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Clinical and research concerns with vibratory stimulation: a review and pilot study of common stimulation devices

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The parameters of vibrators used for sexual stimulation in laboratory settings and therapeutic contexts are usually unknown. The unidentified range of vibrator characteristics commonly used for sexual stimulation would help identify appropriate vibrator for different purposes and clients. Seven vibrators used for sexual stimulation were tested using a piezoelectric accelerometer mounted on their housing to quantify frequency, displacement, and acceleration of each. Vibratory frequency ranged from 43 to 148 Hz, displacement from 37 to 783 μm, and acceleration from 18 to 311 m/s^2. The range suggests vibrators used in laboratory studies could greatly increase their stimulation, while some devices actually may decrease sexual sensitivity temporarily. An in vivo study could characterize patterns of use that could maximize sexual arousal while mitigating potential loss of sensitivity.

Keywords: vibrator; sexual arousal; anorgasmia; delayed ejaculation

Introduction

In the book *Becoming orgasmic: A sexual growth program for women* (Heiman & LoPiccolo, 1988), women with anorgasmia are encouraged to "feel comfortable enough to explore vibrators as another means of learning about [themselves]" (p. 105). The progressive, directed masturbation exercises outlined in that book appear to be a common aspect of anorgasmia treatment (Heiman & Meston, 1997; Leff & Israel, 1983; Morokoff & LoPiccolo, 1986). The possible efficacy of vibrators in anorgasmia has even led to suggestions for using vibrators to induce sexual satiety to supplant risky sexual fetishes (Martz, 2003), induce anti-nociceptive processes in women with vulvodynia (Zolnoun, Lamvu, & Steege, 2008) and increase the breadth of sexual repertoire to increase sexual satisfaction even when a "problem" *per se* is not present (Striar & Bartlik, 1999). Unfortunately, recommendations for selecting a vibrator still largely conclude, "Do some shopping around" (Heiman & LoPiccolo, 1988, p. 107) or vary widely, with little empirical information about the vibratory devices. Given the tremendous variability in genital physiology, stimulation preference and orgasm consistency, this descriptive study described the range of stimulation parameters of several common vibratory stimulation devices. These data provide some empirical basis from which clinicians could work with clients to

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identify vibrators of the desired intensity for the particular client preferences. Not only can more or less intense devices be clearly communicated based on different parameters, but it could raise other concerns (e.g., neuropathy) if client preferences are strongly outside of the maximum or minimum in these ranges.

Laboratory use of vibrators with women

Laboratory studies still induce sexual arousal almost exclusively with visual sexual stimuli, although a few have explored vibratory stimulation as a way to better control the level of stimulus delivered. Film stimuli are vulnerable to individual differences in attention to different components of the stimuli (Rupp & Wallen, 2007), preference for specific content (Janssen, Goodrich, Petrocelli, & Bancroft, 2009) or clinical histories making portions of the stimuli aversive (Wouda et al., 1998). Sexual fantasy relies on the ability of the participant to fantasize effectively, and fantasy often results in no, or lower, levels of sexual arousal (Laan, Everaerd, Van Aanhold, & Rebel, 1993). The resulting uncontrolled levels of sexual arousal always leave the possibility that the stimulus strength varied by individual rather than the intentionally manipulated variable of interest. Vibratory stimulation may offer a method to control at least the level of stimulation input more tightly.

In the few studies using vibrators for women to self-stimulate, most provide very little information about the vibrator or women's use of it (Basson & Brotto, 2003; Levin & Wagner, 1985). One of the first reports using a vibrator to induce sexual response in women appeared in 1976 (Van Dam, Honnebier, Van Zalinge, & Barendregt), which asked women to self-stimulate for three minutes with a vibrator. Another study described the stimulation as a "10 minute vibrator stimulus" (Bechara, Bertolino, Casabe, & Fredotovich, 2004, p. 210) and another as to "allow them to self-stimulate their clitoris" using "clitoral vibration" to orgasm (Levin & Wylie, 2008).

