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An Update on the Use of Wearable Devices in Men's Health

Farhan M. Qureshi^{1,2}, Roei Golan³, Armin Ghomeshi⁴, Ranjith Ramasamy¹

¹Desai Sethi Urology Institute, Miller School of Medicine, University of Miami, ²Medical Scientist Training Program, University of Miami Miller School of Medicine, Miami, FL, ³Department of Clinical Sciences, Florida State University College of Medicine, Tallahassee, FL, ⁴Department of Urology, Herbert Wertheim College of Medicine, Florida International University, Miami, FL, USA

Men's health represents an often-overlooked aspect of public health. Men have higher mortality rates worldwide and are more negatively affected by chronic conditions such as obesity and heart disease, as well as addiction to alcohol and tobacco. Men also have health issues such as prostate cancer and male sexual dysfunction which only affect them. Because of the skewed burden of morbidity and mortality on men, it is imperative from a public health perspective to make a concerted effort to specifically improve men's health. The use of wearable devices in medical practice presents a novel avenue to invest in men's health in a safe, easily scalable, and economic fashion. Wearable devices are now ubiquitous in society, and their use in the healthcare setting is only increasing with time. There are commercially available devices such as smart watches which are available to lay people and healthcare professionals alike to improve overall health and wellness, and there are also purpose-built wearable devices which are used to track or treat a specific disease. In our review of the literature, we found that while research in the field of wearable devices is still in its early stages, there is ample evidence that wearable devices can greatly improve men's health in the long-term.

Keywords: Men's health; Preventive medicine; Wearable device data; Wearable devices; Wearable technology

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INTRODUCTION

Sex and gender can dictate how diseases affect individuals physically, mentally, and socially. Surmounting these differences remains a unique challenge in healthcare, particularly when it comes to men's health. Data from the Human Mortality Database indicates that worldwide, men aged 15–40 die at a rate 2–3 times higher than women, and that this gender gap in mortality continues to increase with age [1]. Men also experience higher mortality in nine out of the ten

highest causes of death in the United States [2]. While this gender gap in mortality should be of utmost concern, it is important to note that men also have generally worse outcomes when considering diseases that place a large burden on the healthcare system [3,4]. Therefore, focusing on men's health issues before they lead to mortality should remain a critical facet of public health initiatives that aim to reduce the strain on already overburdened healthcare systems worldwide. Specific issues which disproportionately affect men include lack of involvement in healthcare decisions, in-

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Correspondence to: Ranjith Ramasamy <https://orcid.org/0000-0003-1387-7904>

Desai Sethi Urology Institute, Miller School of Medicine, University of Miami, 1120 NW 14th St, #1551 Miami, FL 33136, USA.

Tel: +1-305-243-6090, **Fax:** +1-305-243-6597, **E-mail:** Ramasamy@miami.edu

Table 1. Wearable devices in men's health

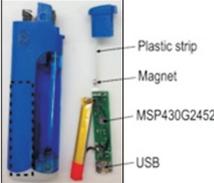
		Device	Parameter
Alcohol and tobacco use	Secure Continuous Remote Alcohol Monitor		Measures transdermal alcohol content. Traditionally used for court-monitored sobriety.
	BACtrack Skyn		Measures transdermal alcohol in real time. Suitable for consumer use.
	Smartphones		"Drunk User Interface" apps measure errors in typing and can measure level of intoxication in real time.
	Acoustic Sensors		Measures smoking-related breathing patterns and measures the number of "smoking puffs" per cigarette.
	PACT2.0		Provides geographic analysis of smoking behaviors through GPS tracking information.
Obesity and heart disease	Nicotine s-band		Sweat band that monitors nicotine levels. Used to measure nicotine exposure through second hand smoke.
	Fitbit		Features step count, heart rate, and motivational reminders. Designed specifically to monitor physical activity progress.
	Smartwatches		Step count, heart rate, blood pressure, and ECG monitoring are features of commercially available devices.
	Amulet Wearable		Smart-watch device specifically created to enhance activity in the elderly population.

