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IMPACT OF OBESITY ON SEMEN ANALYSIS PARAMETERS

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LIZLE OOSTHUIZEN

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SUPERVISORS: PROFESSOR S. DYER & DR. L. WALMSLEY

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1. INTRODUCTION AND BACKGROUND TO STUDY

In current practice, the diagnosis of male infertility is largely dependent on semen analysis parameters. The World Health Organisation (WHO) recommends laboratory standards for the diagnosis of subfertility or infertility. These guidelines are periodically reviewed and updated. Semen parameters, such as motility, morphology, count and concentration, can be used to assess the quality of semen and to predict fertility potential (*Cooper et al., 2010*).

Although female factors account for the majority of cases of infertility, global data estimates that in up to 35% of infertile couples, a male factor can be demonstrated (*Jungwirth et al., 2013*). Local data suggests male factor infertility accounts for 21% of all cases (*Chigumadzi et al., 1998*). A normal semen analysis does not guarantee fertility, yet it remains the most accessible clinical format for assessing male factor subfertility and is considered the gold standard for this diagnosis (*Sermondade et al., 2013*).

There are many known causes of male factor infertility. Among these, lifestyle factors such as obesity have been the focus of much research. If obesity is identified as causal to infertility, it represents a potentially modifiable risk factor. This has important implications especially, but not only, for lower socio-economic communities with restricted access to infertility treatments. The European Society for Human Reproduction and Embryology task force on ethics and law recommends weight loss as part of fertility treatment in women, but as yet has not made any recommendations for men (*Dondorp et al., 2010*). Extensive conflicting international data exist, but there is little published data focusing on the South African context.

The WHO classifies body weight according to the body mass index (BMI). BMI is calculated by a person's weight in kilograms divided by their height in meters squared. A BMI of less than 18.5 kg/m² is defined as underweight, 25 to 29.9 kg/m² as overweight, and over 30 kg/m² as obese (*World Health Organisation, 1997*). A healthy BMI range is between 18.5 and 24.9 kg/m².

When men in Khayelitsha, South Africa, were surveyed, 30% were found to be overweight or obese (*Case et al., 2009*). Similarly, the 1998 South African Demographic Health Survey found that 21% of South African men were overweight and a further 7% were obese (*Puoane et al., 2002*). Of concern is more recent data, in which South African men were found to have a 39% prevalence of being overweight and 14% prevalence of obesity (*Ng et al., 2014*).

This study aims to address the lack of data on the link between BMI and infertility in the South African population by describing the prevalence of male overweight and obesity in a group of men undergoing infertility investigation, as well as assessing any semen analysis abnormalities in these groups. It also aims to describe how well men can predict their BMI category and determine whether weight loss would be an acceptable part of infertility management in overweight or obese male partners. Beliefs surrounding healthy weight and fertility will also be addressed.

2. LITERATURE REVIEW

2.1 PREVALENCE OF OBESITY AND SELF-PERCEPTION OF WEIGHT

The Institution for Health Metrics and Evaluation at the University of Washington recently published a study evaluating the global change in prevalence of overweight and obesity from 1980 to 2013 (*Ng et al., 2014*). A systematic analysis of data trends from 1 769 studies in 188 countries showed a global increase in the prevalence of overweight males from 28.8% to 36.9%. In this study, South African men were found to have a 39% prevalence of being overweight, and 14% prevalence of obesity.

This is an increase from the 1998 South African Demographic and Health Survey, which found 28% of men could be classified as obese or overweight (*Puoane et al., 2002*). When divided into racial groups, white males had a higher prevalence of being overweight or obese (54.4%) in comparison to black males (25%). A rural environment and younger age were seen to be protective.

A survey from 2004-2005 of 500 randomly selected households in Khayelitsha, including 975 adults, assessed BMI differences between age groups and genders (*Case et al., 2009*). Of the 417 men surveyed, 30% were found to be overweight or obese. Participants were asked about perception of both their current and ideal body image. Interestingly, men were found to underestimate their body weight and expressed a wish to gain further weight.

Conflicting results were found in Kenya in a study conducted on 4 934 adults (*Ettarh et al., 2013*). A lower rate of overweight or obesity was found (17.3%). A large proportion of men with a normal BMI felt that they were overweight (15%) or obese (13%). Twenty percent of men indicated an obese image as their ideal body size. The authors did not find cause for this. They hypothesised that this may be due to a cultural belief that associates obesity with health and wealth.

An American study of African-American college students assessed body image perception in male graduates (*Gross et al., 2005*). Of the obese male group, only 39% perceived themselves as obese, while 63% of all males expressed body dissatisfaction. The application

of this sample to our study population is limited by the younger age and American context, but does suggest many men may underestimate their body weight category.

The above literature illustrates that while obesity rates are increasing both locally and globally, very little is known about how South African males perceive their body image. There is no description, to the author's knowledge, of the prevalence of obesity in men presenting to infertility units in South Africa.

2.2 SEMEN ANALYSIS AND OBESITY

Extensive research has been done to evaluate the possible impact of body weight on male fertility. This varies from large epidemiological studies extracting data from existing databases, to observational studies assessing patients presenting to infertility clinics. More recently, large meta-analyses have been conducted. Despite the large pool of data, no consensus has been reached.

2.2.1 EPIDEMIOLOGICAL STUDIES

Several epidemiological studies have fuelled the argument for a link between the prevalence of both overweight and obesity in men and infertility. *Sallmén et al. (2006)* used the data collected in the Agricultural Health Study (United States of America) to show that male obesity is associated with infertility. The study population consisted of 52 395 certified pesticide applicators and their spouses. Infertility was defined as more than 12 months of attempted conception within the four year study period, regardless of final conception outcome. The authors demonstrated an adjusted odds ratio of 1.12 (CI 95%, 1.01-1.25) of infertility in overweight men. They found a dose dependant relationship, with maximal effect at a BMI of 32-43kg/m². This study provided the initial compelling evidence, but it has subsequently been heavily criticised. The infertility rate in this population was 28%, and despite being attributed by the authors to an increased sample mean age over 30, the use of pesticides in this group cannot be overlooked. Female causes of infertility were not excluded. BMI was self-reported, and may not have been the same at the time of infertility as at the time of data collection.

Ramlau-Hansen et al. (2007) extracted data from the Danish National Birth Cohort, consisting of 47 835 women and their partners. They demonstrated that overweight male partners (BMI 25-29.9 kg/m²) had an infertility odds ratio of 1.15 (95% CI 1.09-1.22), and obese partners (>30 kg/m²) had an odds ratio of 1.49 (95% CI 1.34-1.64). The authors defined infertility as any period of twelve months with unsuccessful attempted conception within the study period. The birth registry only documents live births. This therefore excluded all couples who failed to conceive at all during the study period, as well as those who did conceive but miscarried. BMI was reported two years after the attempted pregnancy. Women with known causes of infertility were excluded, but this would have been dependent on the woman involved seeking medical treatment and obtaining a diagnosis.

Nguyen et al. (2007) conducted the Norwegian Mother and Child cohort study, a secondary analysis of a Norwegian database. Using data from 26 303 women and their partners, they found that overweight men had an infertility odds ratio of 1.19 (95% CI 1.03-1.62), and obese men an odds ratio of 1.36 (95% CI 1.12-1.62). A dose-response relationship was also demonstrated, with a plateau over a BMI of 35 kg /m². Women reported their partners' BMI, and infertility was defined as greater than 12 months to time of pregnancy (resulting in live birth). This study was criticized for the use of self-reported BMI and definition of infertility in terms of live birth outcomes. The partner's BMI was documented at the time of pregnancy, but not during the time of subfecundity. The authors conducted a small validity study which showed good correlation between the partners' reported BMI and actual BMI. Factors known to affect female fertility were not corrected for. The documentation of coital frequency did show that the association between male infertility and obesity is not solely explained by sexual dysfunction.

The findings of these studies have been summarized in Appendix A on page 47.

2.2.2 INFERTILITY CLINIC COHORT STUDIES

Several studies of couples presenting to infertility clinics have shown a link between male obesity and infertility. *Magnusdottir et al., (2005)* documented a three times higher incidence of male obesity in patients with male factor subfertility. Seventy-two male

partners presenting to infertility clinics were divided into three groups: male factor subfertility, idiopathic subfertility, and female factor subfertility. The authors' primary objectives were to compare levels of polychlorinated biphenyls and organochlorine pesticides in plasma and semen to assess environmental impact on fertility.

Another study classified men presenting to an infertility clinic into non-obstructive azoospermia, oligoasthenospermia, and normozoospermia (*Zorn et al., 2006*). The BMI of the men in these groups was then correlated, and found to be, on average, 27, 26, and 25 kg/m² respectively. They demonstrated an insignificant increase in BMI among men with non-obstructive azoospermia relative to normozoospermic men. These values were all within the same overweight BMI category, and are therefore of little clinical significance.

The findings of these studies have been tabulated in Appendix B, on page 48.

2.2.3 STUDIES REVIEWING SEMEN ANALYSIS PARAMETERS

Before discussing the literature, it is important to distinguish between sperm concentration and total sperm count as reported in many studies. Concentration is a measure of spermatozoa, in millions per millilitre. Total count is a measure of spermatozoa in millions per ejaculate. The WHO has changed their lower reference limits five times since 1980. We currently use the guidelines set in 2010 (Appendix C, page 49). Many studies have used former guidelines, as were applicable at the time. These discrepancies will be highlighted where relevant. A table with all the results of cited studies' have been included for ease of reference. This can be found in Appendix D on page 50.

Research examining the relationship between obesity and semen quality has provided conflicting results. In one of the most frequently cited studies, *Jensen et al. (2004)* assessed 1 558 Danish military recruits. BMI was directly measured. The participants were subjected to a questionnaire and a physical examination. After correcting for diseases of reproductive organs, they found that men with a BMI >25 kg/m² had a 21.6% decrease in their sperm concentration, when compared to normal-weighted counterparts (no odds ratios published). Total sperm count was also reduced by 23.9%. The actual values were however not below the WHO lower reference limits.

No link between BMI and sperm motility, volume, or morphology was found. An analysis of sperm morphology is difficult due to the high inter-individual variability observed and a lack of standardisation. *Jensen et al. (2004)* applied strict WHO criteria and used only one investigator to analyse the morphology in all of their samples. No relationship was found between morphology and an increasing BMI. This was despite higher reference values having been used, as per previous WHO guidelines.

Another well cited study assessed anthropometric measures of male partners instead of BMI (*Fejes et al., 2005*). The study included 81 couples presenting to an infertility centre. The men were subjected to a detailed questionnaire, a medical examination and endocrine testing. This was done in order to exclude men with an undiagnosed cause of secondary infertility. Two semen samples, taken three weeks apart, were collected and the best result was used. This has been criticized as masking the significant sperm quality differences between weight groups (*Hammoud et al., 2008*). The sperm concentration was negatively correlated (weakly) with hip circumference. Total sperm count also correlated negatively to hip circumference, weight, and waist circumference. Since weight is only relevant when defined in terms of BMI, these findings are of questionable clinical significance. Total sperm count did not correlate with waist-hip ratio. There was no difference between the oligozoospermic and normozoospermic groups, or the asthenzoospermic and normal motility groups in terms of anthropometric data. This study used older WHO guidelines, with higher cut off values.

Kort et al. (2006) assessed male partners presenting to an infertility centre and found that an increase in BMI inversely correlated with sperm motility. Men with previous surgery were excluded. BMI was recorded on the day of sample production. The author used normal motile sperm (NMS) as a measure of motility. This is calculated by multiplication of volume, concentration, motility and morphology. The NMS for obese men was much lower than that of the healthy BMI category (0.7 versus 18.6 respectively). There was no statement of normal values for NMS. It must be kept in mind that as there are four variables in the NMS calculation, a large change in one may affect the result.

