - 0.230, p = 0.067), was found [Figure 4.3]. A week positive correlation between age of welders and total motility (r = 0.072 p=0.320) and progressive motility (r = 0.126, p=0.207) was observed [Figure 4.4 and 4.5].

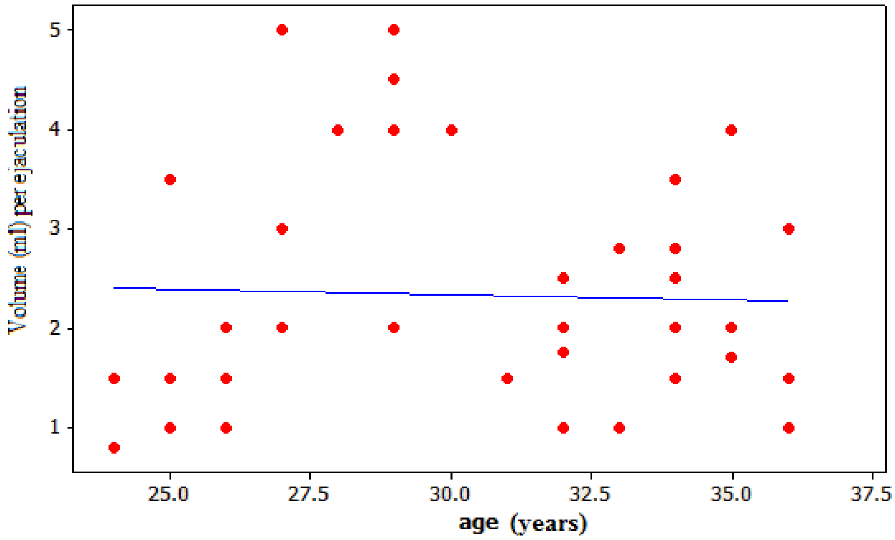

Figure 4.2: Correlation between age of welders with volume (ml) / ejaculation

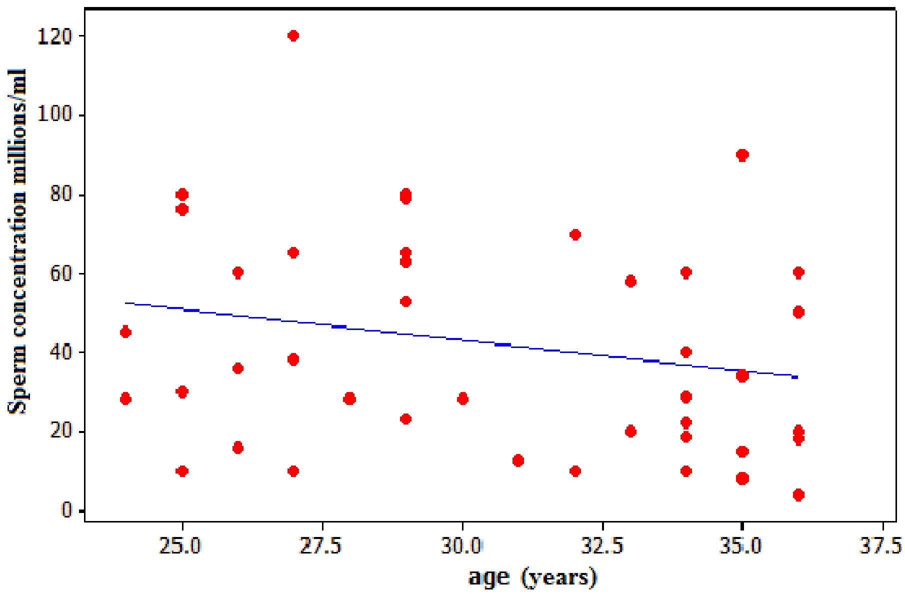

Figure 4.3: Correlation between age of welders with sperm concentration

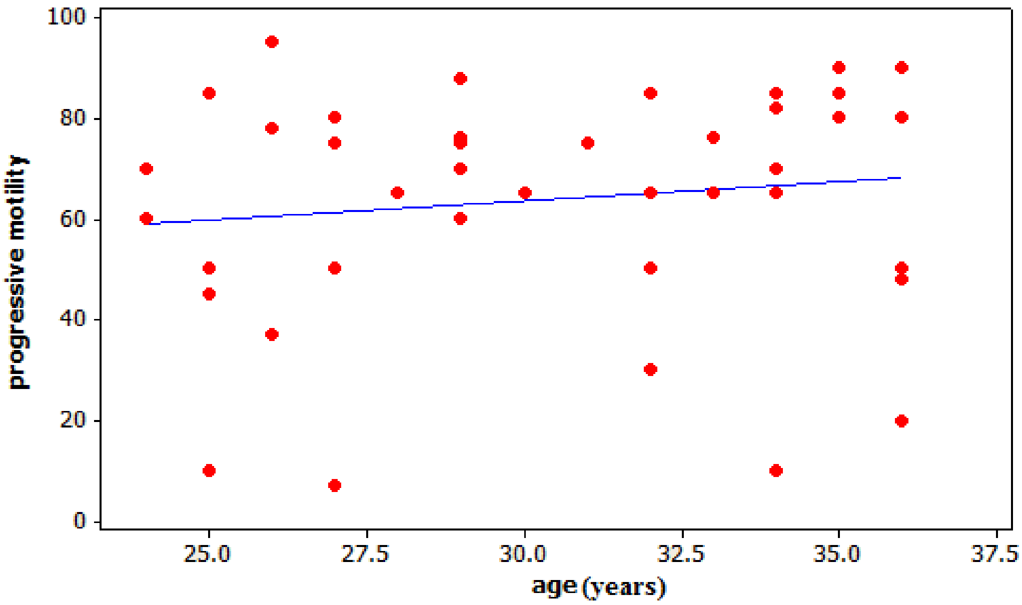

Figure 4.4: Correlation between age of welders and percentage of progressive motility

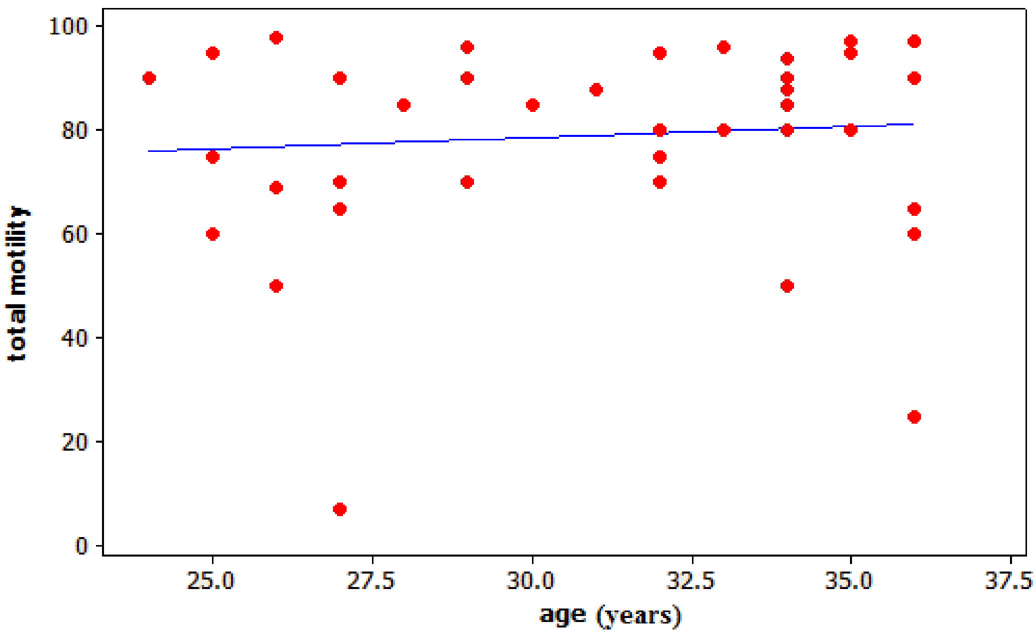

Figure 4.5: Correlation between age of welders and percentage of total motility

When analyzing the relationship between BMI and sperm parameters of welders, it was found that there was a week negative correlation between BMI and semen volume (ml) per ejaculation (r = -0.030 p = 0.424) [Figure 4.6], sperm concentration [Figure 4.7], (r = -0.018 & p= 0.453) and progressive motility [Figure

4.8] (r = - 0.055 & p = 0.36), However, there was an increasing trend of percentage of total motility with BMI of welders [Figure 4.9], but no evidence of linear regression or significant correlation between BMI of welders and sperm parameters. Summary of correlation between socio demographic factors and sperm parameters is given in Table 4.4

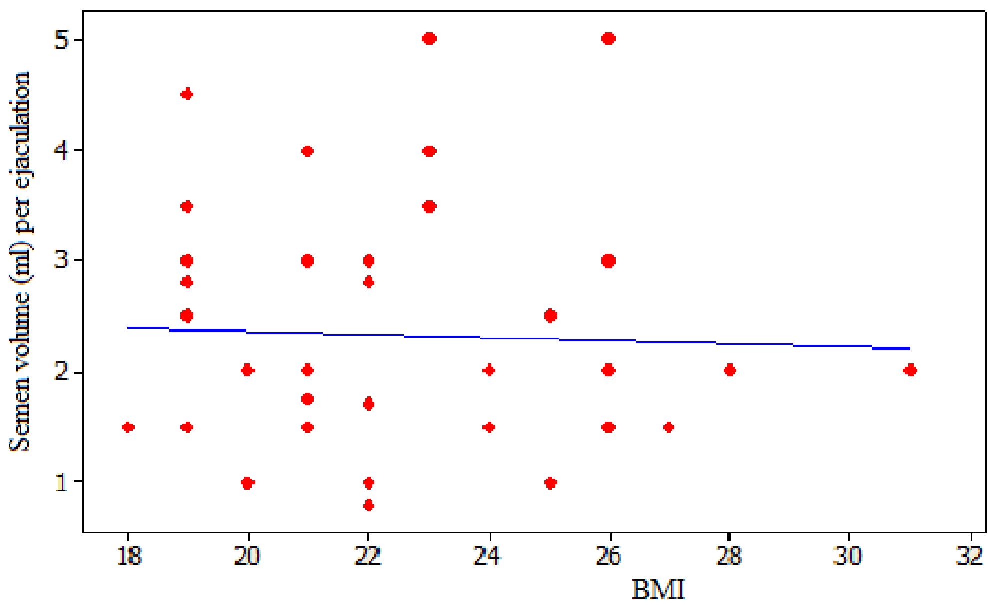

Figure 4.6: Correlation between BMI of welders and semen volume (ml)