Table 1. Continued

	Device	Parameter
	<p>Bioelectrical Impedance Analysis (BIA) Device</p> 	Gives real time measurements of body fat.
	<p>Wrist-worn Oscillometric Blood Pressure Monitor</p> 	Used for continuous blood pressure monitoring with similar accuracy to pressure cuff monitors.
Male sexual health	<p>FirmTech ring</p> 	Monitors penile tumescence, rigidity, and frequency of nocturnal erections.
	<p>Apollo™ Wearables</p> 	Provides vibrations to the skin with adjustable intensity and frequency.
	<p>Morari Medical Device</p> 	Device placed on perineum claiming to stimulate nerves to delay premature ejaculation.
	<p>Viberec</p> 	Penile vibrator claiming to cause a well-tolerated erectogenic effect.

creased rates of tobacco and alcohol use, increased rates of obesity and heart disease, prostate cancer, and male-specific sexual health. These men's health issues incur a significant economic burden on our healthcare system; therefore, it stands to reason that we must invest specifically in men's health. However, despite current efforts to invest in public health infrastructure, men's health has not been made a top priority at a national level [2,4-6].

Wearable technology represents a novel way to invest in men's health in a safe, effective, and economic manner. While the use of wearable technology in healthcare seems like a far-off concept, the idea of

wearable devices has been around for some time. The first wearable computers were developed in the 1960s, and in the six decades since, wearable device technology has improved exponentially [7]. Wearable devices come in many forms, both in research applications as well as commercially available products. Some of the most recognizable smart devices are smart watches and smart glasses produced by companies such as Apple or Google, but other wearable devices with healthcare applications include smart garments, hand and foot-worn devices, patch-embedded sensors, and implants [8] (Table 1). Because of their portability and ability to continuously monitor patients, wearable devices

enhance access to care in underserved areas by providing users another mode of interaction with healthcare providers without having to go to the hospital or doctor's office [9]. In addition, wearable devices may help surmount psychosocial barriers to receiving healthcare, such as anxiety or embarrassment, by limiting the necessary number of appointments and hospital visits for patients. Perhaps the most widely studied wearable technologies currently used in healthcare are the continuous glucose monitors (CGMs) and insulin pumps used by diabetics. These devices make a time-consuming and uncomfortable task (*i.e.*, blood glucose measurement, insulin injection) into a simple, almost automatic process. CGMs and insulin pumps are wearable devices shown to be superior to traditional methods [10] and are widely used by 40% of patients with type 1 diabetes [11]. Thus, wearable devices have already been shown to be a powerful tool for improving health. With regards to men's health specifically, there have been great strides in using commercially available wearable devices to manage chronic medical conditions, while custom devices such as FirmTech's erection ring (<https://myfirmtech.com/>) and Morari Medical's premature ejaculation patch (<https://morarimedical.com/>) represent a new frontier in wearable technology for men's sexual health. In the following review, we have identified five different domains of men's health, and outline how both tailor-made and commercially available wearable devices are used in the management of these conditions.

HEALTHY LIFESTYLES AND WELLBEING

Gender differences play a significant role in shaping the overall decision-making process and health-related behaviors [12]. Past research has shown that men are more likely to engage in risky behaviors [13]. This can lead to poorer health outcomes and chronic illnesses with earlier age of onset. Furthermore, previous studies have shown men have increased mortality and morbidity rates across various illnesses such as cancer and heart disease [14]. This is partly because men are less likely to undergo routine health screenings that can detect certain conditions earlier on to prevent complications of different chronic diseases. For example, past research shows that screening for colorectal cancer, diabetes, and cholesterol levels were all lower in men

compared to women [15].

This data therefore suggests that poorer health outcomes in men are because they are less likely to be proactive and engaged in health-promoting behaviors. Through more frequent primary care visits and routine physical/mental health examinations, different illnesses and complications of chronic diseases can be prevented. The HEYMAN study demonstrated that targeted intervention programs using wearable activity trackers are an effective strategy to promote healthy lifestyle behaviors in young men [16]. Activity trackers such as the FitBit are well established as feasible and reliable technologies, and findings from studies in men with prostate cancer support the integration of fitness tracker data into clinical care [17]. Through resources such as support videos, physical activity trackers, and private discussion groups, men can more easily take responsibility for their health. Healthcare professionals often find that the use of wearable devices improves patient involvement and compliance with treatment [18,19]. Routine doctor appointments may be more difficult for patients to comply with due to lack of access and time, however more feasible, yet effective, options can still be implemented through the use of wearable devices. While wearable devices can be used to improve patient compliance, it is still possible that patients with inadequate health literacy may misinterpret wearable device data and delay seeking out appropriate and timely medical care. However, clinicians can use information from wearable devices when counseling patients on various healthy lifestyle modifications, and increase men's engagement with their health. Ultimately, physicians need to continue using novel technologies to encourage men to keep up with routine health screenings and prioritize their physical and mental wellness.