Hammoud et al. (2008) conducted a retrospective analysis of 390 male partners presenting to an infertility clinic for semen analysis. Obesity was associated with an odds ratio of 3.3 (95% CI 1.19-9.14) for oligozoospermia, using a cut off of 20 million sperm per ejaculate. The range in confidence interval should be noted. In current practice, this concentration value would be viewed as normal. Overweight and obese men formed 43% and 32% of their population sample respectively, which was higher than national norms. Unfortunately, this paper published limited results, and used bar graphs with no data sets. The authors also demonstrated the existence of relationships between obesity and both reduced motile sperm count and increased abnormal sperm morphology. Obese men had higher abnormal morphologies [odds ratio of 1.6 (95% CI 1.05-2.59)]. They did not state what their cut off value was, but it can be assumed to be 15%, in keeping with the guidelines of the time. Due to the absence of tabulated data in their publication, the actual values obtained cannot be commented on.

Aggerholm et al. (2008) collected data from five population based environmental studies of semen quality. Height and weight were self-reported, and BMI was classified into categories. They chose to define underweight as a BMI < 20 kg/m². Later they re-analysed the data using standard WHO BMI groupings, and found no difference in results. A total of 1 989 men were included in the study. The authors found that normal-weighted men had a higher sperm concentration (59 vs 56 x 10⁶/ml) and total sperm count (168 vs 154 million) in comparison to overweight men, but lower than those of obese men (68 x 10⁶/ml, and 190 million sperm respectively). None of these results were statistically or clinically significant.

Men presenting to an academic fertility clinic in America were recruited for a six year period to assess the impact of various lifestyle factors on infertility (*Chavarro et al., 2010*). This study included 483 men, after exclusion of four underweight and 17 azoospermic men (to prevent the data being skewed). Seventy-five percent of men were overweight or obese. After adjustment for confounding factors, increasing BMI was associated with a decrease in semen volume (2.9 ml vs 3.0 ml). These values still fall within current normal reference ranges. Overweight men were found to have a higher total progressive sperm count than their normal-weighted counterparts. This finding could not be explained. After

further dichotomized analyses for semen analysis parameters were conducted, it was suggested that overweight and obesity were associated with a non-significant increased rate of below reference sperm concentration and morphology.

These findings are contradicted by the findings of *Relwani et al. (2011)*. The authors included 530 men, and found no consistent relationship between sperm concentration, motility, or morphology and increasing BMI. BMI was self-reported. Similar results were obtained in a retrospective study conducted in Saudi Arabia on a cohort of 500 men (*Eskandar et al., 2011*). The groups were divided into obese and non-obese males. No difference in semen analysis parameters was found. None of the findings were statistically significant.

Shayeb et al. (2011) analysed 2 035 sperm samples in a Scottish infertility database. Forty-one percent of the men in this group were overweight and 13% were obese, which is representative of the Scottish population. There was no association between BMI and sperm concentration, total sperm count, progressive motility, semen volume, or the total number of morphologically normal, and progressively motile spermatozoa per ejaculate. Sperm with normal morphology were found to be more prevalent in the normal and underweight men than in the overweight and obese men. This was based on previous WHO lower reference limits, using a cut off value of 15%. The mean morphology in the obese group was 6% - a value considered normal by current guidelines. After adjustments for lifestyle factors, obese men were more likely to have a low ejaculate volume (<2 ml) compared with men with a normal weight (adjusted odds ratio of 1.69; 95% CI 1.20-2.38). Again, this cut off value of 2 ml is based on previous guidelines. Current guidelines reference 1.5 ml and above as normal.

Recent publications include a 16 year retrospective study of 2 110 men (*Al-Ali et al., 2014*). Data captured before 1999 was analysed according to WHO standards published in 1992, and data after 1999 according to 1999 guidelines. The publication does not print standard results, but rather classified abnormal mean morphology as a percentage, quoting non-significant results of between 62 and 63% across all BMI categories. Both mean sperm concentration and motility did not vary across the normal and overweight or obese groups. The authors concluded there was no impact of BMI on semen analysis parameters.

Belloc et al. (2014) contradicted this by publishing their findings of BMI affecting all parameters except morphology. Self-reported weight and height were routinely recorded in their laboratory and a retrospective analysis of 10 665 men was carried out. Semen volume means decreased from 3.3 ml to 2.7 ml as BMI increased, but these values were still within current normal ranges. The same can be said of their findings for sperm concentration means ($56.4 \times 10^6/\text{ml}$ to $39.4 \times 10^6/\text{ml}$) and total sperm count (171 million to 92 million). Again these results remain above normal limits. They also found a progressive motility decrease from 36.9% to 34.7%. When adjusted for confounding factors such as age and abstinence, these findings were consistent. Again, it is important to note that findings were not below clinical reference values.

2.2.4 HYALURONAN BINDING & SPERM FUNCTION TESTING

Intracytoplasmic sperm injection (ICSI) has become the technique of choice for male factor infertility or failed fertilization in standard IVF cycles. When IVF was in its infancy, it was found that the spermatozoa of infertile men frequently demonstrated abnormal acrosome reaction, or sperm-zona pellucida interaction (Oehninger et al, 2014). Subsequently, zona pellucida assays and acrosome reaction tests were developed as further investigation for the infertile couple.

The WHO currently regards sperm functional tests as of research value, due to their complexity and difficulty in implementation in routine practise. (Oehninger et al, 2014). Such testing includes sperm penetration assays, sperm-zona pellucida binding tests, acrosome reactions, and hyaluronan binding. It can be hypothesized that an increased BMI may affect the fertilization potential of the spermatozoa. Most research around such testing has focused on their validation for directing couples to ICSI rather than intrauterine insemination or IVF. After an extensive literature search, no relevant human studies were found that detail the effect of obesity on sperm function testing, other than for hyaluronan binding.

Hyaluronan binding (HA-binding) of sperm is a relatively new sperm function test that has shown an improved quantification of sperm quality (*Huszar et al., 2006*). It is thought to be

a marker of complete spermatogenesis and is used to identify mature sperm with normal chromosome development and oocyte-binding function.

Wegner et al. (2010) assessed 107 male patients presenting to a fertility laboratory and grouped them into standard BMI categories. Height and weight were self-reported. An HA-binding score of 80% was associated with improved sperm quality, measured by higher mean sperm concentrations, normal morphology scores, and higher percentage motile sperm scores. They correlated an increase in BMI with a decreasing HA-binding score, following a dose-response relationship. The authors failed to correlate any other sperm parameters with an increase in BMI.

2.2.5 META-ANALYSES

MacDonald et al. (2010) conducted a meta-analysis of all of the existing research on BMI, sperm parameters and hormone profiles. They excluded all animal studies and any studies with small sample sizes (less than 100 participants). They also excluded studies where samples had extremes of age, organic reproductive disorders, azoospermia, exposure to toxins, and those based solely on fertile couples who achieved pregnancy. In total, 6 793 men from 13 studies were included. No relationship between BMI and semen parameters was found. They commented that their stringent exclusion criteria may have excluded data that may have resulted in a relationship.

A second meta-analysis was conducted in 2012, including 21 studies conducted until June 2012 (*Sermondade et al., 2012*). A total of 13 077 men were included from both the general population and those attending infertility clinics. A dichotomized analysis was required to find significant results. A J-shaped graphical curve was found between BMI and both abnormal total sperm count, and abnormal sperm concentration. In the very obese group (>35), the odds ratio of abnormal total sperm count and concentration was 2.04 (95% CI (1.59-2.62), and 1.97 (95% CI 1.27-3.07) respectively. The authors felt that due to the large sample size and inclusion of studies performed after the 2010 meta-analysis, their work represented the true relationship between an increased BMI and parameters of semen analysis

2.3. SOUTH AFRICAN RESEARCH

In contrast to numerous international studies, local data are lacking. A recently published pilot study conducted by the University of the Western Cape recruited men between the ages of 21 and 50 attending private clinics in the Western Cape (*Leisegang et al., 2014*). The primary focus of this study was to correlate seminal insulin and leptin levels with semen analysis parameters. The authors hypothesized that as abdominal obesity is associated with raised plasma insulin and leptin levels, an alteration in seminal levels could translate to impaired reproductive potential. Men with known infertility, vasectomy, genital tract pathology, and known chronic diseases were excluded. After obtaining a detailed history and conducting a physical examination, patients with a new diagnosis of chronic disease or genital tract pathology were further excluded. A cohort of 42 patients was recruited, consisting of 23 obese, and 19 normal or overweight men.

Lower mean values were demonstrated in the obese group for total sperm count, progressive and total motility. These results were not statistically significant. Significance was only proven in the lower mean values for vitality and sperm concentration. Despite these results, only a decrease in vitality and progressive motility were below the recommended 2010 WHO reference values. For ease of reference, the relevant results have been attached as appendix E on page 57.

Weaknesses of this study include the small sample size, predominantly Caucasian demographic (not representative of the local population), and the grouping of overweight and normal BMI patients into the same group. This seems to be the only South African study investigating the impact of weight on semen analysis parameters. The previously mentioned study published on the infertility profile at King Edward VIII Hospital in Durban (*Chigumadzi et al., 1998*) assessed women, and only documented the prevalence of male factor infertility.

3. AIMS AND OBJECTIVES

3.1 AIMS

This study aimed to document the prevalence of overweight and obesity in male partners of infertile couples undergoing investigation at a tertiary referral institution, and to assess the impact of raised BMI on semen quality.

3.2 OBJECTIVES

3.2.1 PRIMARY OBJECTIVES

1. To document the BMI of the male partners of infertile couples presenting for semen analysis.
2. To record the results of the semen analysis of the same subjects.
3. To assess whether an association exists between the male BMI and clinically significant parameters of semen analysis suggestive of infertility.

3.2.2 SECONDARY OBJECTIVES

1. To record the subjects' self-perceived BMI category.
2. To assess subjects' beliefs on the impact of overweight and obesity on fertility.
3. To record the subjects' willingness to lose weight as a fertility improvement strategy.

4 METHODS

4.1 STUDY DESIGN

This was a prospective cross-sectional study.

4.2 STUDY POPULATION AND STUDY SETTING

Men presenting to the Groote Schuur Reproductive Medicine Unit for semen analysis as part of infertility investigations were consecutively recruited into the study. Referrals to this unit were made from gynaecology outpatients departments within the service district. Patients were seen on a Monday and Wednesday at the Andrology Laboratory in Groote Schuur Hospital. They provided a semen sample, which was analysed by clinical technologists within one hour of production as per routine practice.

4.3 STUDY DURATION

Patients were recruited for a period of five months, from 01 June 2014 to 12 November 2014.

4.4 SAMPLE SIZE

The sample size was determined by the time frame of this thesis, which allowed five months for data collection. No power calculation was done. It was anticipated that the results of this study would provide relevant information upon which a larger, appropriately powered study could be based in future.

4.5 INCLUSION CRITERIA

1. All men presenting to the Reproductive Medicine Unit at Groote Schuur Hospital who successfully produced a sample for semen analysis as part of an infertility investigation were eligible to participate.
2. All men who were able to communicate in English, Afrikaans, or Xhosa were included.

4.6 EXCLUSION CRITERIA

1. Patients who were unwilling to be recruited.
2. Patients who had not abstained from sexual intercourse for three days prior to providing the sample.
3. Post-vasectomy patients.

4.7 STUDY RECRUITMENT

Suitable study participants were approached in the waiting area of the Andrology Laboratory by the principal investigator or by staff working in the Reproductive Medicine Unit. Prospective participants were spoken to in a private setting and informed about the study objectives, detailing what their participation would entail. All participants provided written informed consent (Appendix F, page 58).

4.8 DATA COLLECTION

The subjects' weight and height was collected using the same scale. A questionnaire was administered (Appendix G, page 59). The questionnaire addressed whether the men thought they were overweight or obese, and whether they thought their weight would affect the outcome of the semen analysis. They were asked if they would be willing to embark on a weight loss program if one was provided as a part of their management. This questionnaire was translated into Afrikaans and Xhosa.

Semen samples were provided by masturbation. The samples were then analysed within the Reproductive Medicine Unit using standard 2010 WHO protocol. This analysis was done as a part of the routine infertility investigation. This study only captured the data generated.

Three qualified and experienced embryologists working in the Reproductive Medicine Unit performed the semen analysis.

4.9 DATA PROCESSING AND STATISTICAL ANALYSIS

The study participants were each allocated a study number. Their height and weight was captured on the questionnaire. All questionnaires were stored within the department. The semen analysis results were recorded in the laboratory register with the corresponding study number.