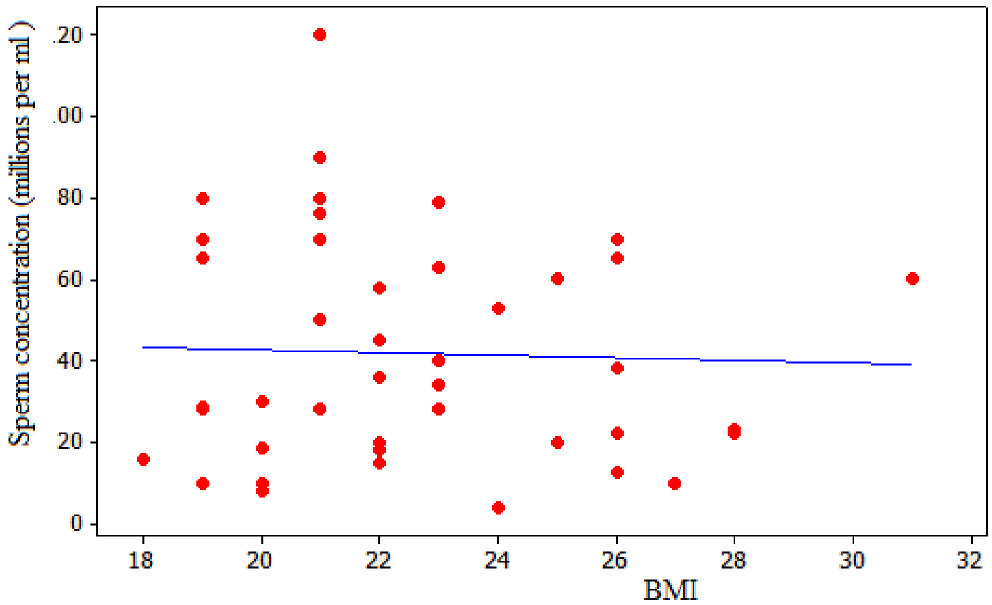

Figure 4.7: Correlation between BMI of welders and sperm concentration

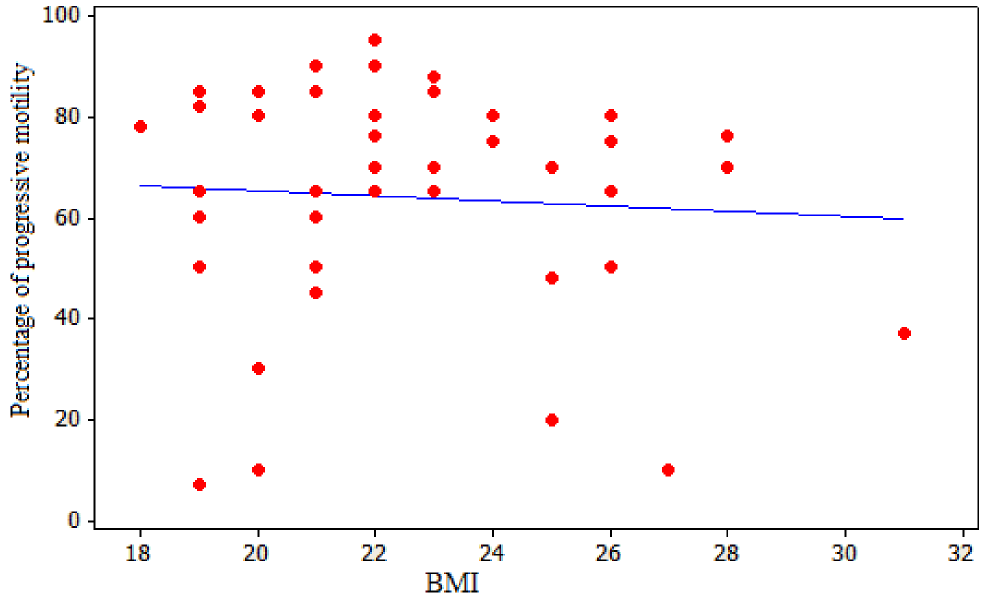

Figure 4.8: Correlation between BMI of welders' and Percentage of progressive motility

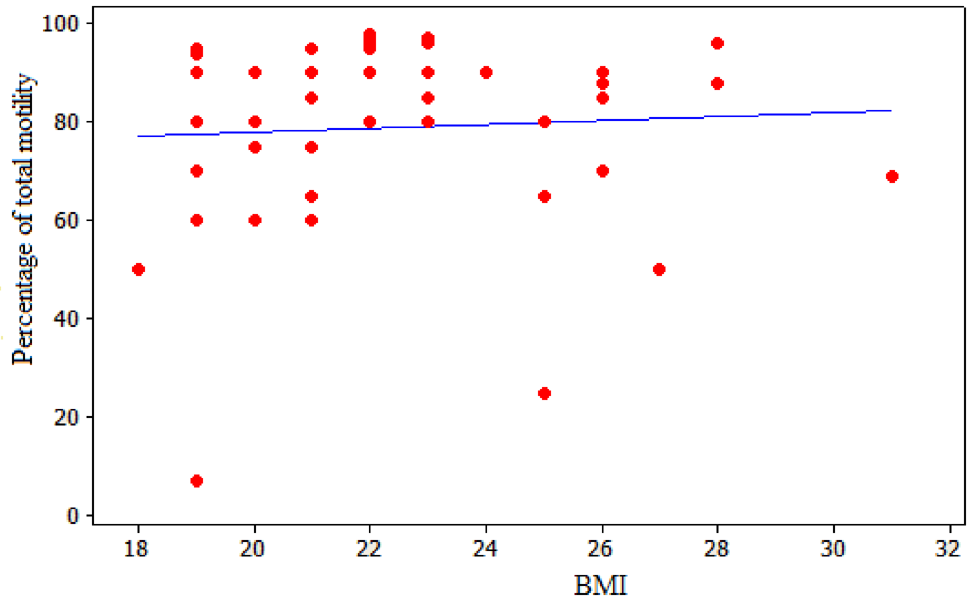

Figure 4.9:- Correlation between BMI of welders and percentage of total motility

Table 4.4: Summary of correlation between socio demographic factors and sperm parameters

Socio demographic factors	**Semen parameters**	**Coefficient of correlation (r)**	**P - value**	**Significance at 95% confidence level**
Age	Volume	-0.04	0.40	NS
	Concentration	-0.23	0.07	NS
	Total motility	0.07	0.32	NS
	Progressive motility	0.13	0.21	NS
BMI	Volume	-0.03	0.42	NS
	Concentration	-0.02	0.45	NS
	Total motility	0.06	0.35	NS
	Progressive motility	-0.06	0.36	NS

NS – Not Significant at $p>0.05$, S – Significant at $p<0.05$

4.4.2 Lifestyle factors and sperm parameters

The life style factors considered in this study of both welders and non-welders were very similar. However the type of underpants was the only observable variable that had a different effect on sperm parameters. When analyzing the effects of underpants on sperm parameters, it was found that there was no significant correlation with colour of underpants or material of underpants. However it was observed that there was a deteriorating tendency of sperm parameters of welders, who regularly wore dark coloured, synthetic underpants, even though it was not very significant (Figure 4.10 – 4.13).

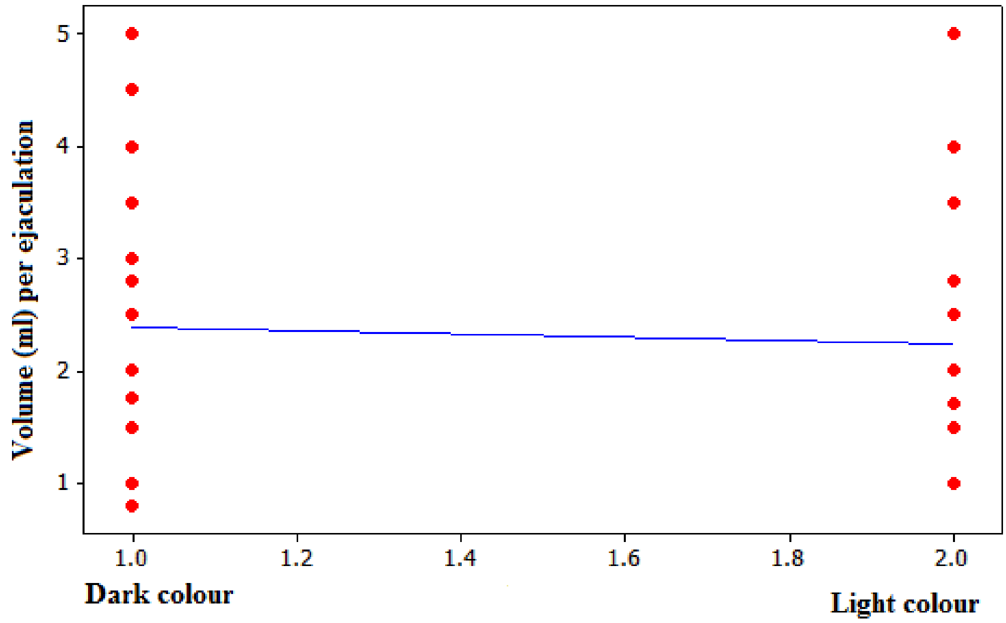

Figure 4.10: Correlation between colour of underpants and volume (ml) per ejaculation

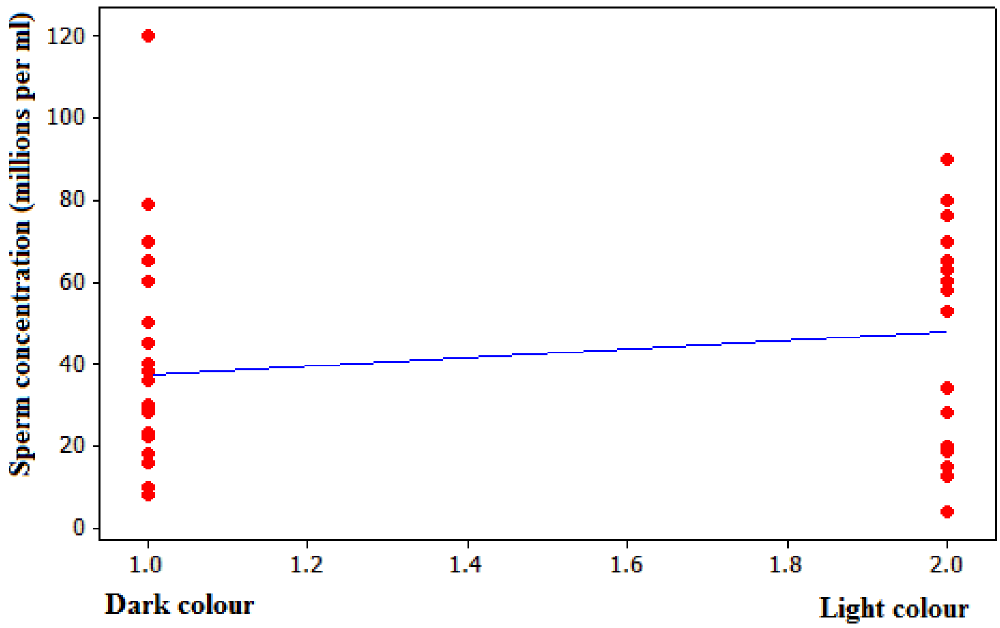

Figure 4.11: Correlation between colour of underpants and sperm concentration

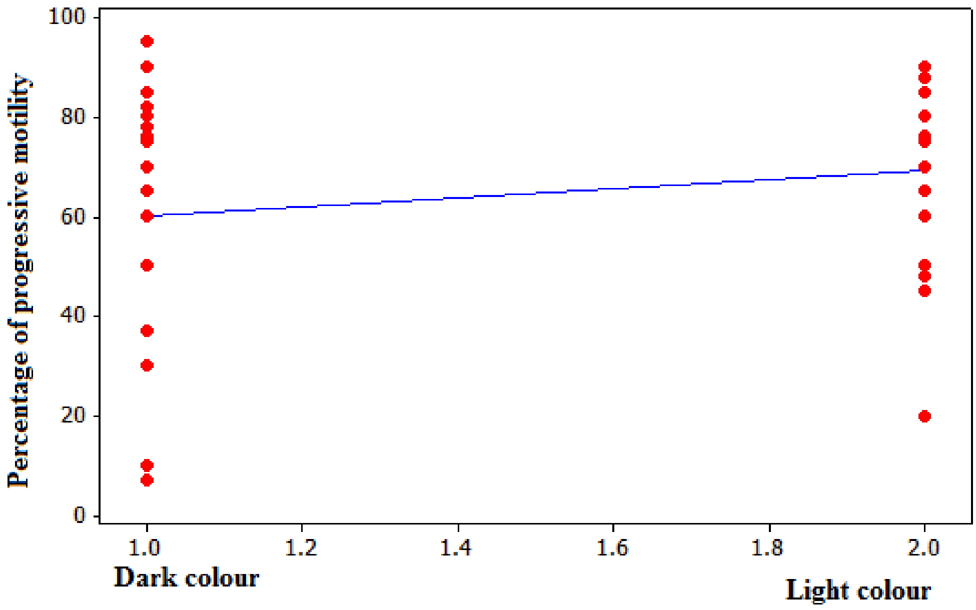

Figure 4.12: Correlation between colour of underpants and percentage of progressive motility

