ABSTRACT
Diagnostic testing for male infertility has traditionally been limited to andrology labs. The advent of home-based semen testing has the potential to allow patients to perform testing in the comfort of their home and screen those who need a formal evaluation. An extensive review of the literature was performed. There are several FDA-approved devices for home semen testing. The mechanism of the test and the results provided differ by test. The existing tests are limited in their diagnostic capabilities but may fill a niche for men who do not have access to andrology lab testing or prefer home testing.

Female factor infertility is a significant contributor to difficulty conceiving for couples around the world, affecting approximately 15% to 20% of couples. Male factor is estimated to contribute in 20% to 30% of couples with infertility and worldwide more than 30 million men are infertile. Male partners are less likely to seek medical care surrounding fertility as compared to females. Furthermore, sociocultural barriers to medical evaluation for men trying to conceive exist in some countries. The cornerstone of the male infertility evaluation is a semen analysis. The two approaches to semen testing are manual microscopic testing and computer-assisted semen analysis, both of which are expensive and require technical experience. Laboratory-based semen testing has associated cost and inconvenience and can cause embarrassment for the patient.

In an effort to avoid an office visit for male patients as well as the expense and manpower associated with laboratory semen testing, home-based screening tests have been developed. This approach allows for at-home testing and may aid in determining which patients need more formal and extensive evaluation by a specialist. Additionally, some couples proceed with assisted reproductive techniques that are costly and burdensome to the female before the male is evaluated. At-home smartphone-based screening tests may prevent unnecessary interventions on the female side if the test can screen for male factor infertility. Resource-poor countries would benefit substantially from this technology as well given that smartphones are omnipresent but andrology services are not.

Andrology laboratory-based semen testing
In general, certified andrology laboratories worldwide follow the World Health Organization (WHO) standards for semen analysis. The testing is either performed manually or using computer assisted semen analyzers (CASA). Although manual semen analysis results are subjective, they are considered accurate when performed by trained medical andrology technicians. Macroscopic and microscopic semen parameters are analyzed to determine the quality of the semen. According to WHO, abnormal semen samples with: 1) <32% progressive motility or 40% total motility are considered as asthenozoospermic; 2) with concentra-
tion < 15 × 10⁶ spermatozoa/mL are termed as oligozoospermic; and 3) with normal sperm forms with <4% are known as teratozoospermic.⁵

**Home sperm testing devices**

Home based semen testing could serve as an alternate for those men who are reluctant to visit the clinic for semen analysis. Furthermore, patients with limited access to male infertility specialists might benefit from home semen testing. These devices allow men to conduct semen testing in a stress-free environment and interpret their own results. Various home sperm testing devices were introduced in the last few years to meet the need for men with infertility who cannot access an andrology lab or do not feel comfortable in a laboratory setting for semen testing. The efficiency and the accuracy in analyzing the semen varies among the different type of devices. In general, the home-based testing devices are easy to use and can save time. Currently, available home sperm testing devices are developed based on microfluidics in association with smartphone technology, centrifugation technique (Trak male infertility testing system) and immunodiagnostic assay (Spermcheck vasectomy, SpermCheck fertility, FertilMarq).⁶

**FDA approved home sperm testing devices**

Existing options for home semen testing approved by the U.S. Food and Drug Administration (FDA) include SpermCheck, Fertilmarq, Trak and Yo. SpermCheck is an immunodiagnostic device used to assess whether sperm concentration is less than or greater than 20 million/mL.⁷ This lateral flow test is developed using monoclonal antibodies specific to acrosomal protein SP-10 expressed on spermatid and spermatozoa. The monoclonal antibodies bind to a sperm surface antigen called SP-10 which has been shown to be a marker of sperm count.⁷ They report that the test was accurate in detecting normozoospermia, oligospermia or severe oligospermia in 96% of patients.⁷

A similar type of immunochromatographic test has been applied to the postvasectomy patient population as well to avoid a return to the clinic for postvasectomy semen analysis to ensure sterility.⁸ Users can interpret the results as normal and abnormal based on the concentration of the spermatozoa in their semen sample. Both SpermCheck and SpermCheck vasectomy are very easy to use and provides results in a very short period of time. Each strip costs about $40.⁶

Trak, like other home-based testing kits, measures the sperm concentration. It is a portable desktop gadget that sells for approximately $150 and syncs with your mobile phone. The device centrifuges a semen specimen generated at home and gauges the level of the column of sperm cells to predict a concentration using a microfluidic device.⁹ Schaff *et al.* showed that the device had a strong linear correlation with computer-assisted semen analysis (r=0.99). The device was approved by the FDA in 2016.