The data were analysed using descriptive statistics. Numerical data were described using appropriate summary statistics, such as the mean, standard deviation, median and range, followed by testing of the data's distribution to inform the choice of statistic. Results were graphically displayed using bar graphs, frequency histograms, and scatter plots.

Four analyses of BMI and semen analysis parameters were conducted. BMI was compared to semen analysis parameters, both assessed as continuous variables. As all of the data was non-normal, the non-parametric Spearman's correlation was used.

Next, each semen analysis parameter was classified as either normal or abnormal on the basis of WHO 2010 guidelines, to assess clinical relevance of findings. These dichotomised parameters were compared to continuous BMI values. Mann-Whitney U tests were used to test whether there was a significant difference in the BMI values associated with the normal and abnormal results. Sperm forward progression was analysed using the Kruskal-Wallis test.

BMI was then categorised (namely $< 25 \text{ kg/m}^2$, $>25 \text{ kg/m}^2$, $>30 \text{ kg/m}^2$). This was compared to unclassified semen analysis parameters (continuous variables). Mann-Whitney U and Kruskal-Wallis tests were applied again.

Lastly, categorised BMI values were compared to classified semen analysis values, and a series of 3x2 frequency tables were generated. Each of the frequency tables was then analysed using Pearson's chi-square test and Fisher's exact test. These tests were conducted to check whether the distribution of observations across the frequency table could occur by chance, if they were taken from the same base population.

4.10 ETHICS

Ethics approval was obtained from the Human Research Ethics Committee of the Faculty of Health Sciences of the University of Cape Town (HREC/REF: 171/2014).

Confidentiality was maintained by all involved in the study, as the semen analysis formed part of the subjects' medical records. Eligible patients who declined to participate in the study were assured that it would not compromise their treatment. Any queries that the subjects had were answered by the investigators, and the relevance of the questionnaire was explained. The participants were assured that their involvement was strictly voluntary and that they could withdraw at any stage without an explanation. No monetary incentives were offered to participate in the study.

All of the data were collated and processed by the principal investigator, under the supervision of the study supervisors.

5. RESULTS

5.1 DESCRIPTIVE AND QUALITATIVE DATA

One hundred and thirteen men were recruited into the study between June 2014 and November 2014. Their average weight was 83.5 kg, with a range of 51.2kg-133.3kg. The average BMI was 27.1 kg/m², with a range of 17.4 kg/m²-43.1 kg/m² (Table 1).

Table 1 – Descriptive statistics for the continuous variables weight, height and BMI.

Variable	N	Minimum	Maximum	Mean	Std. Dev.	Median	p25	p75
Weight (kg)	113	51.2	133.3	83.5	16.3	81.7	71.9	92.4
Height (m)	113	1.6	2.0	1.8	0.1	1.8	1.7	1.8
BMI (kg/m ²)	113	17.4	43.1	27.1	5.0	26.3	23.6	30.1

BMI is usually categorised into four categories, underweight, normal, overweight and obese. As very few of the men in this sample were underweight, the categories of underweight and normal were combined.

There was a good representation across the three BMI categories, with 36.28% of the men demonstrating a BMI <25kg/m², 38.05% a BMI between 25kg/m² and 30kg/m², and 25.66% a BMI >30kg/m². Figure 1 illustrates the distribution of BMI values.

The first section of the questionnaire asked the men to categorise their own BMI. Sixty-six percent of them felt they were “normal”, 25% felt that they were slightly overweight, 5% felt that they were underweight and 2% thought that they were very overweight.

Figure 2 illustrates how self-perceived weight correlated with actual BMI categories. The majority of the men who felt that they were underweight were actually of recommended BMI. Most of the men who felt that they were of a normal weight had a BMI of >25 kg/m² and most of the men who felt that they were slightly overweight were actually in the obese BMI category. Less than half of the men (40.7%) assessed their body weight correctly. In the

incorrect group, 28.2% were out by two BMI categories. The 2% of the men who felt that they were very overweight had a BMI closest to 25 kg/m².

The second section of the questionnaire assessed the men's perceptions of body weight and reproductive potential. Fifty-one of the men (45.13%) felt that being overweight could negatively influence fertility. Twenty-four (21%) did not think being overweight influenced fertility and thirty-eight did not know (33%).

The third aspect of the questionnaire assessed whether the men were willing to partake in a weight loss programme if it was offered to them as a part of their fertility treatment. Eighty-seven percent of the men indicated that they would. Of the eight men who said no, five had a BMI of 25 kg/m² or less and three had a BMI greater than 30kg/m².

Figure 1 – Frequency of BMI.

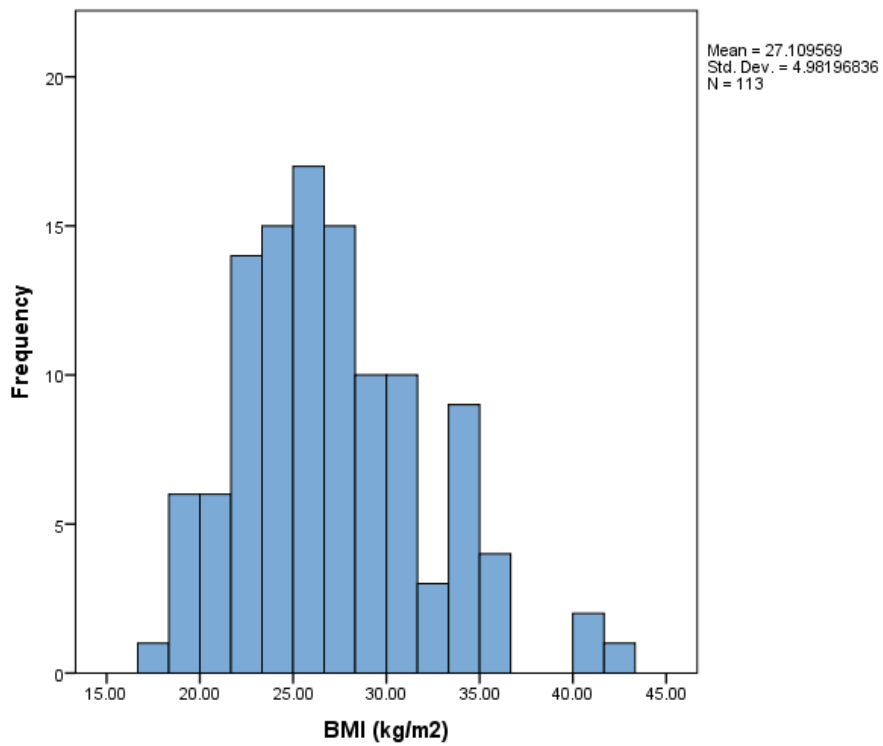
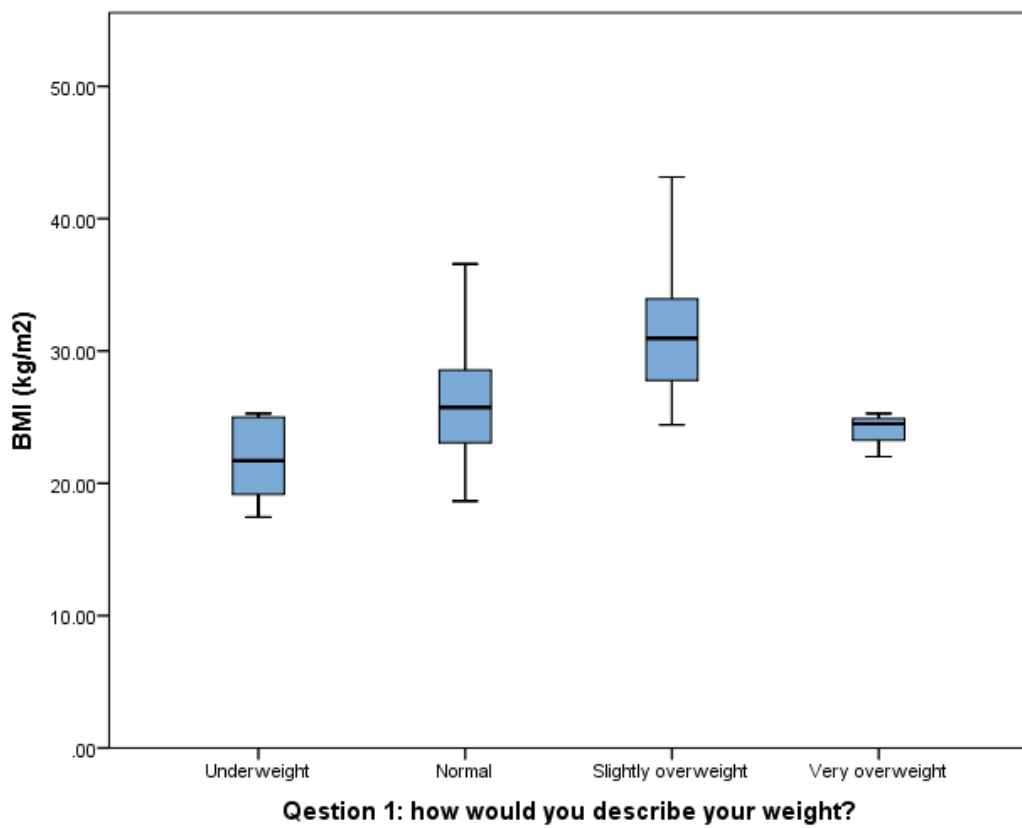


Figure 2 - Comparison of self-perceived BMI and actual BMI.



5.2 SEMEN ANALYSIS FINDINGS

Semen analysis was conducted on the 113 men. Six variables were measured, four continuous variables (volume, pH, motility and concentration) and two ordinal variables (morphology and sperm forward progression (SFP)). The term sperm concentration is used instead of sperm count ($10^6/\text{ml}$) to avoid confusion with the similar-sounding term “total sperm count” (millions per ejaculate). Figure 3 shows the frequencies of the measurements collected for these variables.

Table 2 provides further descriptive statistics of the continuous variables and of the ordinal variable morphology. As SFP has six categories, it is instead summarised by frequency tables, given in Table 3 (page 24).

Each of the variables can be used to classify a man’s semen analysis results as normal or abnormal using WHO suggested reference ranges. This categorisation was done to ensure that the results found here were of clinical relevance. Appendix C (page 49) defines the 2010 WHO reference ranges.

Only 29% of the men were classified as having normal values for every variable in the semen analysis, as defined by the WHO guidelines.

The men had a mean semen volume of 3.0 ml, with a range of 1.0-9.0 ml. Eighty-three percent of the men had a normal volume. The men had an average pH of 7.5, with a range of 6.7-8.0. Eighty-six percent of the men had a pH within the normal range.

Motility was analysed in terms of percentage and SFP. One hundred and six men were included in the assessment, as the motility cannot be calculated when there are no sperm, i.e., in a sperm concentration of 0. The men with motile sperm had on average 41.9% motile sperm in their semen samples, with a range of 0-80%, and 62.83% of these men had a normal motility.

SFP was assessed on a scale of 0 to 4. A value of 2 was taken as normal for our study purposes, but none of the men had an SFP value of 2. Eighty-four percent of the men had an SFP of 2+ or greater.

All 113 men were included in the sperm concentration analysis. The mean was 47.3×10^6 per ml, with a range of 0-140 $\times 10^6$ per ml. Seventy-nine percent of the men had a normal sperm concentration. Seven men had a concentration of 0, and a further fifteen had a concentration of 10 or less.

Morphology was not analysed in samples with a concentration of less than or equal to 10 $\times 10^6$ per ml. Thus 22 samples were excluded from this analysis, leaving 91 men. The average morphology was 5%, with a range of 1-16. Of the 91 men who were analysed, 71.43% had a normal morphology result, and of the total 113 men, 57.52% had a normal morphology result.

Figure 3 – Frequencies of the measurements taken for semen volume, semen pH, sperm motility, SFP, sperm concentration, sperm morphology.