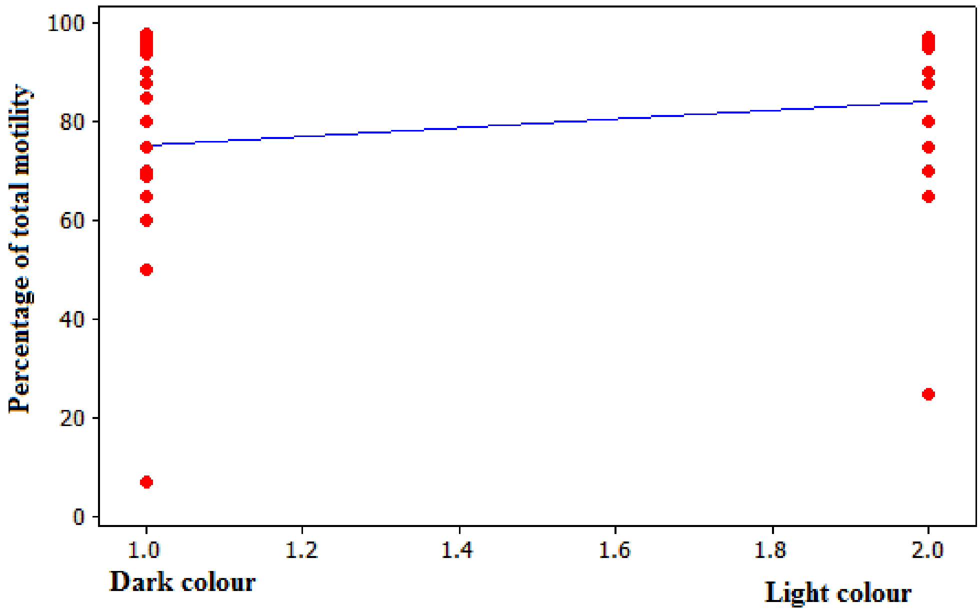

Figure 4.13: Correlation between colour of underpants and percentage of total motility

In contrast a decline in semen volume (r = -0.07, p = 0.33) was seen among the welders who wore light coloured underpants (Figure 4.10). However, an increasing trend of sperm concentration (r = 0.19, p = 0.11) progressive motility (r = 0.21, p = 0.09) and total motility (r = 0.23, p = 0.07) of welders who wear light coloured underpants was observed (Figure 4.11, 4.12 and 4.13).

The material of under garments did not have a significant effect on sperm parameters of welders, but the sperm parameters (volume per ejaculate, count, progressive motility and total motility) of welders who regularly wore cotton underpants seem to be better than those who wore synthetic underpants as shown in the figures [Figure 4.14 to 4.17]. Summary of correlation between lifestyle factors and sperm parameters is given in Table 4.5

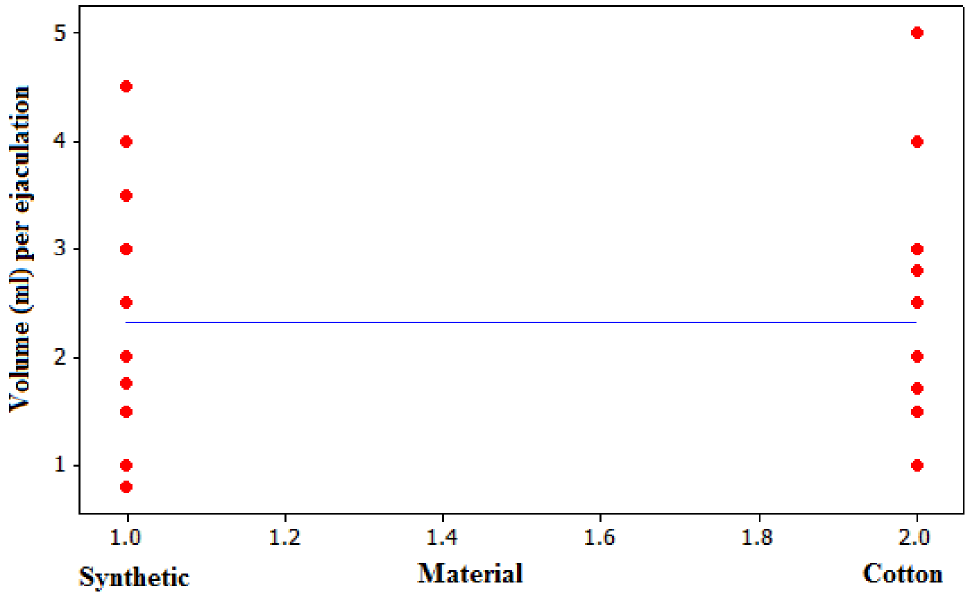

Figure 4.14: Correlation between colour of underpants and volume (ml) per ejaculation

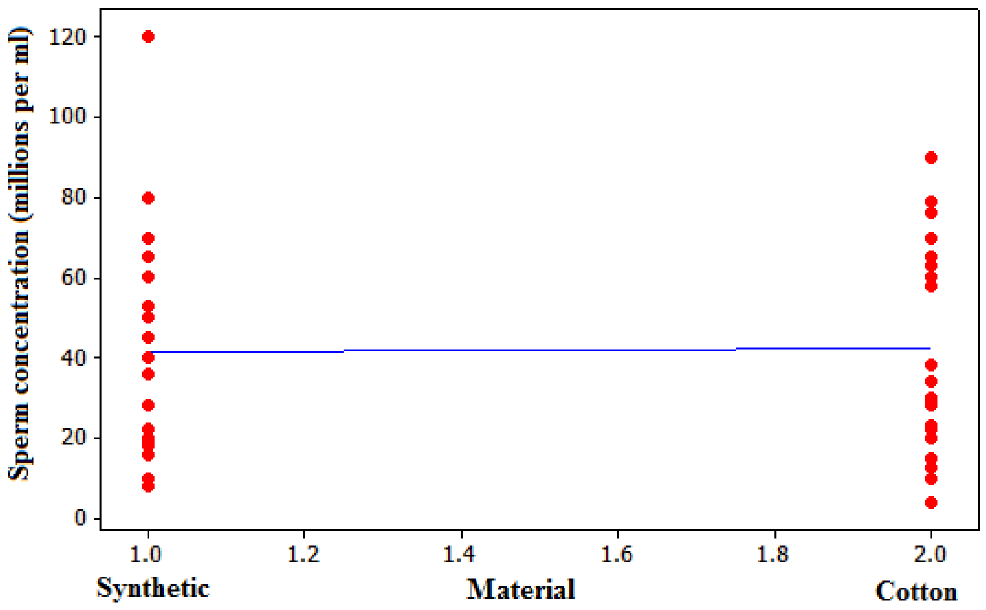

Figure 4.15: Correlation between material of underpants and sperm concentration

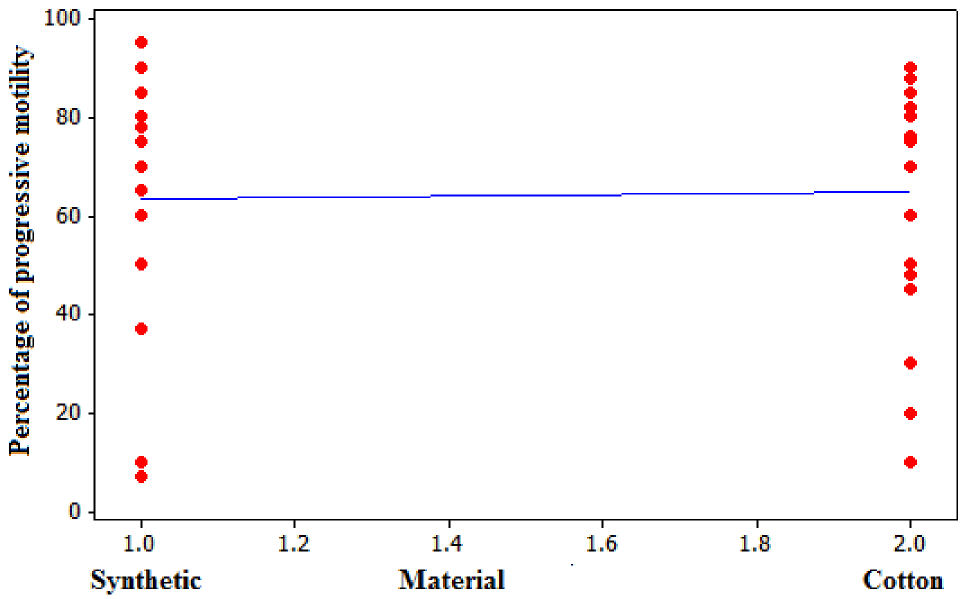

Figure 4.16: Correlation between material of underpants and percentage of progressive motility

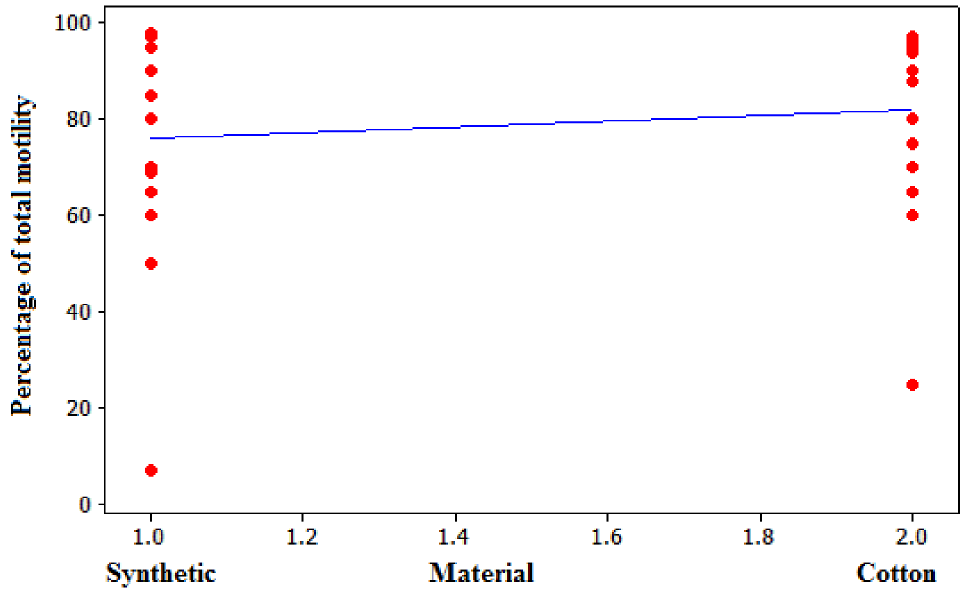

Figure 4.17: Correlation between material of underpants and percentage of total motility

Table 4.5: Summary of correlation between lifestyle factors and sperm parameters

Socio demographic & lifestyle factors	**Semen parameters**	**Coefficient of correlation (r)**	**P - value**	**Significance at 95% confidence level**
Colour of underpants	Volume	-0.07	0.34	NS
	Concentration	0.19	0.11	NS
	Total motility	0.2	0.07	NS
	Progressive motility	0.21	0.07	NS
Materials of underpants	Volume	-0.002	0.5	NS
	Concentration	0.01	0.47	NS
	Total motility	0.16	0.15	NS
	Progressive motility	0.032	0.42	NS

NS – Not Significant at $p>0.05$, S – Significant at $p<0.05$

The tightness of the underpants and the effect on sperm parameters could not be assessed as only four welders reported that they wear tight underpants.