TOBACCO AND ALCOHOL USE

Generally, men are more likely to drink alcohol than women [20]. Not only do men drink more frequently than women, they have a higher tendency to drink greater volumes in one setting [21]. There have been different theories postulating as to why this trend exists. The idea of masculinity and conforming to social norms may explain why men, particularly adolescents and young adults, feel obligated to drink excessively [22]. Alcohol use not only leads to biological damage

to the human body, but also correlates with increased risk-taking behaviors which are also more prevalent in men. Excessive alcohol consumption can lead to severe liver disease, neuropsychiatric deficits, and various malignant cancers [23]. Risky behaviors associated with alcohol dependence include driving under the influence, vehicle accidents, and violence [24]. Ultimately, uncontrolled alcohol use can lead to a slippery slope that seems to negatively impact men's health at a higher rate. Smoking is another maladaptive habit behavior that is more frequently seen in men [25]. Men have also been shown to smoke more cigarettes per day than women [26]. Higher smoking rates may be due to the longstanding trend that men are less likely to seek psychiatric help for mental health issues, and as a result, do not learn healthy coping mechanisms [27]. Rather than addressing their problems, males feel obligated to internalize stress and anxiety, which has been historically shown to lead to unhealthy behaviors such as smoking [28]. With the emergence of the vaping epidemic, adolescents have recently become one of the most vulnerable populations to the harmful effects of tobacco smoking. In addition to the traditional negative effects of smoking such as respiratory diseases and cancers, tobacco use at a younger age has been linked to fertility problems and impotence [29].

Wearable devices are available that monitor alcohol levels and intoxication. A commonly used product in clinical trials, the Secure Continuous Remote Alcohol Monitor (SCRAM), uses transdermal measurements to record alcohol content in sweat and absorption and elimination rate of alcohol [30]. However, these devices are bulky and instead, wrist-worn biosensors are a less invasive method of continuous monitoring of alcohol consumption. As opposed to the SCRAM, there are devices such as the BACtrack Skyn that can measure fluctuations in alcohol intake and are more suited for those who are interested in cessation [31]. However, this device is only available as a prototype and not for consumer purchase as improvements are needed to make the product durable and accurate. Furthermore, some sensors measure behaviors that can be altered due to alcohol consumption, such as gait, rate of typing on a mobile device, and number of errors made while typing [32]. This allows people to continuously monitor the negative effects of alcohol on their bodies in real time.

Due to the continued public health threat from tobacco smoking, various products monitor nicotine levels

and assist in smoking cessation. In order to monitor smoking rates in individuals, wearable sensors are available. Some products allow for the measurement of the frequency of "smoking puffs" per cigarette and also calculate the number of cigarettes smoked in various intervals (hours, days, *etc.*) [33]. Wearable devices provide objective data to users about their smoking habits, allowing users to more deeply analyze their smoking behaviors and eliminate memory biases, which is beneficial for those who are attempting to reduce their smoking habits over a long period of time. [34]. Wearable sensors, such as the Personal Automatic Cigarette Tracker v2, or PACT2.0, have GPS function, allowing for analysis of smoking events based on the individual's location [35]. This novel feature can provide new insights into smoking habits and can be important for targeted interventions for smoking cessation. Currently, there is a wearable sweat band that measures nicotine levels in sweat that is excreted during physical activity [36]. This can be particularly useful for people who are concerned about secondhand smoke and can determine in real-time their nicotine exposure when they are interacting with those who are smoking.