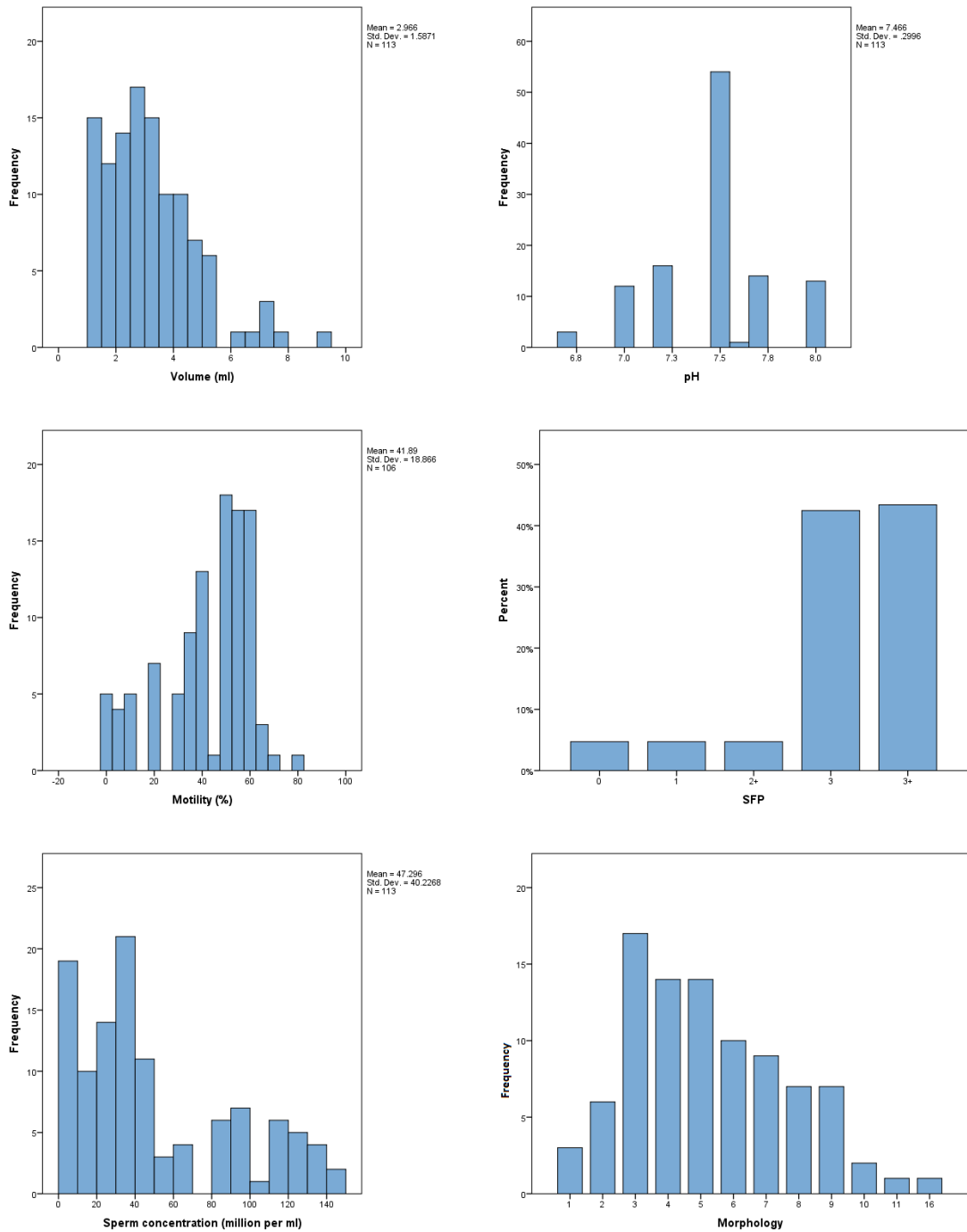


Table 2 - Descriptive statistics for the continuous variables and morphology measured during the semen analysis.

Variable	N	Minimum	Maximum	Mean	Std. Dev.	Median	p25	p75
Volume (ml)	113	1.0	9.0	3.0	1.6	2.5	2.0	4.0
pH	113	6.7	8.0	7.5	0.3	7.5	7.2	7.5
Motility (%)	106	0.0	80.0	41.9	18.9	50.0	33.8	55.0
Concentration (x10 ⁶ /ml)	113	0.0	140.0	47.3	40.2	35.0	18.0	80.0
Morphology (%)	91	1	16	5.29	2.59	5	3	7

Table 3 – Frequency table for the collected SFP data.

	SFP	
	Frequency	Percent
0	5	4.42
1	5	4.42
2+	5	4.42
3	41	39.82
3+	46	40.71
Total (N)	106	100

5.3 COMPARISON OF SEMEN ANALYSIS AND BMI

5.3.1 CONTINUOUS BMI VARIABLES VERSUS UNCLASSIFIED FERTILITY MEASURES

The complete data sets of each of the continuous variables (without first categorising each measured variable as either normal or abnormal) were compared with one another. As all the data were non-normal, the non-parametric Spearman's correlation was used. Spearman's correlation coefficient is a statistical measure of the strength of a monotonic relationship between paired data. The closer the result is to 1, the stronger the monotonic relationship. *P*-values of less than 0.01 were defined as very significant, and less than 0.05 were defined as significant. These results are displayed in Table 4 (page 27).

A significant, strong, positive correlation was found between motility and SFP of 0.693 ($p < 0.001$), as both are measures of how well sperm moves. This was statistically significant.

Sperm concentration correlated moderately with SFP (0.586, $p < 0.001$), and strongly with motility (0.676, $p < 0.001$). This finding is intuitive, as an increase in concentration would result in a higher likelihood of an increased number of motile and forward-progressing sperm. These findings were strongly significant at the 0.01 level.

Morphology was weakly correlated with sperm concentration (0.325, $p = 0.002$). The relationship between concentration and morphology can be explained using the same rationale as the motility argument addressed above.

The evaluation of BMI with semen variables demonstrated that BMI and motility were correlated weakly (0.263, $p = 0.006$) at the 1% level. There was also a very weak correlation between BMI and sperm concentration (0.186, $p = 0.049$), significant at the 5% level. Both BMI vs. concentration and BMI vs. motility did not show any clear relationship (Figure 4, page 26). For comparison, the strong, highly significant correlation between SFP and motility is also plotted, in which a clear monotonic increasing relationship can be seen.

Figure 4 – Comparison of motility and SFP; concentration and BMI; and motility and BMI, indicating a strong correlation well represented by a monotonic positive relationship and two weak correlations, respectively.

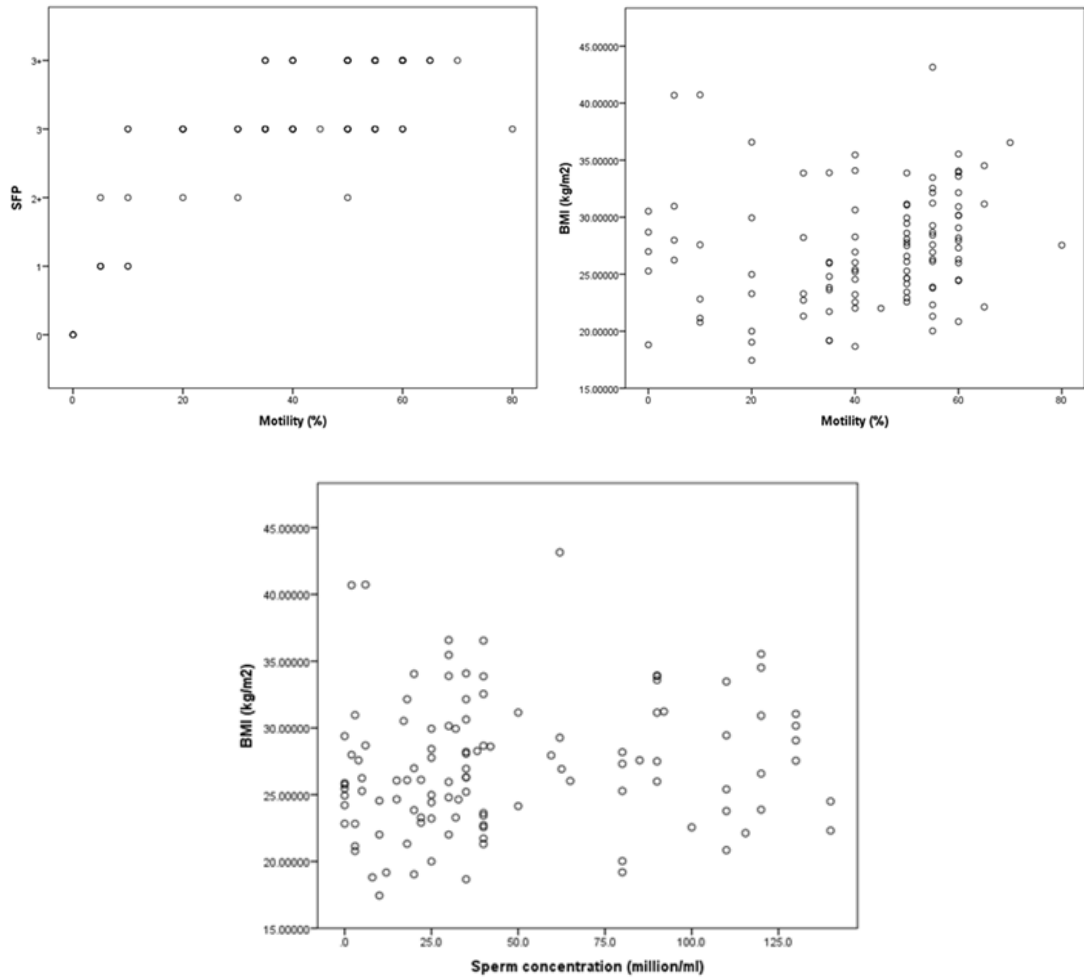


Table 4 - Correlations between the continuous BMI measurements and the continuous semen variables.

			BMI	Volume	SFP	Motility	Concentration	Morphology	
Spearman's rho	BMI	Correlation Coefficient	1.000						
		Sig. (2-tailed)	.						
		N	113						
	Volume	Correlation Coefficient	.133	1.000					
		Sig. (2-tailed)	.161	.					
		N	113	113					
	SFP	Correlation Coefficient	.090	.048	1.000				
		Sig. (2-tailed)	.359	.627	.				
		N	106	106	106				
	Motility	Correlation Coefficient	.263**	.096	.693**	1.000			
		Sig. (2-tailed)	.006	.328	.000	.			
		N	106	106	106	106			
	Concentration	Correlation Coefficient	.186*	.063	.586**	.676**	1.000		
		Sig. (2-tailed)	.049	.505	.000	.000	.		
		N	113	113	106	106	113		
	Morphology	Correlation Coefficient	.087	-.157	.073*	.125*	.325**	1.000	
		Sig. (2-tailed)	.410	.138	.492	.239	.002	.	
		N	91	91	91	91	91	91	
	**. Correlation is significant at the 0.01 level (2-tailed).								
	*. Correlation is significant at the 0.05 level (2-tailed).								

5.3.2 CONTINUOUS BMI VALUES VERSUS CLASSIFIED FERTILITY MEASURES

Each of the measured variables of semen quality has a reference value for normality. Each individual was classified as either normal or abnormal for each parameter. Table 5 (page 29) shows the descriptive statistics of the BMI values for each group of normal/abnormal individuals, as classified by each measurement.

This categorisation to test the correlations found when applying non-parametric testing was done to determine any clinical significance. Mann-Whitney U tests were used to test whether there was a significant difference in the BMI values associated with the normal and abnormal individual parameters. As well as testing the two groups with normal and abnormal SFP values, a Kruskal-Wallis test was conducted on the BMI values associated with the five groups of raw SFP scores (0, 1, 2, 3, 4+). Table 6 (page 30) indicates the test statistics and the probability of homogeneity.

P-values of greater than 0.05 were obtained from almost all of the tests, indicating that the null hypothesis of homogeneity was not rejected: there was no significant difference in the BMI values for the normal and abnormal individuals, as measured by most of the categorised semen analysis results. The exception was motility.