4.4.3 Occupational factors and sperm parameters

Dose exposure to welding and sperm parameters

When analyzing the relationship between dose exposure of welders with sperm parameters, it was found that the volume of semen per ejaculation tend to decrease with increased dose of exposure ($r = -0.115$, $p = 0.459$) [Figure 4.18]. There was no significant linear relation between dose of exposure and sperm parameters.

However a slight positive correlation between dose of exposure with sperm concentration / ml ($r = 0.084$, $p = 0.59$), [Figure 4.19], progressive motility ($r = 0.091$, $p = 0.56$), [Figure 4.20], and total motility ($r = 0.102$, $p = 0.51$) was observed [Figure 4.21].

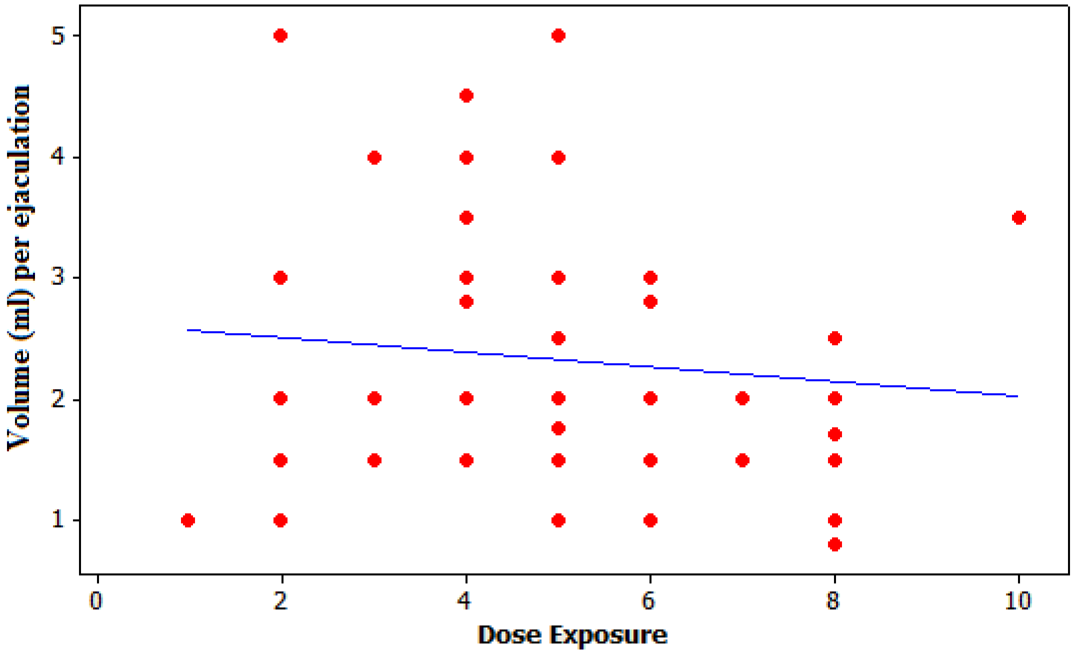

Figure 4.18: Correlation between dose of exposure and volume (ml) per ejaculation

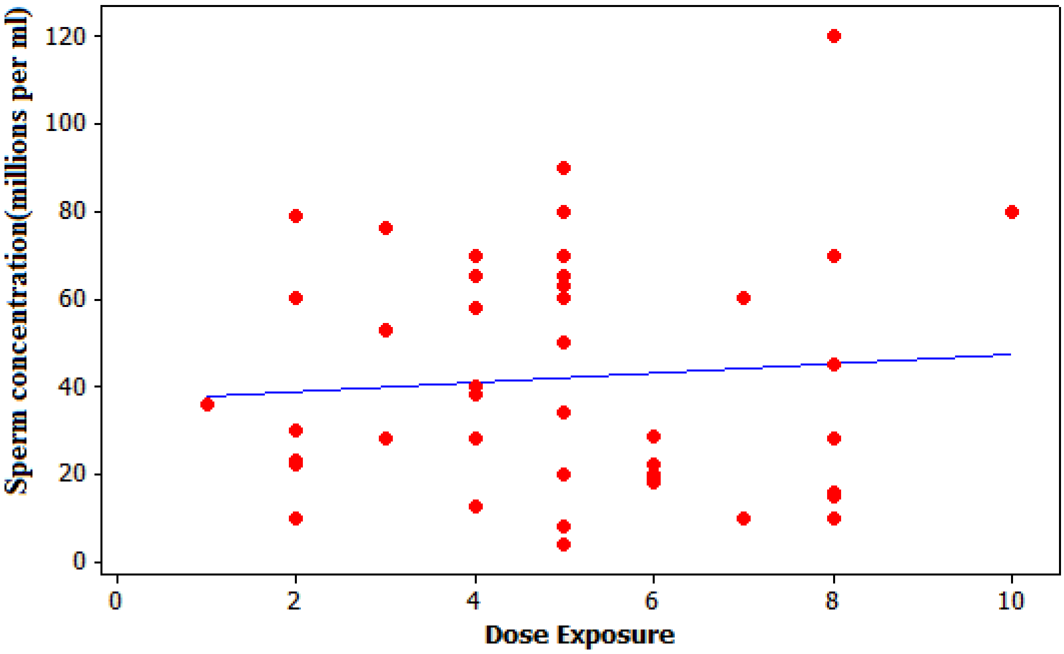

Figure 4.19: Correlation between dose exposure and sperm concentration

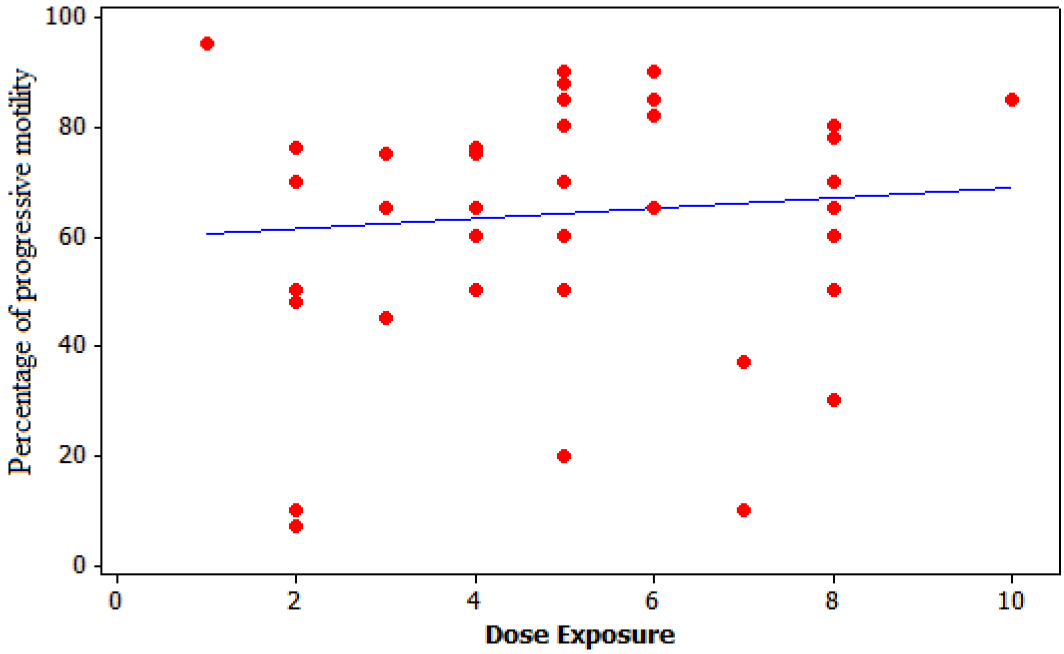

Figure 4.20: Correlation between dose of exposure and percentage of progressive motility

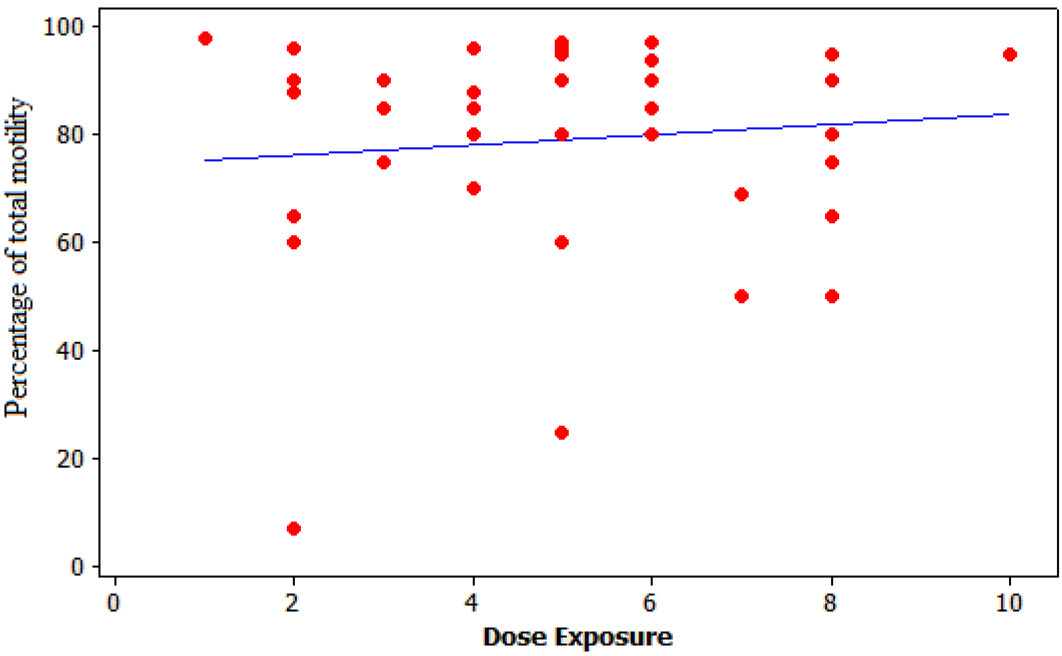

Figure 4.21: Correlation between dose of exposure and percentage of total motility

Total exposure to welding and sperm parameters

When evaluating the association between total exposures to welding emission with sperm parameters, it was observed that there was negative correlation with volume per ejaculation (r = - 0.063, p = 0.683), [Figure 4.22]. Sperm concentration (r = - 0.401, p = 0.007<0.01) [Figure 4.23] and sperm total motility (r = - 0.059, p = 0.7), [Figure 4.25]. Although unexpected there was a week positive correlation with percentage of progressive motility [Figure 4.24] with a correlation coefficient of 0.061