OBESITY AND HEART DISEASE

Obesity is a global epidemic, with skyrocketing obesity rates worldwide. Since 1975, worldwide obesity rates have tripled [37], and men remain the most affected by this disease. In the United States, 34.1% of men are overweight, and 43% are obese, compared to 27.5% and 41.9% of women respectively [38]. While obesity itself is a disease that contributes to morbidity and mortality, it is inextricably linked to cardiovascular disease, which is the leading cause of death worldwide [39,40]. Obesity contributes to heart disease indirectly by leading to cardiovascular risk factors such as type 2 diabetes mellitus, hypertension, and sleep apnea; however, it is also a direct contributor to cardiovascular morbidity and mortality in and of itself [41]. In fact, obesity is the dominant risk factor for heart disease in men. Lowering BMI to $<25 \text{ kg/m}^2$ would reduce the 10-year risk for coronary heart disease in men by 47%, even after correcting for other contributing factors [42]. Overall rates of cardiovascular disease are higher in men until age 80, which has been attributed to inherent biological differences between men and women in the pathogenesis of cardiovascular disease (*e.g.*, cardioprotective

effects of estrogen), as well as increased prevalence of risk factors such as obesity in men [43]. However, men also continue to have increased cardiovascular mortality independent of nearly all major risk factors, including obesity [43-45]. The inherent risk for obesity and cardiovascular disease in men, and the overall burden it places on healthcare systems worldwide makes this a ripe target for innovative strategies involving cost-effective and highly efficient wearable tech devices.

Already, wearable technologies are being used to target obesity and heart disease. In England, the National Health Service (NHS) has begun distributing wearable devices as part of a program for obesity prevention [46]. The major goal of wearable tech devices is to increase physical activity and encourage weight loss and healthy habits [47]. Commercially available devices such as the Fitbit, and smartwatches produced by Apple, Google, Samsung, *etc.* include activity trackers, step counters, heart rate monitors, as well as encouraging messages which motivate and enable users to increase physical activity. It has been shown in numerous clinical trials that the use of these off-the-shelf devices significantly increases physical activity and weight loss in overweight and obese patients [47-50]. New, custom wearable devices are also being developed specifically for weight loss. A new device is being developed to specifically target the elderly population which may not as easily adopt current wearable devices [51]. Another example of a custom device for obesity is a prototype bioelectrical impedance analysis (BIA) device which provides real time analysis of body fat percentage comparable to that of a DEXA scan [52]. These devices, while still in their nascent stages, represent a new frontier in wearable device technology that will be used to fight obesity in many populations. However, it is important to note that more research needs to be done in this field. Because of the complexity of factors that affect weight loss, studies cannot assess whether wearable devices independently affect weight loss [47,49,53,54]. Regardless, based on current evidence, it is still recommended that health care professionals should consider adopting this technology to promote weight loss in obese patients [47,53].

Beyond tracking activity to promote weight loss, wearable devices can help treat heart disease by directly tracking heart rate, rhythm, blood pressure, and other biochemical parameters [55-57]. Studies have validated wrist-worn oscillometric and cuffless wear-

able devices for continuous blood pressure monitoring. The use of these devices facilitates patient adherence to blood pressure checks and allows physicians to use accurate data to screen patients for hypertension and guide treatment [58-60]. Similar technology has been studied more extensively for heart failure patients. In one study, patients who were managed with a portable pulmonary arterial pressure monitor had a 39% reduction in heart failure-related hospitalization [61]. In other studies, heart failure patients managed with a multi-wearable device strategy (wearable ECG monitor, blood pressure monitor, and O₂ sensor) had lower all-cause mortality [62,63]. While wearable device strategies for hypertension and heart failure require more specialized equipment, management of arrhythmias such as atrial fibrillation is more feasible with commercial systems. Studies indicate that the Apple Watch and other smartwatch devices have clinically acceptable accuracy for heart rate measurements and had a specificity of 94% and sensitivity of 93% in detecting atrial fibrillation [64,65]. The use of these devices will allow patients to target when they take medications, such as anticoagulants, only when an irregular pulse is detected [66,67]. While many devices marketed towards managing cardiovascular disease have passed U.S. Food and Drug Administration (FDA) clearance, none has achieved stringent FDA approval yet [55]. Thus, reflecting the necessity for more research in this arena. Overall, it is evident that while more research is needed, both commercially available and custom-made wearable devices are the future of healthcare when it comes to obesity and heart disease, which are two major facets of men's healthcare and overall public health.

PROSTATE CANCER

Prostate cancer is the most common cancer in men worldwide [68]. While appropriate timely doctor appointments are the most effective primary prevention method, it is also necessary to improve quality of life in men with current or previous diagnosis. Improvements include exercise, diet, and weight control, all of which are recommended in most instances [69].