The median values of BMI were significantly different between the <40% and ≥40% categories of motility [median=24.98, IQR=(21.52-28.45) and median=27.55, IQR=(24.52-30.99) respectively]. The *p*-value was 0.026. Both inter-quartile ranges were widely distributed.

Table 5 – Descriptive statistics of the BMI values in each group of normal/abnormal fertility patients, as classified by each measurement.

		BMI							
		N	Min	Max	Mean	Std. Dev.	Median	Percentile 25	Percentile 75
Question 1: How would you describe your weight?	Underweight	6	17.45	25.28	21.71	3.15	21.71	19.17	24.98
	Normal	75	18.66	40.69	26.11	4.42	25.74	23.06	28.55
	Slightly Overweight	29	24.42	43.15	31.14	4.34	30.96	27.77	33.93
	Very Overweight	3	22.01	25.28	23.93	1.71	24.50	23.25	24.89
SFP	0	5	18.81	30.52	26.06	4.49	26.98	25.28	28.69
	1	5	20.78	40.73	29.34	7.37	27.99	26.24	30.96
	2+	5	17.45	40.69	26.63	8.82	26.09	21.32	27.58
	3	45	18.66	36.57	26.68	4.65	25.40	23.29	29.44
	3+	46	19.17	43.15	27.70	4.99	27.67	23.88	31.15
pH	<7.2	15	22.56	35.53	27.24	4.16	26.30	24.21	29.80
	>=7.2	98	17.45	43.15	27.09	5.11	26.27	23.44	30.15
Volume	<=1.5	15	18.81	36.57	25.80	4.93	25.40	23.25	27.22
	>1.5	98	17.45	43.15	27.31	4.99	26.93	23.84	30.16
Motility	<40	35	17.45	40.73	25.95	5.92	24.98	21.52	28.45
	>=40	71	18.66	43.15	27.84	4.57	27.55	24.52	30.99
Concentration	<15	23	17.45	40.73	25.93	6.94	24.91	20.96	28.34
	>=15	90	18.66	43.15	27.45	4.72	26.96	23.84	30.63
SFP	<2	10	18.81	40.73	27.70	6.01	27.48	25.28	30.52
	>=2	96	17.45	43.15	27.17	5.04	26.44	23.36	30.40
Morphology	< 4	26	18.66	36.54	26.20	4.68	25.99	23.29	28.43
	>= 4	65	19.19	43.15	27.82	4.77	27.58	24.42	30.92
BMI	<25	41	17.45	24.80	22.15	1.99	22.56	20.85	23.78
	25-30	43	24.98	29.94	27.30	1.38	27.50	26.10	28.24
	30+	29	30.15	43.15	33.75	3.29	33.59	31.15	34.52

Table 6 – Test statistics indicating the probability of homogeneity in BMI values between individuals with normal and abnormal fertility, as measured by each measurement.

Mann-Whitney U tests of significance		
Variable	Test statistic	p-value
SFP	2.118	0.714
pH	-0.157	0.876
Volume	1.172	0.241
Motility	2.22	0.026
Concentration	1.836	0.066
Morphology	1.524	0.127
SFP (Re-categorised)	-0.303	0.762

5.3.3 CLASSIFIED BMI VALUES VERSUS UNCLASSIFIED FERTILITY MEASURES

In the previous section, each semen analysis parameter was used to classify each individual as normal or abnormal, and then Mann-Whitney U tests were used to check whether normal and abnormal individuals differed in their BMI. We then classified each individual on the basis of their BMI as either underweight, normal, overweight, or obese. As there was only one underweight individual, the underweight and normal categories were combined. Kruskal Wallis tests were then used to test whether there was a significant difference in the distribution of each continuous and ordinal semen analysis parameter in the three BMI categories.

Table 7 (page 32) summarises the descriptive statistics of the continuous semen parameters (volume, pH, motility, and concentration) as well as the many-category ordinal variable morphology, classified by BMI. The SFP data is rather described as a comparative bar chart (Figures 5, page 33).

The parameters that appear to have the greatest differences between the subpopulations are motility and volume. Box plots of these two sets of subpopulations are displayed in Figure 6 (page 34). Neither these differences nor the differences in any other parameter across the subpopulations were significantly different, as measured by the Kruskal Wallis tests (shown in Table 8, page 35).

Table 7 – Descriptive statistics of the semen analysis parameters of each group of normal/overweight/obese patients, as classified by BMI.

		N	Mean	Median	Std. Dev	Min	Max	Percentile 25	Percentile 75
Volume	Normal	31	2.523	2.5	0.9517	1	5	2	3
	Overweight	34	3.603	3.25	1.9839	1	9	2	4.5
	Obese	26	2.962	2.5	1.612	1	7	1.5	4
pH	Normal	31	7.497	7.5	0.2927	7	8	7.5	7.5
	Overweight	34	7.456	7.5	0.2389	6.7	8	7.5	7.5
	Obese	26	7.469	7.5	0.3296	6.7	8	7.2	7.7
Motility	Normal	31	43.39	45	12.74	20	65	35	55
	Overweight	34	47.5	50	14.681	0	80	40	55
	Obese	26	50.38	55	15.616	0	70	40	60
Concentration	Normal	31	53.203	40	39.897	12	140	25	80
	Overweight	34	56.506	39.1	34.8206	15	130	30	80
	Obese	26	65.154	45	39.5097	17	130	30	92
Morphology	Normal	31	5.03	4	3.104	1	16	3	7
	Overweight	34	5.47	5	2.377	2	11	3	7
	Obese	26	5.35	5	2.244	1	9	4	7

Figure 5 – Frequency of the SFP categories recorded in the three BMI categories.

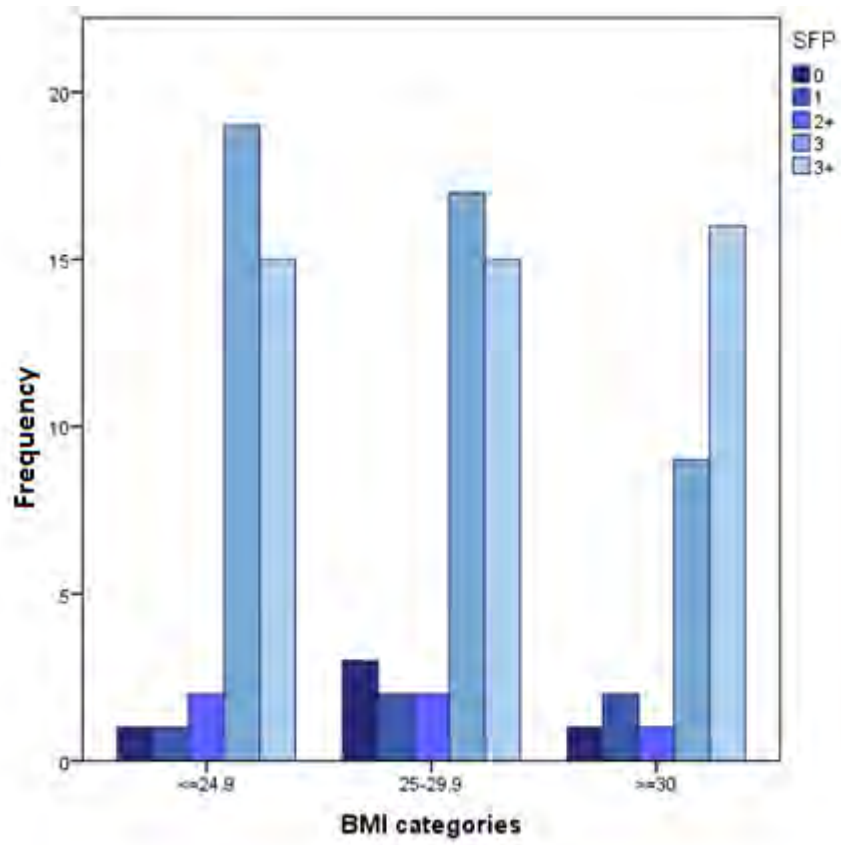


Figure 6 – The distribution of volume and motility measurements in the three BMI categories.

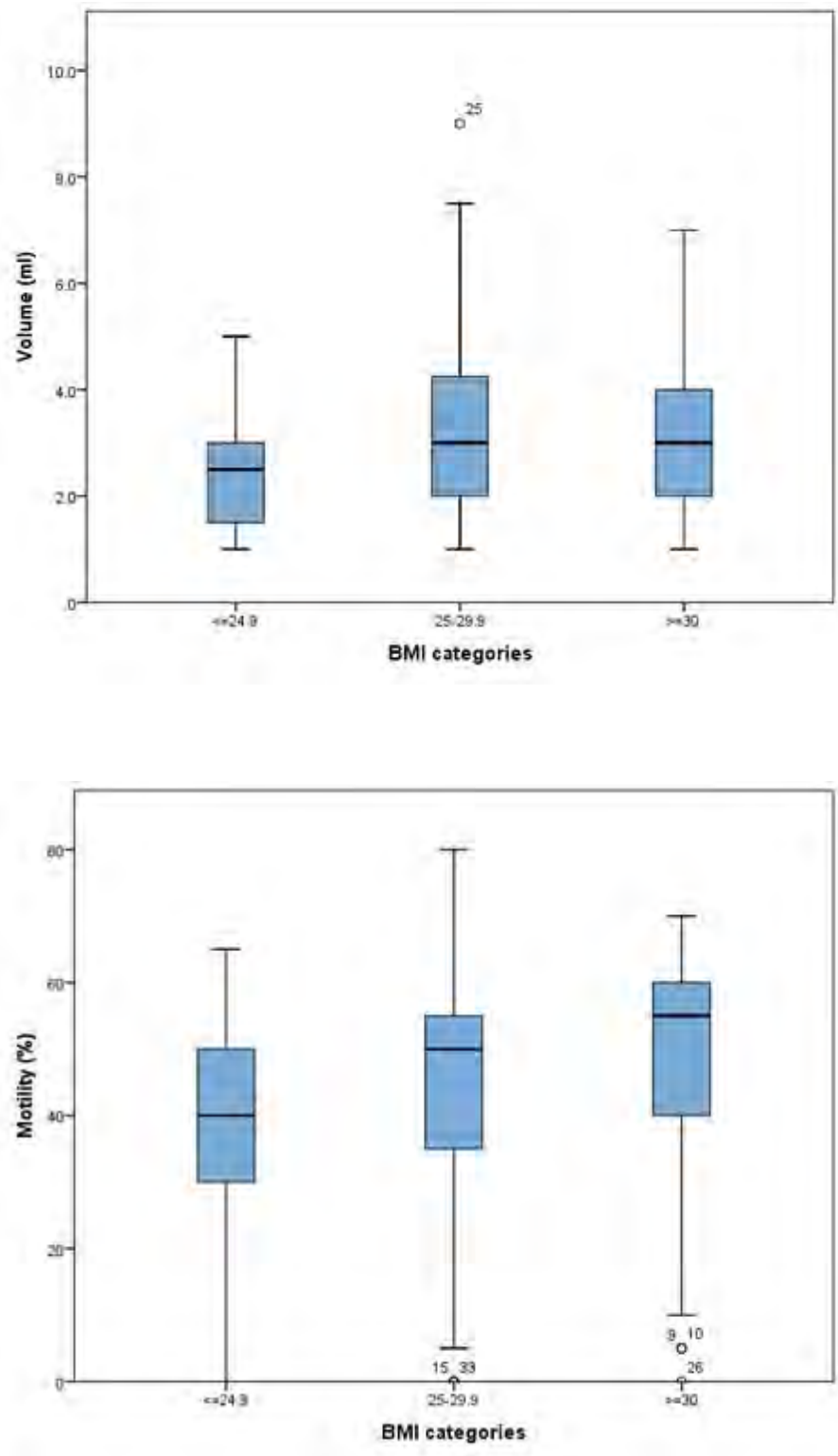


Table 8 – Test statistics indicating the probability of homogeneity in each semen analysis parameter between individuals with normal, overweight and obese BMI values, tested using Kruskal-Wallis H test.