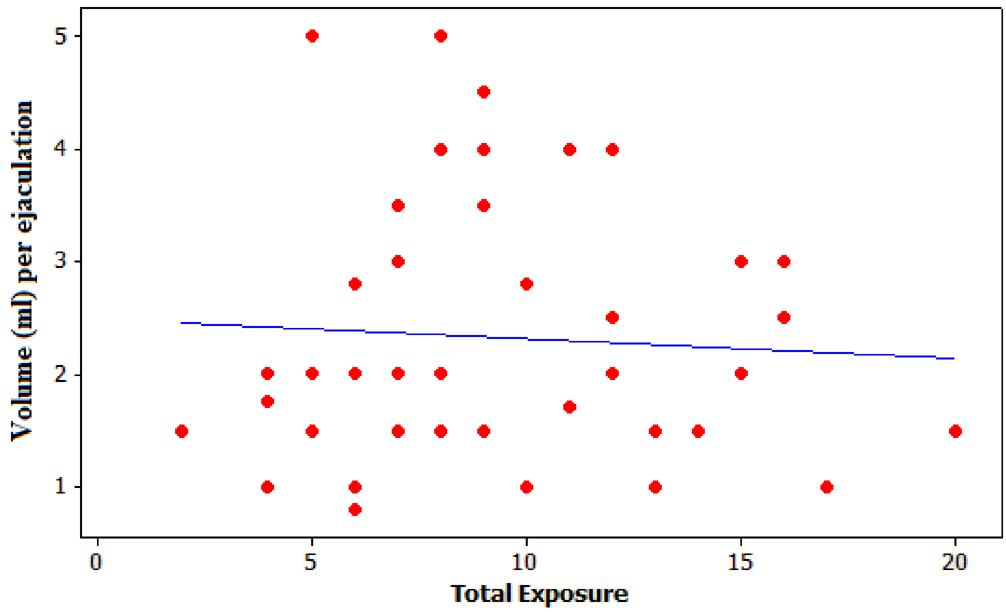

Figure 4.22: Correlation between total duration exposed to welding emission and volume (ml) per ejaculation

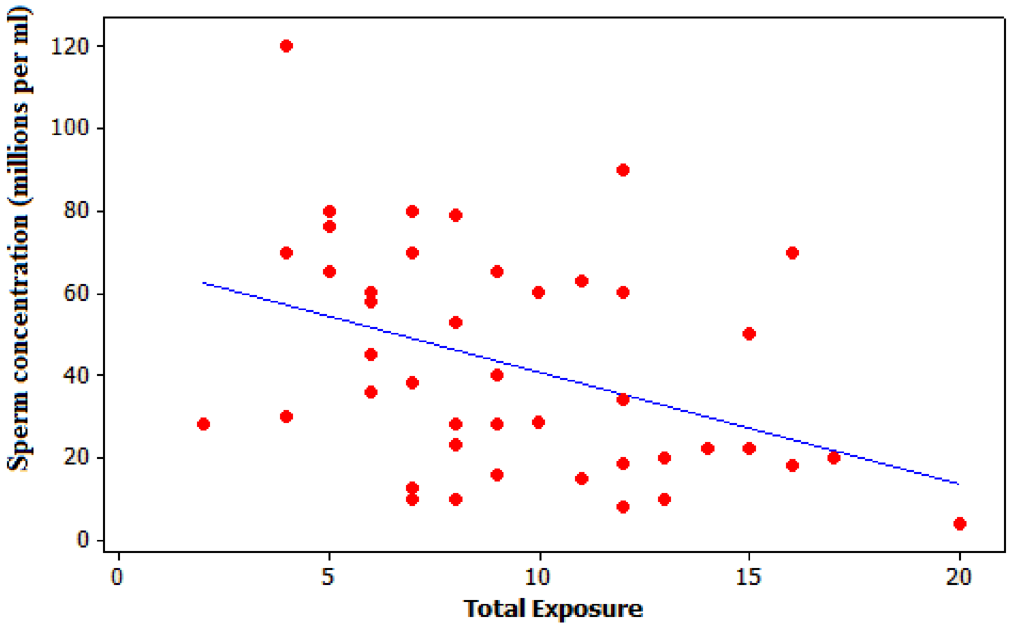

Figure 4.23: Correlation between total duration exposed to welding emission and sperm concentration (millions per ml)

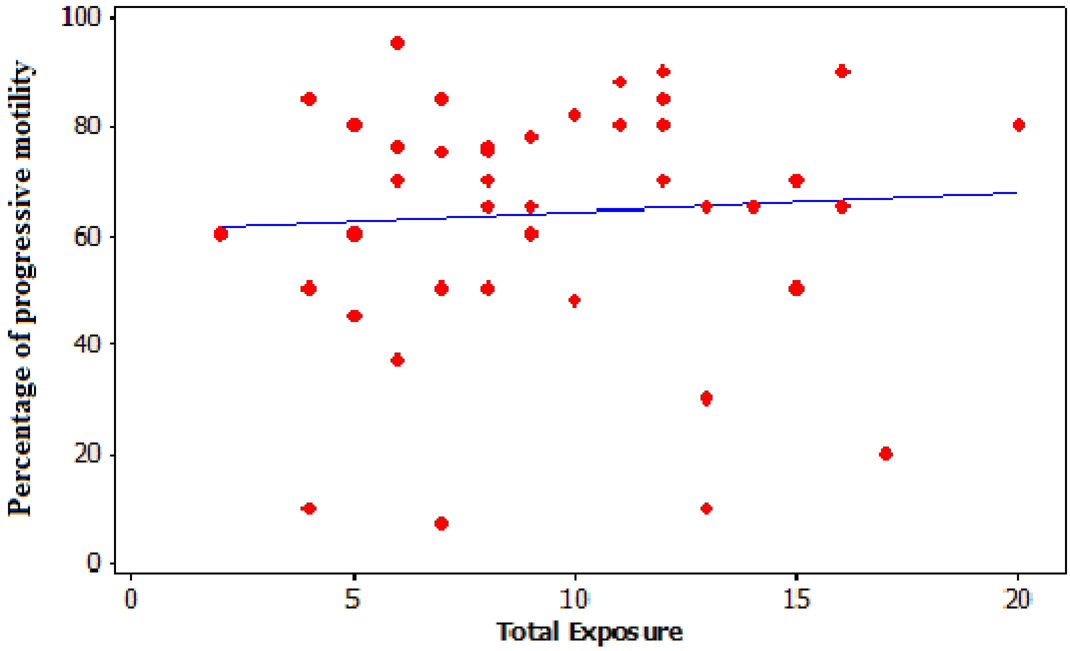

Figure 4.24: Correlation between total duration exposed to welding emission and percentage of progressive motility

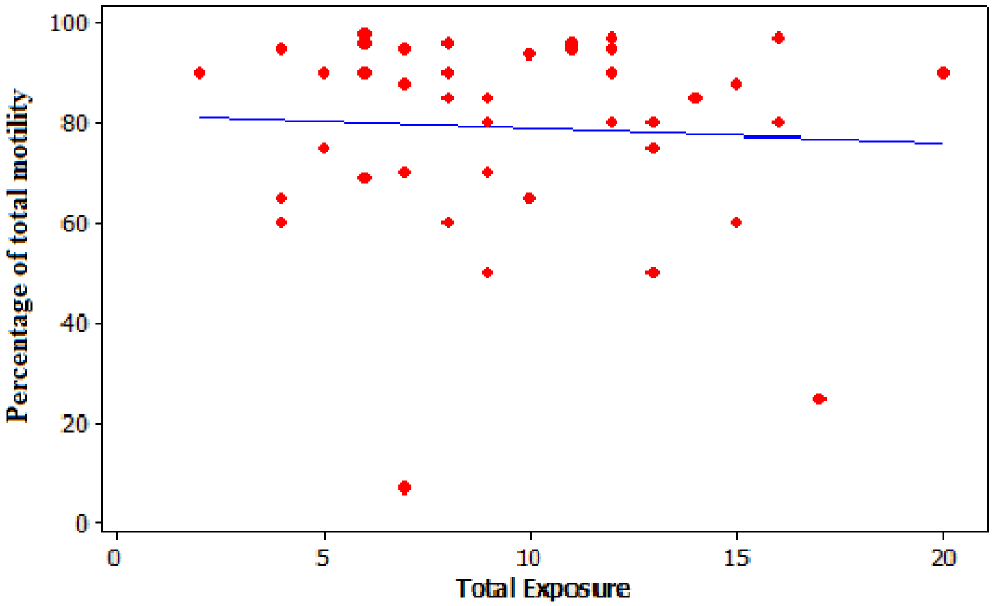

Figure 4.25: Correlation between total duration exposed to welding emission and percentage of total motility

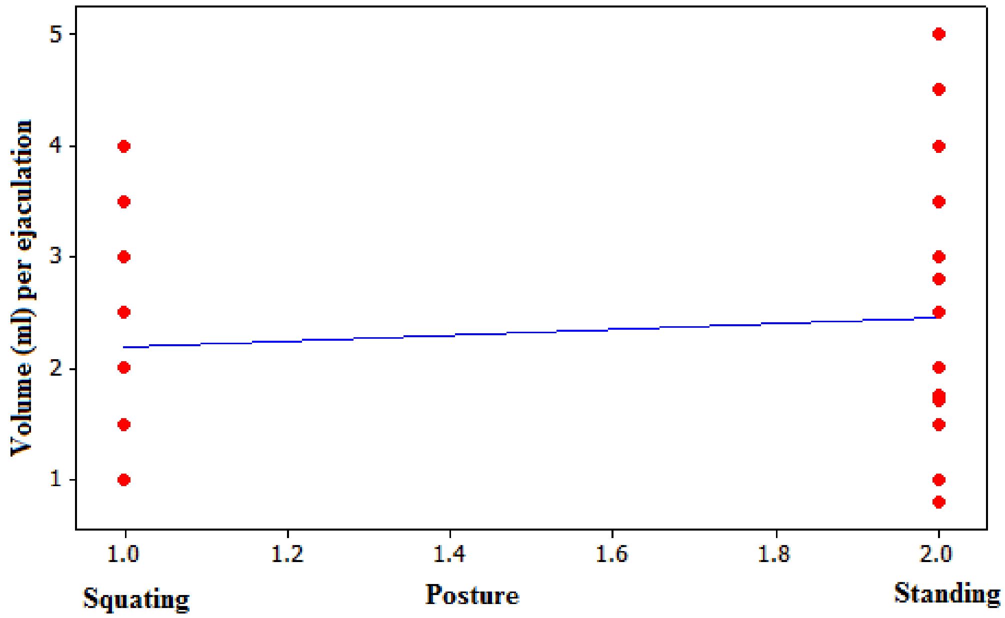

Figure 4.26: Correlation between posture of welders and volume (ml) per ejaculation