In a pilot study using wearable devices, vigorous activity, brisk walking, smoking cessation, and six dietary improvements were tracked in men with prostate cancer [70]. Diet improvements included replacing solid fats with vegetable oils, consumption of cruciferous

vegetables, cooked tomatoes, fish, and avoiding all processed meat and single vitamin or mineral supplements (unless medically prescribed; multivitamins or fish oil were allowed). Findings of the study indicated that the group with wearable devices significantly improved in all outcomes involving healthier lifestyle choices when compared to the control group. Outcomes at 12 weeks indicated that the intervention arm with wearable devices significantly improved in consumption of cooked tomatoes, cruciferous vegetables, fish, and processed meat, but not vegetable fat. Furthermore, moderate to vigorous activity, and steps per day increased in comparison to control, but not to the extent of statistical significance [70].

Lee et al [71] observed the use of wearable pedometers and smartphone applications in men treated with androgen deprivation therapy for prostate cancer. It was found that both wearable pedometers and smartphone applications significantly improved physical exercise and function while preserving a high rate of maintenance [71]. While most studies discuss positive findings on the effects and compliance of wearable technologies, it is important to continue finding methods to improve patient compliance. These studies provide evidence that wearable technologies are acceptable and feasible which is important to reduce non-compliance [72]. Other studies on patients with cancer provide similar results on feasibility and compliance with wearable technologies [72]. A recent study found that wearable technologies that provided generated data to patients increased the likelihood of users, compliance, and engagement [73].

MEN'S SEXUAL HEALTH

Wearable devices may also be implemented in men's sexual health. A variety of products are currently marketed in sexual health. Yet, research remains scarce or absent in this field. A penis ring known as FirmTech™ ring is marketed as a device that can indicate cardiovascular health, the duration of erection, and the firmness of the penis. Although there are currently no published studies on its efficacy, its proposed mechanism to assess changes in sexual and cardiovascular health is valid. The ring's ability to count the number of nocturnal erections over time may provide important data to patients and clinicians. Monitoring of nocturnal penile tumescence and rigidity may be a useful tool in the

evaluation of male sexual dysfunction over time [74].

Other wearable vibratory devices such as the Apollo™ Wearable provides vibrations to the body through any part of the body claiming to promote relaxation. No clinical trials have studied its efficacy and whether its vibrations are as efficacious as other established technologies used in vibration therapy. Morari Medical company is developing a wearable patch advertised to interfere with the nerve signals from the penis to the brain to delay an ejaculation. There are several management options for premature ejaculation, but none are approved by the FDA. Current studies support the off-label use of selective serotonin reuptake inhibitors, local anesthetics, and mental health assessment [75]. To our knowledge, there are no studies on devices that can treat or delay premature ejaculation. However, the HuMOVE platform is a wearable device specifically for human sexual performance analysis compatible with sexual intercourse [76]. The device is described as a helpful tool for physicians to accurately classify sexual disorders, such as premature or delayed ejaculation [76].

Another new technology in the men's sexual health space is the Viberec device. This device is a non-invasive penile vibrator claiming to cause a well-tolerated erectogenic effect [77]. Minimal clinical research indicates that penile vibratory stimulation may be an effective method to provoke erections via neuro-stimulatory principles [78]. Two clinical trials, which have since been discontinued, observed its effect on men with mild-moderate erectile dysfunction (NCT01715571) and to enhance recovery of erectile function and urinary continence post-prostatectomy (NCT01718704).

CONCLUSION

While wearable devices are still in their nascent stages in the healthcare arena, it is already evident that men's health will be positively impacted using wearable technology. Wearable devices are simple to use and implement in a healthcare setting, and can either be purchased off-the-shelf, or produced specifically for the treatment of different conditions. Already, physicians and national healthcare systems are incorporating these devices into their practice because of the accurate user feedback, monitoring, and awareness they provide [7,18]. Meanwhile, continuous technological advancements are increasing the accuracy of measurements made by wearable devices, while also expanding

their use for a variety of different diseases. As these advances are made, we expect wearable devices to have more integration in the management of men's health.

Conflict of Interest

The authors have nothing to disclose.

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Author Contribution

Conceptualization: RR. Investigation: FMQ, RG, AG. Writing: FMQ, RG, AG, RR.

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