Dependent variable	Test statistic	<i>p</i>-value
Viscosity	1.355	0.508
SFP	1.710	0.425
pH	0.243	0.886
Volume	4.964	0.084
Motility	5.489	0.064
Concentration	4.063	0.131
Morphology	1.531	0.465
^a :Significance at $p < 0.05$		
^b : All categorised by BMI		

5.3.4 CLASSIFIED BMI VALUES VERSUS CLASSIFIED FERTILITY MEASURES

In the final step of the analysis, individuals were classified by both their BMI (giving three categories) and by each semen analysis parameter.

Using three categories for BMI and two categories for each measurement of semen analysis (normal or abnormal) resulted in a series of 3x2 frequency tables. Once again, both categorised and uncategorised SFP were checked. Unclassified SFP resulted in a 3x5 frequency table. Only the frequency tables for BMI, motility, and morphology are shown (Table 9, page 36).

Table 9 – Frequency table for motility (normal and abnormal) and BMI (normal, overweight and obese); Frequency table for morphology (normal and abnormal) and BMI (normal, overweight and obese).

		Motility		Total
		<40	>=40	
BMI	<25	17	21	38
	25-30	11	28	39
	>30	7	22	29
Total		35	71	106

		Morphology		Total
		<4	>=4	
BMI	<25	12	19	31
	25-30	9	25	34
	>30	5	21	26
Total		26	65	91

Each of the frequency tables was then analysed using Pearson's chi-square test and Fisher's exact test. If at least one cell in a frequency tables has a value of less than five, the Fisher exact test is more appropriate than the Pearson's chi-square test.

The results of the categorical tests are shown in Table 10 (page 37). No association between BMI categories and normal/ abnormal semen parameters were found.

As a final test, the combined effect of all of the parameters was tested. If an individual had at least one semen analysis parameter with an abnormal value, then that individual was

classified as abnormal. According to this final analysis, BMI values did not differ when comparing participants who had only normal semen parameters with those who had one or more abnormal parameters (Table 10, below).

Table 10 - Results of categorical tests for the BMI and semen analysis variables.

Variable	Test	Test Statistic	d.f.	p-value
SFP*	Pearson Chi-Square	4.667 ^a	8	.792
	Fisher's Exact Test	4.907		.806
pH	Pearson Chi-Square	.174 ^a	2	.917
	Fisher's Exact Test	.270		.940
Volume	Pearson Chi-Square	.831 ^a	2	.660
	Fisher's Exact Test	.794		.732
Motility	Pearson Chi-Square	3.802 ^a	2	.149
	Fisher's Exact Test	3.646		.158
Concentration	Pearson Chi-Square	2.861 ^a	2	.239
	Fisher's Exact Test	2.831		.246
SFP (Re-categorised)	Pearson Chi-Square	1.325 ^a	2	.515
	Fisher's Exact Test	1.379		.588
Morphology	Pearson Chi-Square	1.761 ^a	2	.415
	Fisher's Exact Test	1.787		.412

6. DISCUSSION

6.1 QUANTITATIVE AND QUALITATIVE BMI FINDINGS

The results of this study provide local demographic data not previously described. Our recruit BMIs were well distributed across the three categories of normal, overweight, and obese. The mean BMI of men presenting to the unit as part of an infertility investigation was 27.1kg/m². These findings are similar to those published by *Eskandar et al. (2011)*. The distribution of men across the weight categories was more proportional than that measured by *Leisegang et al., (2014)*. In comparison to the findings of *Ng et al. (2014)*, this sample had a similar proportion of overweight men (38% vs 37%), but a higher proportion of obese men (14% vs 25%). These values are also higher than the previously quoted figures from both the 1998 South African Demographic Health Survey and the *Case et al., Khayelitsha House Survey (2004)*. Although the current findings were based on a small, urban sample population, they suggest that the prevalence of overweight and obesity are increasing.

As documented in the preceding literature review, very little is known about South African men's perception and beliefs about body image. When asked to assess their general weight, almost 60% of the men underestimated their true weight. Twenty-eight percent of these men were incorrect in their self-assessment by two BMI categories. The 2% of men who felt they were obese were not. These findings mirror those reported by *Case et al. (2009)*, who demonstrated a general underestimation of body weight. This finding becomes significant when considering literature that was based on self-reported BMI.

Less than half of the men felt that there was a relationship between increased body habitus and fertility difficulties. One-third of the men responded that they were not sure. This perception would need to be addressed should this relationship ever be proven. It may also reflect a societal disregard about the risks of being overweight and associated health implications in general.

An overwhelming 87% of the participants said that they would partake in a weight loss plan if one was prescribed as part of the fertility treatment. Of the eight men who admitted that they would not, five did not need to lose weight as their BMI fell within a healthy range – a fair reply. Whether this reflects the men’s desire to conceive or an actual wish to achieve a healthier lifestyle is unclear. This finding is encouraging and suggests clinicians should address issues of lifestyle and weight loss in all clinical encounters. The effects of obesity reach further than fertility, and this finding has important applications in general practice. Pathways to facilitate lifestyle advice and assistance should be clearly defined and offered to all patients.

6.2 SEMEN ANALYSIS FINDINGS

6.2.1 IMPORTANCE OF CATEGORISING SEMEN ANALYSIS VALUES

Most research has focused on an association between BMI and semen analysis parameters as a continuous variable regardless of whether the change represents a clinically significant finding. *Jensen et al. (2004)* found a significant difference between the median total sperm count of men with a BMI greater than 25 kg/m² (138 million per ejaculate) and obese men (116 million per ejaculate). The median BMI value for the obese men was lower but it did not represent a clinically abnormal value. *Aggerholm et al. (2008)* demonstrated a decrease in sperm concentration and total count in overweight men only. These results were not statistically significant, and the mean values for this group were still well above normal ranges. More recently, *Belloc et al. (2014)* found that increasing BMI was associated with a decrease in all semen analysis parameters, except for morphology. The lower means were again not below clinically relevant thresholds. The current study focussed on findings of clinical relevance, not decreasing trends.

6.2.2 PREVALENCE OF SEMEN ANALYSIS ABNORMALITIES

Many sources quote a figure of between 35 and 50% of male factor involvement in infertility. Our study found that only 29% of men had a completely normal semen analysis by published 2010 WHO standards. A single abnormal parameter can however not necessarily be extrapolated to infertility rates.

6.2.3 SEMEN VOLUME

Eighty-three percent of the participants had a normal semen volume. Causes of an abnormal volume may include non-abstinence, obstructive pathology, or seminal vesicle pathology. All of the men had to confirm three days of abstinence, but we did not screen for anatomical pathology in our sample. Of the 17% of men with an abnormal semen volume, five had a sperm concentration of 0 or too low to allow morphology to be tested.

There was no correlation between the collected values for volume and BMI. There was no difference between the BMIs of men classified with normal or abnormal semen volume, nor a significant difference between the volumes measured in men categorised as normal, overweight, or obese. A categorical analysis showed no correlation between volume and BMI. This negative result is in line with the only other South African data published by *Leisegang et al. (2014)*, as well as *Relwani et al., (2011)*, and *Eskandar et al., (2011)*. Volume findings are not commonly included in studies assessing BMI and infertility relationships, but *Shayeb et al. (2011)* found a correlation between decreasing volume and increasing BMI. The author's volume lower reference limit was 2.0 ml. This is in keeping with former WHO guidelines. *Chavarro et al. (2010)* also found a decrease in semen volume in obese men, but again the reference limit was cited as 2.0 ml. This may account for the differences observed.

6.2.4 SEMEN PH

The mean pH of our cohort was 7.5, with 86% of men having a pH that fell within the normal range. There was no correlation between semen pH and BMI in this sample, either in comparing the two sets of measured data, or comparing BMI (pH) distributions across subpopulations divided by their pH (BMI). There is little existing comparison between abnormal seminal pH and BMI in published literature.

6.2.5 MOTILITY

Motility revealed some of the more interesting results. The mean motility was 41.8%. Only 62.8% of the men had a normal motility. Not surprisingly, a significant, strong, positive correlation was found between motility and SFP of 0.693 ($p < 0.001$) when comparing them

as continuous variables. Motility and SFP do not have a perfect correlation, yet both are measures of how well sperm move. Motility and sperm concentration were also strongly correlated (0.676, $p < 0.01$) as continuous variables, suggesting a higher concentration results in higher numbers of normal motile sperm.

BMI (as a continuous variable) and motility were weakly correlated (0.263) at the 1% level. When motility was categorised into normal and abnormal subgroups, the median BMI in the less motile group (24.98 kg/m²) was found to be significantly lower than in the normal motility group (27.55 kg/m²). This correlation disappeared when BMI was categorised into WHO groups and compared with either the raw motility data or the categorised motility scores. This result suggests that the weak correlation found does not have any clinical impact. The motility results changed with variations in BMI, but there was no clear difference between the findings in the men with a healthy BMI versus those who were overweight or obese. We therefore conclude there is no clinically important relationship between BMI and motility.

Jensen et al. (2004), Shayeb et al. (2011), and Relwani et al. (2011) found no correlation between motility and BMI. These studies included large sample sizes. *Jensen et al. (2004)* used Danish military recruits, thus avoiding an already known infertility investigation cohort. *Shayeb et al. (2011)* performed a retrospective study but had an obesity incidence similar to their study population's national data. *Relwani et al. (2011)* used self-reported BMI. Two large meta-analyses also showed no relationship between BMI and motility (*MacDonald et al., 2010; Sermondade et al., 2012*).

These findings are in contrast to *Fejes et al. (2005)*, and *Hammoud et al. (2008)* who both demonstrated a relationship between motility and BMI, or other measure of obesity. *Fejes et al. (2005)* used normal motile sperm cells (NMS) as their measure of motility, which involved multiplication of volume, motility, morphology and total count. They did not stipulate a normal NMS value. The clinical significance of these results is therefore unclear. The correlation was with weight alone, not BMI. Their findings cannot be directly compared to studies assessing pure motility.

Hammoud et al. (2008) had a very high proportion of overweight and obese males, which was not representative of a normal population. Their data was represented in terms of odds ratios and prevalence percentages, and was based on older, now outdated, reference values. They used progressively motile sperm (10×10^6 motile sperm per ejaculate) as their motility measure. As they did not publish mean data, the clinical significance of their findings cannot be commented on. Again, these results cannot be directly compared.

6.2.6 SPERM FORWARD PROGRESSION

Sperm forward progression (SFP) refers to a grading of how many motile sperm are moving in a forward direction. It was graded by the analysis laboratory from 0 to 4 where a value of 2 was normal. Eighty-four percent of men had a normal SFP.

The strong correlation between the collected scores for motility and SFP has been discussed above. SFP was also moderately correlated with sperm concentration (0.586, $p < 0.01$), suggesting that a higher concentration of sperm results in more forwardly progressive motile sperm.

There was no correlation between the collected values for SFP and BMI. There was also no significant difference between the BMIs of men classified with normal or abnormal SFP, nor a significant difference between the SFP measured in men categorised as normal, overweight, or obese. A categorical analysis showed no correlation between volume and SFP. This is not a parameter often commented on in the literature. We conclude there is no clinically significant relationship between BMI and SFP.

6.2.7 SPERM CONCENTRATION

The mean sperm concentration was found to be 47.3×10^6 /ml. Oligozoospermia (defined as $< 15 \times 10^6$ per ml) was present in 20.35% of men, including seven with azoospermia.

As discussed above, sperm concentration was correlated moderately with SFP and strongly to motility (0.586 and 0.676 respectively, $p < 0.01$). Concentration was weakly correlated

with morphology (0.325, $p < 0.01$), again illustrating that an increased concentration results in a higher chance of morphologically normal sperm.

There was a very weak correlation between the collected BMI and concentration scores (0.186, $p < 0.05$). The mean BMI of men in both the normozoospermic and oligozoospermic groups were similar, at 26.6 kg/m² and 27.7 kg/m² respectively. This correlation disappeared when concentration was categorised as normal or abnormal, or when BMI was categorised as normal, overweight, or obese. We conclude there is no clinically significant relationship between BMI and sperm concentration according to our results.

This result is again in keeping with the only available South African data by *Leisegang et al. (2014)*. *Relwani et al. (2011)* also found no relationship between concentration and BMI. *Chavarro et al. (2010)* found only an insignificant, weak correlation after dichotomised statistical analysis.