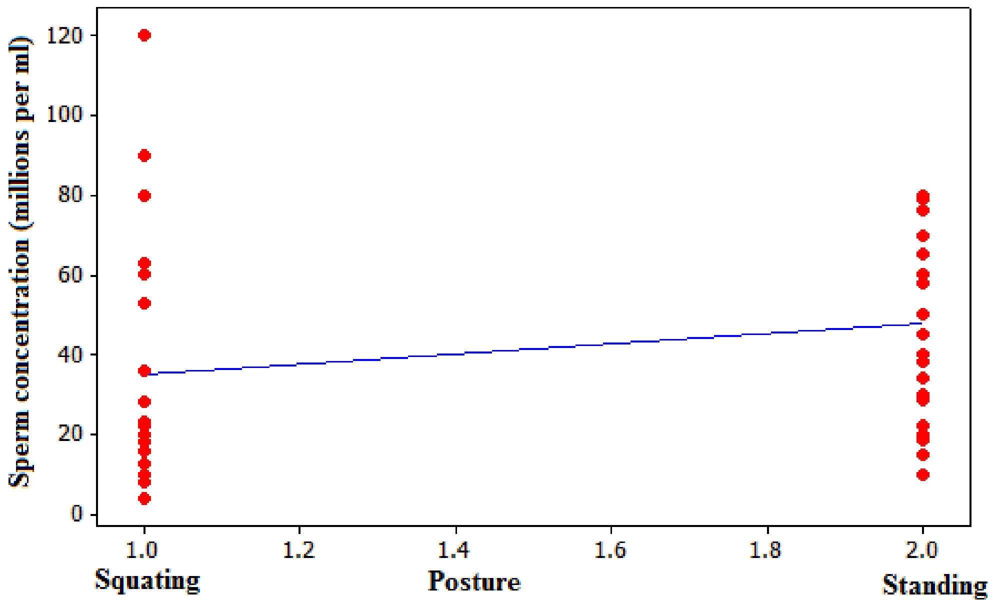

Figure 4.27: Correlation between posture of welders and sperm concentration

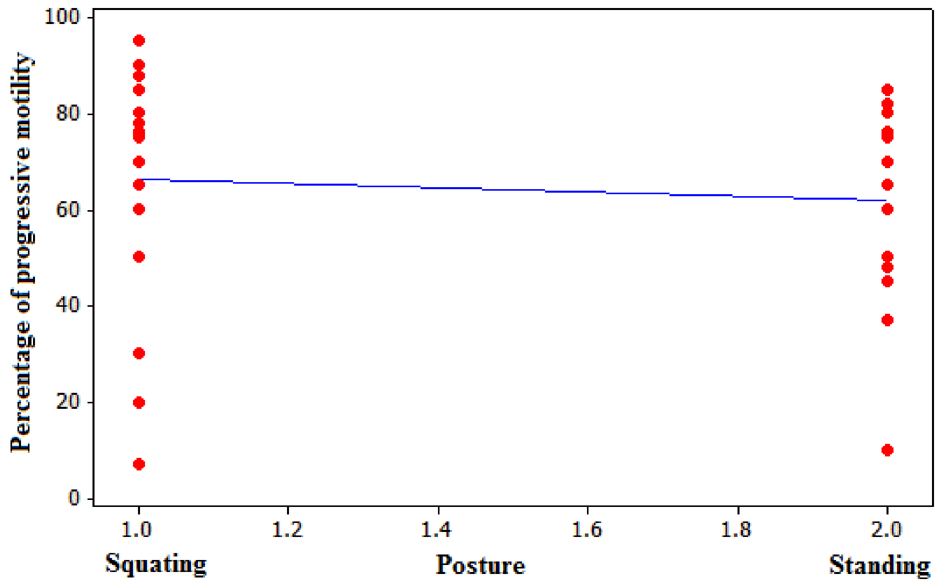

Figure 4.28: Correlation between posture of welders and percentage of progressive motility

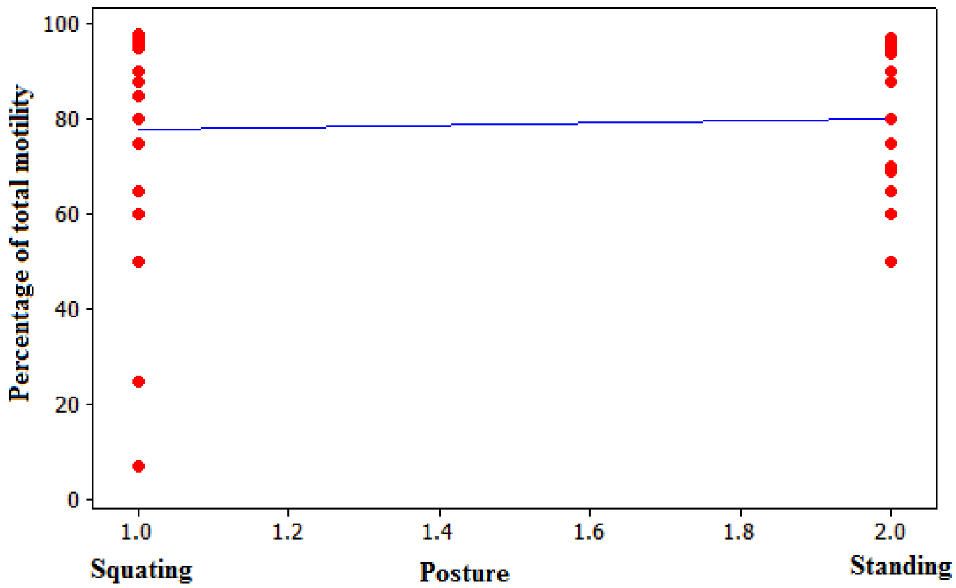

Figure 4.29: Correlation between posture of welders and percentage of total motility

Welding position and sperm parameters

On assessing the correlation between the posture of welders and sperm parameters, it was observed that posture of welders did not have a significant effect on sperm parameters. However a decreasing trend of volume per ejaculation, sperm concentration and total motility, of welders who used to weld in squatting posture was observed [Figure 4.26 to 4.28]. The trend of sperm progressive motility with posture was different as shown in Figure 4.25. Summary of correlation between occupational factors and semen parameters are given in Table 4.6

Table 4.6: Summary of correlation between occupational factors and sperm parameters

Occupational factors	**Semen parameters**	**Coefficient of correlation (r)**	**P - value**	**Significance at 95% confidence level**
Dose exposure	Volume	-0.12	0.46	NS
	Concentration	0.08	0.57	NS
	Total motility	0.1	0.51	NS
	Progressive motility	0.09	0.57	NS
Total duration of exposure (experience)	Volume	-0.06	0.68	NS
	Concentration	-0.4	0.007	Significant at 99% confidence level
	Total motility	-0.06	0.7	NS
	Progressive motility	0.06	0.69	NS
Posture	Volume	0.12	0.23	NS
	Concentration	0.24	0.06	NS
	Total motility	0.06	0.34	NS
	Progressive motility	-0.1	0.25	NS

NS – Not Significant at $p>0.05$, S – Significant at $p<0.05$ in 95% confidence level

Significant at $p<0.01$ in 99% confidence level

Out of 44 welders, 19 had the total duration of exposure more than the mean (9.5 years). In them average daily exposure was 5.5 hours and the mean total duration of exposure was 13.4 years. Of them 26% had abnormal sperm parameters and these sperm abnormalities are illustrated in Figure 4.30.

Of the 44 welders, 25 welders had total duration of exposure less than mean (9.5 years). In them average daily exposure was 4.5 hours and total duration of exposure was 6.6 years. Among them 12% had abnormal sperm parameters and these sperm abnormalities are shown in Figure 4.31.

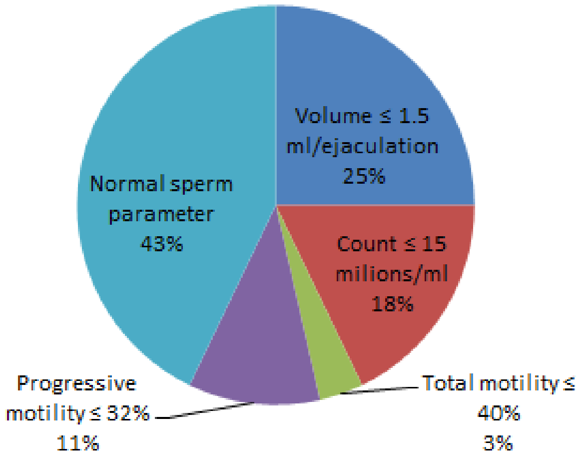

Figure 4.30: Graphical presentation of sperm abnormalities of welders (n=19) with a total exposure more than mean total exposure (=9.5years)

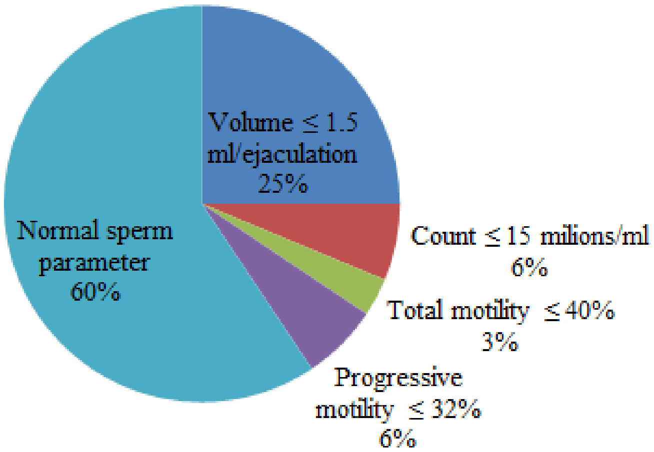

Figure 4.31: Graphical presentation of sperm abnormalities of welders (n=25) with a total exposure less than mean total exposure (=9.5)

5. DISCUSSION

This study was the first research carried out on the sailors of the Sri Lanka Navy engaged in welding. To achieve the objectives of the study two groups of sailors were selected from the SLN base in Colombo, namely those engaged in welding and those doing desk jobs.

The socio-demographic characters and standards maintained during the stay in SLN are similar among all those recruited to SLN. Consequently, the socio-demographical and lifestyle factors among naval sailors involved in welding and those who engaged in desk jobs seem similar in the current study. As evident by the mean age of welders (31years) and non-welders (27years) of this research, all of them were in the reproductive age. The mean BMI of both groups was similar and as expected was well within the normal range. The duration of working experience was greater among the welders and the mean time period taken to have the first child was considerably longer for welders (18.5 months) when compared to non-welders (11 months).

Both welders and non-welders have been abstaining from life style factors which are known to adversely influence fertility such as addiction to alcoholic drinks, smoking, illicit drugs and caffeine containing drinks. Further in the Sri Lanka Navy, it is compulsory to attend regular morning physical exercise on weekdays. A medical staff approved nourishing diet is also provided to all sailors. This probably helped to regain losses and maintain reproductive functions of men including spermatogenesis. Though both groups of welders and non-welders had similar life styles, 41.6% of married welders were infertile according to WHO classification. Occupational factors pertaining to welding may have contributed to their infertility. However, finding the information on the fertility status of their wives was not within the scope of this study.

The workshop where the welders of the current study engages in welding is located in Colombo harbor front, taking the advantage of natural ventilation throughout the year which wipes out both fumes and heat emissions generated during welding. Welding is performed under a shed with low environmental temperature. Although the welders using multiple methods to weld undertake intricate fabrications which are time consuming procedures, the welders who work in the workshop are not exposed to a long period of continuous welding. The average continuous exposure period for a particular job was about 20 seconds in the workshop and another 2-3 minute rest period would be taken, depending on the nature of the job performed. In addition, every welder could obtain 7-8 days of vacation period per month and abstaining from welding during weekends except in case of emergencies. Personal protective equipment (PPE) was also provided to welders to mitigate welding exposure to a certain extent. All welders were aware of the health effects of welding and they were self-motivated to wear PPE. This may have contributed to keep SLN welders out of risk during short term exposure. However, these environmental conditions do not prevail in the shipyard. In contrast the welders who work onboard the ship or at the shipyard have to perform welding continuously and could be exposed to welding emissions more than those in the workshop; especially those who work in confined space are more liable to get exposed to extensive fumes and heat. Though the confined areas of ships are ventilated, accumulation of fumes in spaces cannot be avoided in fully thereby inhalation of toxic gases/fumes cannot be eluded. Further the steel hull of the ship gets heated during the day time because of direct sun rays. As a result, working in ship / ship yard environment may have an influence on the testicular temperature of the welders [46].

All 44 welders except 08 (18.2%) had a sperm concentration above 15 million/ml, which is the cut off value for sperm count (WHO, 2010). In this study the percentage of welders with normal sperm parameters was less than that of the non-welders.

Further the welders had a higher proportion of sperm concentration and motility abnormalities than the non-welders even though there was no statistically significant difference of sperm parameters of welders and non-welders. Thus the abnormalities of semen parameters among welders cannot be ignored. This may be a warning to take additional precautionary measures to protect welders from the effects of welding and time to re-think ways to mitigate welding emissions.

In this there was no significant change in sperm parameters of welders with age because the selected group of welders was in reproductive age and the age range of 11 years, may not be enough to see significant changes in sperm parameters. BMI is reported as an influential factor to reduce sperm quality [44][94][113]. However, this study did not demonstrate a significant effect because that the BMI of the selected group of welders is within the normal range and the range is not enough to see significant changes in semen parameters.