**Smartphone-based home sperm testing devices**

The technology and options available in a smartphone make them a user friendly device ideal for home sperm testing. Several groups have introduced new devices to meet the needs of smartphone-based semen testing.¹⁰ Kobori *et al.* developed a single-ball lens microscope attachment for smartphones to be used for semen testing.¹¹ A small aliquot of the semen sample is placed on a polyethylene sheet that attaches to the single-ball lens microscope device by magnetic force. The smartphone camera is then able to generate a movie clip of the sperm which is then projected on to a computer screen to enable manual counting and motility assessment. The sensitivity and specificity of accurately diagnosing oligospermia (concentration <15 million/mL) when compared to computer-assisted semen analysis varied by the type of smartphone used, ranging from 75.5% to 90.9% for sensitivity and 87.8% to 90.9% for specificity. The authors report the cost of the attachment is $7. The need for a computer to analyze results is a limitation of this device. Additionally, concentration and motility are only reported parameters although these are arguably the two most important.

An automated smartphone-based point-of-care device was developed by integrating microfluidics and optical sensing technology with smartphones.¹² This device can determine motility and concentration of the semen samples with >98% accuracy. Microfluidic slides loaded with 35 µL of semen sample are inserted into the optical device attached to the smartphone. The optical attachment is aligned to the smartphone camera and captures the movement of the spermatozoa. The material cost of the microfluidic accessories was estimated to be less than $5. Even though this device can assess the sperm motility and concentration, it can falsely identify the round cells and artifacts as spermatozoa.

**FDA approved smartphone-based home sperm testing devices**

The most recent FDA-approved home sperm test introduced into the market is the YO Home Sperm Test
The ideal semen test would provide rapid, reliable, inexpensive, point-of-care results for sperm concentration, motility and morphology. Motility in particular allows the calculation of total motile count which is used by reproductive endocrinologist to drive the selection of assisted reproductive techniques.

A smartphone-based platform for laboratory testing has been applied in other fields. Zhu et al. describe a smartphone program that can calculated hemoglobin and white blood cell concentration. Smartphones have the following advantages for home analysis of human bodily fluid: high resolution, digital camera, easy of sharing results with members of the healthcare field, memory to store data in a secure fashion. Smartphones are also available to the majority of the population, an additional advantage particularly useful for male fertility assessment given that there are not male infertility specialists in many regions of the world. The challenge lies in developing a smartphone-based test with high sensitivity and specificity that can provide information beyond simply a count at an affordable cost to the consumer.

The emerging use of mobile phones as testing devices establishes the smartphone as a powerful platform for home diagnostic testing because this portable platform incorporates technology for processing vast amounts of information, communication, onboard sensing modalities and engaging human interactive interfaces. Ultimately, a home test platform should provide the consumer with sufficient clinically accurate and relevant information so that one can make a determination to seek further professional medical advice or not.

An accurate detailed male fertility assessment requires a history and physical by a subspecialized physician. Unfortunately, this cannot occur in several parts of the world. The advent of home testing using a smartphone is valuable addition to the male fertility space given that many men do not have access to an assessment or prefer to have a preliminary assessment at home. It is important that the manufacturers of these devices communicate the limitations of these tests and remind the patients to consult physicians for a formal evaluation.

### Limitations

Home-based sperm testing kits have several limitations over the conventional semen analysis performed at andrology laboratories. The smartphone based sperm testing devices provides only basic semen parameters such as sperm count or MSC. In some cases, failure to follow the manu-
factor’s instructions may lead to false negative results, which may delay the actual diagnosis or treatment process. Additionally, young men are often not well interfaced with the healthcare system, so a formal fertility assessment can be beneficial to them. A home-based screening test cannot replace an office visit with a physician.

Conclusions

Smartphone-based home sperm testing devices may allow for a cursory fertility assessment given that male infertility specialist access is limited. Ease of use and low cost nature of the home sperm testing devices brings a form of fertility assessment to all male patients.

References


Conflicts of interest.—The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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