In contrast, *Jensen et al. (2004)* showed a decrease in sperm concentration of 21.6%, using now outdated reference values. The mean sperm concentration remained at 39×10^6 /ml, which falls into the current WHO guideline's normal range. The clinical significance of this is questionable. *Fejes et al. (2005)* only found a correlation between sperm concentration and hip circumference, which is not an accepted measurement of obesity. They found no anthropometric differences between the oligozoospermic and normozoospermic groups.

Hammoud et al. (2008) found a definite increase in the incidence of oligozoospermia as BMI increased. They used 20×10^6 /ml as their cut off, a higher value than is currently accepted. The BMI in this study was self-reported. The results collected here showed that men tend to incorrectly estimate their weight, making self-reporting a very inaccurate tool and any results based on this equally inaccurate. There was also a very high incidence of overweight and obese recruits in the *Hammoud et al. (2008)* study, which may have skewed the results.

Sermondade et al. (2012) conducted a meta-analysis that showed a J-shaped curve between BMI and sperm concentration. The odds ratio of a sperm concentration of $< 15 \times 10^6$ /ml was 1.06 and 1.31 in BMI values over 25 and 30 kg/m² respectively. The largest

increase was found in men with a BMI > 35 kg/m², showing an odds ratio of 1.97. These results were not seen until the data was dichotomised for analysis. Our sample only included six men with a BMI of over 35 kg/m², so this analysis was not done.

6.2.8 MORPHOLOGY

Morphology was analysed in 91 of our recruited men. The mean morphology was 5%, with 57.52% of samples analysed having a morphology result within the normal range.

The collected morphology results were moderately correlated with concentration (0.325, $p < 0.01$). These results have already been discussed in the above text.

No correlation between BMI and morphology was found by comparing collected values, categorising BMI or morphology values, or by categorising both variables and comparing the frequencies. This is in keeping with the findings of three studies (*Jensen et al., 2004; Relwani et al., 2011; Belloc et al., 2014*).

Shayeb et al. (2011) found a decreasing percentage of normal morphologies as the BMI category increased. The lowest of these values was 6%, which is still above the WHO lower limit reference ranges used today and is thus clinically insignificant. *Chavarro et al. (2010)* found only an insignificant, weak correlation after dichotomised statistical analysis.

Two meta-analyses (*Macdonald et al., 2010; Sermondade et al., 2012*) also found no correlation between morphology and BMI.

6.2.9 COMPARISON OF FINAL RESULTS WITH PUBLISHED DATA

Al-Ali et al. (2014) conducted a 16-year retrospective analysis of men presenting to an infertility clinic. Their findings support those of the current study in concluding that BMI has no effect on semen analysis parameters. They applied two sets of WHO semen analysis guidelines (1992 and 1999) to their data. Both guidelines are currently outdated, and the use of two measures of normal is questionable.

Our findings are in keeping with the *Macdonald et al. (2010)* meta-analysis, which found no relationship between BMI and any of the semen analysis parameters. They included 13 studies of 6 793 men in total. None of the studies had less than 100 participants. In contrast, *Sermondade et al. (2012)* conducted a later meta-analysis of 13 studies (13 077 men) and found a significant relationship between total count (not analysed in our study) and sperm concentration. This analysis was conducted using currently accepted WHO semen analysis guidelines. They did not find a relationship when comparing normozoospermia and oligozoospermia. However, a difference was found when the oligozoospermia group was divided into azoospermia and oligozoospermia.

The only local data to the author's knowledge is that of *Leisegang et al. (2014)*. They found a decrease in sperm concentration with increasing BMI, but this was not of clinical significance with a mean value of $23.7 \times 10^6/\text{ml}$. As the current study was concerned with findings of clinical relevance, these results are not necessarily contradictory. We did not measure vitality and therefore cannot comment on this finding.

6.3 STUDY STRENGTHS AND WEAKNESSES

The sample size of 113 men may be viewed as a study limitation. However, our sample size is almost three times larger than that of the only other South African data available (40 men) and significantly larger than the sample size used by *Fejes et al. (2005)*.

There was a good distribution of overweight and normal-weighted men across the three BMI categories, allowing each category to be analysed separately. This is in contrast to

Leisegang et al. (2014), who grouped overweight and normal-weighted men together. BMI was also measured directly, making this study's BMI results more accurate than many international studies that cite self-reported or partner-reported weight and height.

This study assessed men's perceptions of their body image and the impact of weight on fertility, as well as their said acceptance of weight loss measures if implemented in fertility management. This provides new information on the local population.

7. CONCLUSIONS AND RECOMMENDATIONS FOR FURTHER RESEARCH

This study has demonstrated a larger prevalence of obesity in South African men than has previously been documented, as well as the inability of men to accurately self-report where they fall on the weight curve in terms of BMI. We also demonstrated a mixed opinion about the effects of weight on fertility and that most men were willing to accept advice on weight loss. The European Society for Human Reproduction and Embryology task force on ethics and law recommend weight loss as part of fertility treatment in women (*Dondorp et al., 2010*). The consultation with a couple seeking fertility advice should therefore encourage behaviour modification counselling.

We conclude that there is no difference between normal, overweight and obese South African men in terms of clinically significant semen analysis markers for infertility in our study.

8. APPENDIX A: SUMMARY OF EPIDEMIOLOGICAL STUDIES

Study	Participants	Sample Size	Results	Notes and Summary of Findings
Sallmén et al., 2006	Secondary analysis of data extracted from the Agricultural Health Study (Pesticide applicators and spouses). United States of America.	1 329 couples (initial study comprised of 52 395 pesticide applicators).	BMI>30 associated with odds ratio 1.12 (CI 95% 1.01-1.25) of infertility. Dose-response relationship between increasing BMI and infertility.	Very high baseline infertility rate of 28%. BMI self-reported, not at time of reported infertility. Infertility defined as 12 month period of no conception in a 4 year study period.
Ramlau-Hansen et al., 2007	Extracted data from the Danish National Birth Cohort. Denmark.	47 835 women and their male partners.	BMI>25 associated with odds ratio of 1.15 (95% CI 1.09-1.22) of infertility. BMI>30 associated with odds ratio of 1.49 (95% CI 1.34-1.64) of infertility. Dose-response relationship demonstrated	Subfecundity defined as 12 months to achieve a pregnancy resulting in live birth - excluded couples who ultimately did not conceive, or who miscarried (due to register only documenting live births). BMI reported 2 years after the attempted pregnancy.
Nguyen et al., 2007	Secondary analysis of a Norwegian database (Mother and Child Cohort Study). Norway.	26 303 women and their male partners.	BMI >25 associated with odds ratio for infertility of 1.19 (95% CI 1.03-1.62). BMI >30 associated with an odds ratio of 1.36 (95% CI 1.12-1.62). Dose-response relationship demonstrated.	Infertility defined as 12 months to time of pregnancy, resulting in live birth. Self-reported BMI at time of pregnancy.

9. APPENDIX B: SUMMARY OF INFERTILITY CLINIC STUDIES

Study	Participants	Sample Size	Results	Notes
Magnusdottir et al.,2005	Men who had previously had semen analysis done at the tertiary hospital. Iceland.	72 men 25 men male factor subfertility (MFS) 20 men idiopathic subfertility (IS) 27 men female factor subfertility (FFS)	MFS: prevalence of obesity: 40% IS: prevalence of obesity:5% FFS: prevalence of obesity: 10%	Primary objective comparing levels polychlorinated biphenyls and organochlorine pesticides in plasma and semen to assess environmental impact on fertility. BMI measures as a secondary outcome.
Zorn et al., 2006	Male partners of infertile couples. Slovenia.	210 men Non-obstructive azoospermia n=42 Obstructive azoospermia n=15 Oligoasthenoteratozoospermia n=86 Normozoospermia n=85	BMI 27.15 BMI 26.75 BMI 26.22 BMI 25.52	Small increase in BMI among males with non-obstructive azoospermia relative to normozoospermic men.

10. APPENDIX C: WHO SEMEN ANALYSIS REFERENCE RANGES (Menkveld., 2010)

Parameter	1992		1999		2010	
	Lower Limit	Reference	Lower Limit	Reference	Lower Limit	Reference
Volume (ml)	2.0		2.0		1.5	
pH	Not specified		Not specified		>7.2	
Motility (%)	50		50		40	
Sperm concentration (10⁶ per ml)	20		20		15	
Morphology (normal forms, %)	30 (arbitrary value)		14		4	

11. APPENDIX D: SUMMARY OF STUDYS COMPARING BMI WITH SEMEN ANALYSIS RESULTS

Study	Participants	Sample Size	Results	Notes and Summary of Findings
<i>Jensen et al., 2004</i>	Danish military recruits. Denmark.	1 558 men BMI < 20 n = 217 BMI 20-25 n = 1042 BMI > 25 n = 299	Volume (ml) BMI < 20 = 3.0 BMI 20-25 = 3.2 BMI > 25 = 3.2 Concentration (10⁶/ml) BMI < 20 = 40 BMI 20-25 = 46 BMI > 25 = 39 Total sperm count BMI < 20 = 105 BMI 20-25 = 138 BMI >25 = 116 Motility (%) BMI < 20 = 63.7 BMI 20-25 = 65.4 BMI > 25 = 65.5 Morphology (%) BMI < 20 = 6.8 BMI 20-25 = 7.4 BMI > 25 = 7.1	Subjects underwent questionnaire, physical examination, endocrine testing. Statistical correction for diseases of the reproductive organs. WHO 1992 semen analysis parameter lower reference ranges used. BMI >25 kg/m ² had a 21.6% decrease in their sperm concentration vs <25 kg/m ² counterparts. Total sperm count was also reduced by 23.9%. No link between BMI and sperm motility, volume, or morphology was found.
<i>Fejes et al., 2005</i>	Couples presenting to infertility clinic. Hungary.	81 couples.	Concentration (10⁶/ml) Sperm concentration negatively correlated with increasing hip circumference (r=-0.24; p=0.033).	Questionnaire, medical, endocrine testing. Waist-hip ratio calculated. Men with secondary infertility excluded.

			<p>Total sperm count (millions)</p> <p>Total sperm count negatively correlated to increasing hip circumference (r=-0.22, p=0.009), Weight (r=-0.024, p=0.031), Waist circumference (r=-0.26, p=0.007).</p> <p>Motility</p> <p>Correlation between body weight and total motile sperm count (r=-0.22, p=0.048)</p> <p>Morphology</p> <p>No anthropometric differences between groups with normal and abnormal motility.</p> <p>No mean values provided.</p>	<p>Two semen samples taken - best result used.</p> <p>WHO 1999 semen analysis parameter lower reference ranges used.</p>
Kort et al., 2006	<p>Men presenting to infertility clinic.</p> <p>United States of America.</p>	520 men.	<p>Significant negative relationship between raised BMI and normal-motile sperm cells (NMS).</p> <p>BMI <25 NMS =18.6 BMI >25 NMS = 3.6 BMI >30 NMS = 0.7</p> <p>NMS = volume × concentration × %motility × %morphology.</p>	<p>Numbers of men in each weight category not stated.</p> <p>Limited outcome data.</p> <p>WHO 1999 semen analysis parameter lower reference ranges used.</p> <p>No definition of normal values for NMS.</p>
Aggerholm et al., 2008	Data from five previous population-based environmental	<p>1 989 men.</p> <p>BMI < 20 n = 67</p>	<p>Concentration</p> <p>BMI < 20 = 82 BMI <25 = 74 BMI >25 = 70</p>	Results re-classified with WHO BMI categories – no difference found.