The life style factors of the welders and non-welders were similar in this study. The only factor that seemed to have an effect on sperm parameters was the colour and material of underpants. As shown in the current study the dark coloured synthetic underpants contributed to lower the sperm concentration of welders. This may be related to the poor transmission of heat by dark colors and the synthetic material. Considering this factor, it may be worthwhile to recommend to the welders to avoid dark colours and not to wear synthetic underpants.

Increasing the duration of welding hours per day does not seem to make a significant change in sperm parameters of welders as expected, so it may be argued that a low level of exposure may not contribute to significant changes in the sperm parameters. . In contrast, the present study indicates that there was a significant reduction in sperm concentration of welders with increase in numbers of years of exposure to welding emissions, but motility of sperm was not affected. On analytical comparison of sperm parameters of welders who had total duration of exposure more than the mean total duration of exposure (9.5 years) as in Figure 4.30 and total duration of exposure less than the mean total duration of exposure as in Figure 4.31, it is clear that, long term effects of welding exposure has deteriorated the quality of sperm of welders in SLN. Several studies have shown the relationship between welding emission and sperm quality [117 -122]. Detrimental effects on sperm quality of stainless steel & alloy steel welders exposed to chromium and nickel have been shown as a considerable decrease in sperm concentration and motility, and this decrease correlated with the number of years of exposure to welding fumes [118]. It is also reported that exposure to low level of chromium and nickel did not cause major hazards to sperm production [122]. Further it has been reported that in welders who were exposed to moderate radiant heat, there was no significant decrease in sperm count or motility but the sperm morphology was affected significantly after 6 weeks of exposure to radiant heat [117]. Though, many studies have discussed the effects of welding fumes on male fertility, studies on the relationship of radiant heat on fertility was hardly found, but the effect of temperature on spermatogenesis has been demonstrated in men engaged in occupations which increases testicular temperature [44].

It has been reported that elevation of testicular temperature by 1^0C above baseline depresses spermatogenesis by 14% and 6-8 months of exposure to high temperature leads to an increase in abnormal forms of sperm from 30% to60% [35]. However, this process of radiant heat which increase groin temperature by an average of 1.4^0C leading to decrease quality of sperm is reported to be reversible [54].

In addition to the working environment in ship repair areas the working position may have contributed to lower the sperm concentration of welders with increase in number of years served. The position adopted for welding in the ship was squatting position. Continuous welding in squatting position over a period of time may have affected the sperm parameters of welders due to the effects on the testicular heat exchange mechanism [43 - 46].

Based on the findings of the current study, it can be inferred that extensive exposure to thermal radiation and fumes may have contributed to decrease sperm concentration and motility of SLN welders. However, the results of study showed that the effects are seen with long term exposure, but not with short term exposure.

Effects of thermal radiation on sperm quality have been reported by many, but effects of fumes generated by steel used in SLN have yet to be identified. Therefore, the research should further analyze fume samples to identify the available toxic substances and their effects on sperm quality to obtain comprehensive results. The facility to analyse fumes in SLN was not available.

Although many investigators have reported an effect on sperm parameters on welders, the mechanism by which these changes occur is not clear. However, toxic metals present in the welding fumes or toxic gases emanated or intense heat produced during welding operation or a combination of these may be responsible for the deterioration of the semen quality among the welders.

Among welders in the SLN, improvement of quality of semen can be expected by further mitigation of welding exposure. Fumes and heat generated during welding can be controlled by changing welding process and by improving the ventilation system. Further mitigation of exposure to welding can be achieved by introducing safety policies, rules, suitable working schedules and training the workers to achieve safety goals and creating awareness on the health effects. It can be recommended to the management to initiate better administrative control over the workshop. Management can implement regulations by limiting exposure levels. Job rotation or job sharing is one way by which administrative control can limit the exposure to welding emission. Conducting awareness programs will also enable the welders to take further precautions.

Intensity of fume generation depends on the welding process generation, for example, gas tungsten arc welding or submerged arc welding processes produce very low fume levels, but they have significant process limitations. Gas metal arc welding (GMAW) is also a relatively low fume generation process that has fewer limitations. Each of the emission controlling methods mentioned above can be a part of the solution for a specific application, but each has its own limitations. Isolation of welding process is a possible approach to reduce worker exposure by separating, or enclosing or automating the fume generating source. It is practical to implement an automatic welding process using automation or robotic welding equipment that can be enclosed. However, considering the conditions in the SLN workshop isolation of welding source is not practical and not economical.

Ventilation system affords a range of methods that can be used to control welding fumes. Ventilation methods include natural ventilation, general mechanical ventilation and local exhaust ventilation. Natural ventilation is less controllable and can be a good solution where welding is done outside or in large working areas with high ceilings and cross ventilation. General mechanical ventilation, such as wall or roof exhaust fans, provides general fume removal but is less effective than local exhaust ventilation in the control of individual exposures. Local exhaust ventilation is a very effective alternative for most welding exposure where better control is needed. Some welding consumables that contain toxic elements such as chromium and nickel in stainless steel need low exposure limits, it may require additional ventilation.

In addition, individual welders should make an attempt to protect themselves from welding emissions. Personal protective equipment is the best solution to limit individual exposure. Protective clothing and respiratory equipment must be worn during all welding operations to eliminate inhalation of toxic fumes/gases and prevent the exposure of the body to heat, hot metal particles or arc rays during the process. There are several types of respirators which can be used depending on the environment conditions and process controlling methods. Protective clothing prevents the welder from exposure to heat during welding process.

On the basis of available data, it appears that welding emission cause a considerable effect on sperm count and motility which is more significant with long duration of exposure. However, there is a need to conduct a more comprehensive study of SLN welders.

6. CONCLUSION AND RECOMMENDATION

The current research was done among welders (mean age 30.7 ±3.9) and non-welders (those doing desk jobs) (mean age 27 ± 2.2) in the Sri Lanka Navy base in Colombo. The welders comprised those working in the welding workshop and onboard the ships. The socio demographic and lifestyle factors among the welders and the non-welders were similar. However, the time taken to have the first child among the welders was longer (18.5months) when compared to the non-welders (11 months) and 41.6% of welders were infertile as per WHO classification.

The working hours per day and the protective wear worn during working hours were similar among welders in the workshop and those working in the shipyard. Welders in shipyard however were working in confined space with less natural ventilation although emissions were removed by forced ventilation. Thus the welders in ships were more liable to be exposed to welding emissions than those who weld in the workshop.

Among welders all sperm parameters were normal in 70% when compared to 86% of non-welders. Among welders sperm concentration was abnormal in 16% and sperm motility was abnormal in 11%. In contrast only 7% of non-welders had abnormal sperm concentration and motility was normal in all of them. However, there was no statistically significant difference in sperm parameters between the welders and non-welders.

Short term exposure to welding emission did not have a significant effect on sperm parameters of welders. However, long term exposure to welding emissions had a negative correlation with sperm concentration of welders ($r = -0.4$, $p = 0.007$) but there was no significant effect on sperm motility ($r = -0.06$, $p = 0.7$). Squatting position and wearing synthetic underpants may have contributed to lower the sperm concentration of welders.

The results of the current study conducted among sailors of SLN base in Colombo among welders and non-welders showed that long term exposure to welding emission had a significant effect on sperm concentration but there were no effects on sperm parameters with short duration of exposure. This effect on sperm concentration may be due to the exposure to radiant heat or fumes or combination of both. However, long term studies with larger samples are necessary to come to more definitive conclusions. To identify the effects categorically, analysis of emitted fumes for different toxicants is necessary. Taking maximum possible efforts to mitigate welding emission in SLN workshops and in the ships is recommended to prevent hazardous effects on the reproductive health of welders.

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Appendix - I

DETAILS OF THE PERSONAL'S WHO CONSENT TO PARTICIPATE FOR THE RESEARCH "EFFECTS OF WELDING ON MALE FERTILITY"

Identification No. :-

Personal Details

1. Rate : - ………
2. Date of birth : - ……… 3. Age :-
4. Weight : - ……….. Kg. 5 Height : - ...ft …inch
6. BMI : - ………

7. Residency:-

Urban	
Suburban	
Rural	

8. Marital status:-

Single	
Married	
Divorced	
Separated	
Living together	

9. Date of married:

DD / MM / YY

10. Age to the date of marriage:-

DD / MM / YY

11. Children:-

i. a. Sex :-

Male	
Female	

b. Date of birth

DD / MM / YY

c. Time duration after marriage: - …………

d. ☐ Before ☐ After

Commencement of profession

ii. a. Sex :-

Male	
Female	

b. Date of birth

DD / MM / YY

c. Time duration after marriage:-……………….

d. ☐ Before ☐ After

Commencement of profession

Professional Details

1. Date of enlistment to Sri Lanka Navy

DD / MM / YY

2. Inception of profession as a welder in SLN

DD / MM / YY

3. Professional service in SLN

DD / MM / YY

4. Profession prior to joint SLN : ……………………………………………….

5. Professional service prior to joint SLN

DD / MM / YY

6. Total service as welder

DD / MM / YY

7. Nature of the present duty

Yard	
Workshop	

8. Type of welding

Arc		Gas	
TIG		Multi welding	
MIG		Other	

9. Average time duration exposed to active welding per day: - …………….Hrs

10. Do you use a respirator during welding?

Yes	
No	

11 Type of dust mask if yes:-………………………………..

12. Do you use an apron during welding?

Yes	
No	

13. Type of apron if yes :-……………………………….

14. Normal position of welding:-

Standing	
Sitting/squatting	

Lifestyle Factors

1. Smoking

Yes	
No	

if yes, frequency ……………..

2. Tobacco chewing

Yes	
No	

if yes, frequency ……………..

3. Alcohol

Yes	
No	

if yes, frequency ………………..

4. Use of illegal drugs

Yes	
No	

if yes, frequency ………………..

5. Addiction to beverages containing caffeine.

If yes, frequency: - ………

Yes	
No	

7. Do you attend physical exercise?

Yes	
No	

8. Use of sauna / steam bath

If yes, frequency:-…………

Yes	
No	

9. Food habits……………………………………………………………..……...

………………………………………………………………………………

10 Any chronic disease

Details if yes…………………

Yes	
No	

11. Use of any medication at present

Details if yes…………. ………

Yes	
No	

12. Use of mobile phone

Yes	
No	

13. If yes, where do you keep it?

Shirt pocket	
Trouser pocket	
Other place	

14 Use of cosmetic ……………

Yes	
No	

15. Use of laptop.

Yes	
No	

On lap	
Table	

16. Sleep deprivation ……………

Yes	
No	

17 Any domestic / occupational stress

Yes	
No	

18. Contact with any chemical / solvent

Details, if yes. …………………….

……………………………………………………………………

Yes	
No	

19. Mumps / any viral infection

Yes	
No	

Childhood	
Teenage	
Adults	

20. Prolong bicycling…………

Yes	
No	

21. Family planning…………..

Yes	
No	

Condom	
Drugs	
Natural means	

22. Surgery proceeded on testis

Yes	
No	

23. Details of surgery proceeded, if Yes………………………………………….

…………………………………………………………………………………….

.

24. Cultural belief ………………

Yes	
No	

25. Presence of testis ………

Yes	
No	

26. Un-descended testis

Yes	
No	

27. Fitness of underpants

Normal	
Tight	

28. Colour of unde pants

Dark	
Light	

29. Type of unde pants

Cotton	
Synthetics	
Mix	

30. Working dress………..

Overall	
Other	

31. Colour of working dress

Dark	
Light	

32 Type of working dress

Cotton	
Synthetics	
Mix	

33. Any social transmitted disease

Details, if yes…………………

Yes	
No	

.