	<p>studies of semen quality were combined into one Database.</p> <p>Denmark.</p>	<p>BMI <25 n = 986</p> <p>BMI >25 n = 773</p> <p>BMI> 30 n = 163</p>	<p>BMI> 30 = 80</p> <p>Total sperm count (millions)</p> <p>BMI < 20 = 256</p> <p>BMI <25 = 231</p> <p>BMI >25 = 216</p> <p>BMI> 30 = 265</p> <p>Motility (%)</p> <p>BMI < 20 = 42</p> <p>BMI <25 = 41</p> <p>BMI >25 = 48</p> <p>BMI> 30 = 54</p>	<p>Self-reported height and weight.</p> <p>Analysed for cofounders.</p> <p>WHO reference ranges not specified.</p> <p>Normal weighted men had a higher sperm concentration and total sperm count than overweight men.</p> <p>Normal weighted men had a lower sperm concentration and total sperm count than obese men.</p> <p>None of results statistically significant.</p>
<p>Hammoud et al., 2008</p>	<p>Male partners of couples presenting to infertility clinic.</p> <p>United States of America.</p>	<p>390 men.</p> <p>BMI < 25 n = 94</p> <p>BMI > 25 n = 168</p> <p>BMI > 30 n = 128</p>	<p>Total sperm count – in terms of incidence of oligozoospermia(%)</p> <p>BMI < 25 = 5.32</p> <p>BMI >25 = 9.52</p> <p>BMI>30 = 15.62</p> <p>Motility in terms of incidence of low progressively motile sperm count (%)</p> <p>BMI < 25 = 4.25</p> <p>BMI >25 = 8.93</p> <p>BMI>30 = 13.28</p> <p>Morphology</p> <p>OR of abnormal morphology in obese group 1.6 (95% CI 1.05 – 2.59)</p> <p>No mean values provided.</p>	<p>Secondary causes of infertility excluded.</p> <p>High proportion of overweight and obese participants.</p> <p>Weight and height self-reported.</p> <p>WHO 1999 semen analysis parameter lower reference ranges used.</p> <p>Obesity was associated with increased odds ratio for oligozoospermia.</p> <p>Obese men had higher abnormal morphology incidence.</p> <p>Obese men had lower</p>

				progressively motile sperm count incidence.
Chavarro et al., 2010	Men presenting to an infertility clinic. United States of America	384 men. BMI < 25 n = 123 BMI > 25 n = 233 BMI > 30 n = 87 BMI > 35 n = 40	Concentration (10⁶/ml) BMI < 25 = 76 BMI > 25 = 81 BMI > 30 = 87 BMI > 35 = 77 Sperm motility (%) BMI < 25 = 49 BMI > 25 = 55 BMI > 30 = 54 BMI > 35 = 55 Morphology (%) BMI < 25 = 7 BMI > 25 = 7 BMI > 30 = 7 BMI > 35 = 6 Volume (ml) BMI < 25 = 3.2 BMI > 25 = 2.9 BMI > 30 = 3.0 BMI > 35 = 2.6 Total progressive sperm count (millions) BMI < 25 = 63 BMI > 25 = 71 BMI > 30 = 71 BMI > 35 = 55	Directly measured BMI. Underweight and azoospermic men excluded from analysis. WHO 1999 semen analysis parameter lower reference ranges used. Increasing BMI associated with a decreasing semen volume. Overweight men have a higher total progressive sperm count than their normal-weighted counterparts – unexplained.
Eskandar et al., 2011	Men presenting to infertility centre. Saudi Arabia.	500 men. BMI < 30 n = 322 BMI > 30 n = 178	Volume (ml) BMI < 30 n = 2.5 BMI > 30 n = 2.5 Concentration (10⁶/ml) BMI < 30 n = 40 BMI > 30 n = 40	Retrospective study Direct measurement BMI. Results all p > 0.05. WHO 1999 semen analysis parameter lower reference ranges used.

			Total count (millions) BMI < 30 n = 81.5 BMI > 30 n = 93 Motility (%) BMI < 30 n = 49 BMI > 30 n = 50 Morphology (%) BMI < 30 n = 17 BMI > 30 n = 17	No relationship between BMI and semen analysis parameters.
Relwani et al., 2011	Men who had a semen analysis at Montefiore Institute for Reproductive Medicine and Health or at MAZE Andrology Laboratory. United States of America.	530 men. No breakdown of men per BMI category provided	Volume (ml) BMI 15.15 - 25.8 = 2.93 BMI 25.82 - 29.68 = 2.73 BMI 29.7 - 60.69 = 3.01 Concentration (10⁶/ml) BMI 15.15 - 25.8 = 57.95 BMI 25.82 - 29.68 = 56.94 BMI 29.7 - 60.69 = 51.28 Motility (%) BMI 15.15 - 25.8 = 53.71 BMI 25.82 - 29.68 = 54.84 BMI 29.7 - 60.69 = 53.06 Morphology (%) BMI 15.15 - 25.8 = 10.79 BMI 25.82 - 29.68 = 10.28 BMI 29.7 - 60.69 = 10.53	Secondary causes of infertility excluded. Weight and height self-reported. 2010 WHO criteria used. No consistent relationship between sperm concentration, motility, or morphology and increasing BMI.
Shayeb et al., 2011	Male partners of couples undergoing fertility investigations. Scotland.	2 035 men. BMI < 18.5 n = 18 BMI <25 n = 839 BMI >25 n = 909 BMI >30 n = 269	Volume (ml) BMI < 18.5 = 3.2 BMI < 25 = 3.5 BMI > 25 = 3.5 BMI > 30 = 3.2 Concentration (10⁶/ml) BMI < 18.5 = 45.9 BMI < 25 = 47.9 BMI > 25 = 47.0	Proportion of overweight to normal weighted men representative of population. Retrospective analysis of data from 1990 – 2007. WHO 1999 semen analysis parameter lower reference

			<p>BMI > 30 = 50.8</p> <p>Total Sperm Count (millions)</p> <p>BMI < 18.5 = 147.2</p> <p>BMI < 25 = 144.0</p> <p>BMI > 25 = 153.0</p> <p>BMI > 30 = 162.7</p> <p>Motility (%)</p> <p>BMI < 18.5 = 40.8</p> <p>BMI < 25 = 45.0</p> <p>BMI > 25 = 45.4</p> <p>BMI > 30 = 47</p> <p>Morphology (%)</p> <p>BMI < 18.5 = 11.0</p> <p>BMI < 25 = 9.0</p> <p>BMI > 25 = 8.0</p> <p>BMI > 30 = 6.0</p>	<p>ranges used.</p> <p>No association between BMI and sperm concentration, total sperm count, progressive motility, semen volume, or the total number of morphologically normal and progressively motile spermatozoa per ejaculate.</p> <p>Sperm with normal morphology more prevalent in the normal and underweight men than in the overweight and obese men.</p>
Al-Ali et al., 2014	16 year retrospective study of men presenting to infertility clinics in Austria and Germany.	<p>2110 men.</p> <p>BMI < 18.5</p> <p>n = 16</p> <p>BMI < 25</p> <p>n = 1082</p> <p>BMI > 25</p> <p>n = 821</p> <p>BMI > 30</p> <p>n = 191</p>	<p>Mean pathological sperm morphology (%)</p> <p>BMI < 25 = 63</p> <p>BMI > 25 = 62</p> <p>BMI > 30 = 63</p> <p>BMI > 35 = 63</p> <p>Mean sperm concentration (%)</p> <p>BMI < 25 = 30.7</p> <p>BMI > 25 = 63.09</p> <p>BMI > 30 = 66.39</p> <p>BMI > 35 = 62.06</p> <p>Mean sperm motility (%)</p> <p>BMI < 25 = 20.94</p> <p>BMI > 25 = 24.59</p> <p>BMI > 30 = 24.76</p> <p>BMI > 35 = 24.53</p>	<p>Direct measurement of BMI.</p> <p>Use of two different WHO criteria 5 years into study (1992; 1999).</p> <p>No impact of BMI on semen analysis parameters.</p>

<p>Belloc et al., 2014</p>	<p>Men presenting to an infertility clinic.</p> <p>France.</p>	<p>10 665 men.</p> <p>BMI < 18.5 n = 27</p> <p>BMI < 25 n = 5799</p> <p>BMI > 25 n = 3607</p> <p>BMI > 30 n = 634</p> <p>BMI > 35 n = 97</p> <p>BMI > 40 n = 33</p>	<p>Volume (ml)</p> <p>BMI < 18.5 n = 3.0</p> <p>BMI < 25 n = 3.9</p> <p>BMI > 25 n = 3.8</p> <p>BMI > 30 n = 3.8</p> <p>BMI > 35 n = 4.0</p> <p>BMI > 40 n = 3.7</p> <p>Concentration (10⁶/ml)</p> <p>BMI < 18.5 n = 49.5</p> <p>BMI < 25 n = 56.4</p> <p>BMI > 25 n = 55.1</p> <p>BMI > 30 n = 50.7</p> <p>BMI > 35 n = 49.7</p> <p>BMI > 40 n = 39.4</p> <p>Total sperm count (millions)</p> <p>BMI < 18.5 n = 133</p> <p>BMI < 25 n = 171</p> <p>BMI > 25 n = 163</p> <p>BMI > 30 n = 141</p> <p>BMI > 35 n = 136</p> <p>BMI > 40 n = 92</p> <p>Motility (%)</p> <p>BMI < 18.5 n = 38.3</p> <p>BMI < 25 n = 39.7</p> <p>BMI > 25 n = 39.4</p> <p>BMI > 30 n = 37.5</p> <p>BMI > 35 n = 38.5</p> <p>BMI > 40 n = 38.0</p> <p>Morphology (%)</p> <p>BMI < 18.5 n = 10.7</p> <p>BMI < 25 n = 12.1</p> <p>BMI > 25 n = 11.9</p> <p>BMI > 30 n = 11.5</p> <p>BMI > 35 n = 12.0</p> <p>BMI > 40 n = 12.5</p>	<p>Self-assessed BMI recorded.</p> <p>Second largest study to date.</p> <p>WHO 2010 semen analysis parameter lower reference ranges used.</p> <p>BMI affected all semen analysis parameters except morphology.</p>
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12. APPENDIX E: SUMMARY OF RESULTS LEISEGANG ET AL. (2014)

	Non-Obese n=19	Obese n=23	
	Mean (range)	Mean (range)	P value
Semen volume (ml)	2.7 (1.2-5.5)	2.5 (0.4-7.0)	0.6217
Sperm concentration (10⁶/ml)	35.3 (8.8-72.4)	23.7 (7.5-49.5)	0.0145
Total sperm count (x 10⁶)	96.5 (13.2 – 243.7)	64.4 (3.7-247.5)	0.0863
Progressive motility (%)	33.8 (0-59.5)	24.5 (0-70.1)	0.0986
Total motility (%)	52.2 (18.5-78.6)	41.4 (1.1-74.9)	0.1066
Vitality (%)	62.6 (29-92)	45.0 (6-88)	0.0172
Normal morphology (%)	2.57 (1-7)	1.95 (0-5)	0.2371

13. APPENDIX F: INFORMED CONSENT

IMPACT OF MALE BODY WEIGHT ON SEMEN ANALYSIS PARAMETERS

(HREC/REF: 171/2014)

UNIVERSITY OF CAPE TOWN 2014

This study is conducted by Dr. L.J. Oosthuizen, a registrar in the Department of Obstetrics and Gynaecology at the University of Cape Town. All men presenting to the Reproductive Medicine Unit at the University of Cape Town are invited to enrol in this study.

The aim of this research is to document the body mass index (weight/height²) of men presenting to the unit and compare it to the results of their sperm sample analysis.

If you are willing to participate in this study, we will ask you to please fill in a questionnaire, and allow us to measure your weight and height. We will ask your permission to use your sperm analysis results. Our copy of the results will contain only a participant number, not your name. All of the details recorded will be kept anonymous.

There is no monetary incentive to participate in this study. You are allowed to decline participation and, should you chose to participate, you may withdraw from the study at any point. Your decision to participate will not influence the clinical care that you receive. You may ask any questions you feel necessary to determine whether you are willing to participate in this study.

SIGNED:

DATE:

WITNESS:

STUDY NUMBER:

14. APPENDIX G: QUESTIONNAIRE

QUESTIONNAIRE (HREC/REF: 171/2014)

DATE:

STUDY NUMBER:

Please read the question and tick the answer you feel is most correct for you:

1. How would you describe your weight?

Underweight	Normal	Slightly Overweight	Very Overweight
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2. Do you think being overweight or obese can affect your fertility as a man?

Yes	No	I don't know
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3. If you felt you were overweight, would you follow a weight loss programme if one was offered to you as part of your fertility treatment?

Yes	No	I don't know
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