34. Masturbation

Frequency………

Yes	
No	

35. Any other information's……………………………………………………….

Appendix-II

Letter of approval received form ethical committee at Kothalawala Defense University

Ethical Review Committee

Faculty of Medicine
General Sir John Kotelawala Defence University
Ratmalana

Tel:+94(0)11-2635268
Fax:+94(0)11-2638660
Email:ethicalreview committee.fomkdu@gmail.com

20/04/2017

Capton (E) NSMDK Nanayakkara
Marine/Mechanical Engineer
Naval Headquarters
Colombo 01.

(RP/2016/18) "The study of the effects of welding on male fertility."

The project proposal submitted by you for ethical clearance under the above title was taken up at the Ethical Review Committee meeting held on the 20th of April 2017. We are pleased to inform you that the committee has decided to grant the ethical approval.

Please submit a progress report on the completion of your research project or at the end of one year after starting the project.

Snr Prof Rohini Fernandopulle
(Chair, Ethics Review Committee)
FOM,KDU.

Appendix - III

51
03 DEC 2014

SLN 121/ 1009

Naval Headquarters
Colombo 1

The Commander Western Naval Area

30th November 2014

TO OBTAIN APPROVAL TO CONDUCT RESEARCH ON THE TOPIC
"EFFECTS OF WELDING ON MALE FERTILITY"
COMMANDER (E) NSMDK NANAYAKKARA, NRE 1009

Reference: Your letter No. CW 51 dated 29th October 2014.

Please inform above named officer that his submission forwarded vide quoted reference is approved.

GL SUBASINGHE
Lieutenant (S) SLN
Aide & Personal Secretary
for COMMANDER OF THE NAVY

Appendix -IV

INFORMATION TO PARTICIPANTS AND CONSENT FORM

SPONSOR:

INVESTIGATOR (Principal and at least one Co-Investigator):

……………………………………………………………………………………………

Name of Participant: ……………………………………………………………….

Title: study to determine the effects of welding on male fertility

1. You are invited to take part in this research study. The information in this document is meant to help you decide whether or not to take part. Please feel free to ask if you have any queries or concerns. You are being asked to participate in this study being conducted in … … … … … …. …. ………………. (Name of the institution) because you satisfy our eligibility criteria which are:

   (1) Identified as occupational welder (or working at office or workshop without exposing to welding) in Sri Lanka Navy.

   (2) You are exposure to welding (or working at office/workshops without exposing to welding) more than 03 years.

   (3) Age between 23 to 36 years.

You will be one of the ….. (give total number of participants to be enrolled in the study*)* participant we plan to recruit in this study. You will be assigned to either of the two study groups. One group of participants (those who will not be exposed to welding) will be tested as a control group while other group of participant (occupational welders) will be the subject group. Investigations and sample testing will be conducted at the Naval General Hospital – Colombo with the approval of the Commander of the Navy.

2. What is the purpose of research?

The purpose of this study is to evaluate the relationship between male fertility and exposure to welding emission. Discussion made with infertile male welders, who exposed to welding emission long period discovered that a conceptual idea has been established amongst them that the infertility caused by the long term exposure to welding emissions. However it is very hard to find a research in Sri Lanka context to support or expel this concept amongst the welders. Therefore this study will assist to evaluate the so called relationship and to take actions to mitigate exposure.

3. The study design

All participants in the study will be divided into two groups. You will be assigned to either of the two groups. One group is the subject group, composed with welders and the other group is the control group, consist of personals, who will not be exposed to welding. Each participant has to give semen sample thrice at the laboratory of Naval General Hospital – Colombo. Second sample of semen will be tested after six month in case of any abnormalities are found in the first. Third sample of semen will be received in any abnormalities found in the second sample. Healthy personals will be selected for the control group and their SFA parameter will be kept as a reference value to compare with the subject group.

4. Study Procedures

Semen will be collected by self-masturbation into an approved sterile container, at the laboratory of Naval General Hospital – Colombo. Participants should be abstained from ejaculation for 3 -4 days before providing the semen. The fresh semen sample will be incubated for 30 min at 37°C for liquefaction and routine semen fluid analysis (**SFA**) will be performed according to WHO standards to measure volume, sperm Count /ml/10^6, total motility, and total morphology. Obtained sample will be undergone investigation for approximately 02 hrs. You can collect the sample after the test if not the sample will be washed out as routine procedure by the laboratory staff.

Once you are enrolled in the study, you will be required to follow the instructions given below.

(1) Taking of any medication prescribed by the physician

(2) Change of any lifestyle factors [diet / take the drugs as instructed and detailed on the envelope / avoid alcohol / smoking / any other precautions].

(3) Taking any medications other than the ones prescribed by your physician. If you need to take some treatment (drug / physiotherapy / other), you must inform your investigator before taking that treatment

5. Preparation for Semen Analysis

The laboratory technician will let you know what you should do in preparation for the semen analysis. It’s very important to follow these instructions to get the best sample for accurate results

- Refrain from any sexual activity, including masturbation, for 3 to 4 days before the test. Longer or shorter periods are also not recommended.
- Avoid alcohol, caffeine, and drugs such as cocaine and marijuana two to five days before test
- Stop taking any herbal medications, what you have already declared to the investigation team
- Avoid any hormone medications
- Give the specimen directly to the laboratory staff or the receptionist to ensure immediate attention.
- Discuss any medications you’re taking with your investigator team, if any.

6. Possible risks to you

The study team expects only semen samples from you for the analysis and you will not be given any medications for the study. Certain emotional and physical discomfort risks may be associated with the collection of semen samples by masturbation, unless other than that there is no any potential risk involvement of taking semen samples for this study.

7. Possible benefits to you

You will be able to get following benefits on this research study.

(1) Free investigation of your semen samples and get to know the quality of your semen sample

(2) At the end of the study you may be able to know, that any effects of welding emission on your fertility.

8. Compensation

You will not receive any compensation for the inconvenience and travel. You will be provided only transport facilities. You will also benefit from being on this research study in terms of free investigations/tests. Additionally participants will be provided medical facilities in case of any risk involvement observed during the period of research

9. Possible benefits to the institution and other people

The results of the research may provide benefits to the institution & society in terms of advanced knowledge of welding technology and how to mitigate welding emissions. The results of the study may further support to change the working environment and lifestyle of occupational welders to ensure health and wellbeing

10. Cost to the participant

You will not be required to pay for the semen sample analysis. You will be provided transport facilities to travel from your workstation to Naval General Hospital – Colombo to participate the research study.

11. Who is paying for this research?

Sri Lanka Navy is the sponsors of the study and are providing laboratory facilities at the Nava General Hospital - Colombo for the research. The investigator or any of his/her team member or any participant for the study does not receive any direct payment from the sponsor.

12. Confidentiality of the information obtained from you

You have the right to confidentiality regarding the privacy of your information (personal details, occupational details, lifestyle and results of semen analysis). By signing this document, you will be allowing the research team investigators, other study personnel, sponsors, institutional ethics committee and any person or agency required to view your data, if required. The information from this study, if published in scientific journals or presented at scientific meetings, will not reveal your identity.

It is ensured that only research team will have access to review your personal data obtained through questioner. It is further confirmed that the details of semen analysis will not be reflected identification of the participant whilst dissemination of study finding through a research paper or journal or any publication

13. How will your decision to not participate in the study affect you?

Your decision not to participate in this research study will not affect your relationship with the investigator or the institution. You will further not lose any benefits to which you are entitled.

14. Can you decide to stop participating in the study once you start?

The participation in this research is purely voluntary and you have the right to withdraw from this study at any time during the course of the study without giving any reasons. However, it is advisable that you talk to the research team prior to stopping participation. However it is not mandatory to give reason for withdrawing.

15. Can the investigator take you off the study?

You may be taken off the study without your consent if you do not follow instructions of the investigators or the research team or if the investigator thinks that further participation may cause you harm.

16. Right to know information

The obtained results will be disclosed to any participants on their personal request.

17. Right to new information

If the research team gets any new information during this research study that may affect your decision to continue participating in the study, or may raise some doubts, you will be told about that information.

18. Contact persons

For further information / questions, you can contact us at the following address:

Principal Investigator:

Captain (E) N.S.M.D.K. Nanayakkara Ph 071 822 3860

Dept. of Marine Engineering, Sri Lanka Naval Headquarters, Colombo 01

Email: kapila1009@gmail.com / kapila1009@navy.lk

Co-Investigator

Dr. H.K.G Punchihewa, Ph. 071 622 0236

Dept. of Mechanical Engineering, University of Moratuwa, Katubedda, Moratuwa.

Email: hkgpunchihewa@gmail.com Fax: +94 11 2650622

Contact Person(s):

Captain (E) N.S.M.D.K. Nanayakkara Ph 071 822 3860

Dept. of Marine Engineering, Sri Lanka Naval Headquartes, Colombo 01

Email: kapila1009@gmail.com / kapila1009@navy.lk

PARTICIPANTS CONSENT FORM

[Title of the study]

Name of the participant: ____

Name of the Principal (Co-) Investigator: ________________________________

Name of the Institution: ____

Name and address of the sponsoring (funding) agency (ies): _________________

____

Documentation of the informed consent

I… ……………………………………………………………….have read the information in this form (or it has been read to me). I was free to ask any questions and they have been answered. I am over 18 years of age and, exercising my free power of choice, hereby give my consent to be included as a participant in "………...

… … … … … … … … … … … … … … . … … … … … … … … … … … … … …
" (title of the study)

(1) I have read and understood this consent form and the in formations provided to me.

(2) I have had the consent document explained to me.

(3) I have been explained about the nature of the study.

(4) My rights and responsibilities have been explained to me by the investigator.

(5) I have been advised about the risks associated with my participation in the study.

(6) I have informed the investigator of all the treatments I am taking or have taken in the past… … . months including any *desi* (alternative) treatments.

(7) I agree to cooperate with the investigator and I will inform him/her immediately if I get any medical treatment during the study period

(8) I have not participated in any research study within the past … .. month(s).

(9) I am aware of the fact that I can opt out of the study at any time without having to give any reason and this will not affect my future.

(10) I am also aware that the investigators may terminate my participation in the study at any time, for any reason, without my consent.

(11) I hereby give permission to the investigators to release the information obtained from me as result of participation in this study to the sponsors, regulatory authorities, Government agencies, and ethics committee. I understand that they may inspect my original records.

(13) My identity will be kept confidential if my data are publicly presented.

(14) I have had my questions answered to my satisfaction.

(15) I have decided to be in the research study.

I am aware, that if I have any questions during this study, I should contact at one of the addresses listed above. By signing this consent from, I attest that the information given in this document and the consent form has been clearly explained to me and apparently understood by me. I will be given a copy of this consent document.

For participants

Name and signature / thumb impression of the participant (or legal representative if participant incompetent):

……………………………….…………… (Name) ………………………….. (Signature)

Date: ………………………….. Time: …………….

Name and signature of impartial witness (required for illiterate patients):

……………………………………………… (Name) ……………………………. (Signature)

Date:…………………………… Time: ………………………….

Address and contact number of the impartial witness:

……………………………………………………………………………………………

and signature of the Investigator or his representative obtaining consent:

…………………………………………….. (Name) ………………………………… (Signature)

……………………………………….. (Date)

Investigator Certificate

I certify that all the elements including the nature, purpose and possible risks and benefits of the above study as described in this consent document have been fully explained to the subject. In my judgment, the participant possesses the legal capacity to give informed consent to participate in this research and is voluntarily and knowingly giving informed consent to participate,

Signature of the Investigator: ________________ Dated: __________

Name of the Investigator: ___________________