Surprisingly, experimenters rarely attempt to control the vibratory stimulation level for stimulation in women. Experimenters successfully conditioned sexual response using two second stimulation periods from a 2cm butterfly-style ("hands-off") vibrator (Both et al., 2008). Laan and van Lunsen (2002) used vibratory stimulation to successfully induce orgasm in all the female participants in a laboratory study, which has been reported only in poster format to date. These 10 women all were orgasmic prior to the study, although half denied having ever used a vibrator before. Women adjusted the frequency to what they felt was "sexually arousing", but the associated vibratory parameters are not reported. Only one publication includes the exact settings of an experimenter-controlled vibrator. Gillan and Brindley (1979) used an air sack pneumatically linked to a vibrator and attached to the clitoris with eyelash glue. They describe frequencies between 30 and 130 Hz as "effective" and used 80 Hz for controlled stimulation. Their device extended 4 mm over the clitoral hood and 6 mm along the labia minora, vibrating at an amplitude of 2 μm. They reported response latencies from two to four seconds. A difference from the male literature, they noted no difference in response magnitude between vibratory and fantasy stimulation.

A number of challenges exist to using vibrators to induce sexual arousal in the laboratory. Sexual arousal reduces vibratory thresholds across high and low frequencies (Chuanshu, Peter, Patricia, & Turman, 2007), so vibrators used for sexual stimulation may also need to accommodate acute sensitization if used on individuals who already are sexually aroused. Longer time between intermittent stimulation or lower speeds may accomplish this. Also, vibrators increase sexual arousal only when presented in a sexual context, but not when presented in isolation. Thus it still would be necessary to identify the minimal sexual context necessary for the vibrator to be processed as a sexual stimulus. Finally, the identification of optimal vibrator characteristics and patterns of stimulation are needed. The mechanical data sampled herein provide a range of common stimulation intensity to assist in instrumentation and study design.

Researchers primarily have used erotic films to induce sexual arousal. The films initially excluded actual intercourse (Hoon, Wincze, & Hoon, 1976). Subsequently, films were recommended to include ''female-initiated, female-centered erotic videotape[s]'' (Laan, Everaerd, & Evers, 1995, p. 447) and better specify the behaviors portrayed (e.g., excluding violence, including foreplay: Hamilton, Fogle, & Meston, 2008). Today, most film stimuli are edited to portray equal lengths of foreplay, then oral sex and then vaginal intercourse (Janssen, Carpenter, & Graham, 2003). This approach confounds time and stimulus intensity, making differences in responses difficult to interpret. Furthermore, presenting films in this way seems to rest on the assumption that foreplay and oral sex are needed to ''warm up'', whereas women actually report being more aroused by intercourse (Woodard et al., 2008). Sexual arousal might be maximized in brief periods, and the time confound removed, by presenting primarily intercourse. Still, individuals will vary tremendously in the visual cues that signal sexual arousal to them (Graham, Sanders, Milhausen, & McBride, 2004). Aside from erotic films, researchers have also used imagery (e.g., Dekker & Everaerd, 1993), guided imagery (e.g., Harrell & Stolp, 1985), photographs (e.g., Laan & Everaerd, 1995), fantasy (e.g., Smith & Over, 1987; Youn, 2006), manual self-stimulation (e.g., Sipski, Alexander, & Rosen, 1995) and manual clitoral stimulation alone (e.g., Sipski, Rosen, & Alexander, 1996).

Non-genital vibratory stimulation

Vibration can be detected on most non-genital skin locations at <1 Hz, although individual differences in physiology can alter thresholds, such as subcutaneous fat increasing perceptual thresholds (Bikah, Hallbeck, & Flowers, 2008). Mechanoreceptor types and density vary considerably by skin type at different locations on the body. These differences in mechanoreceptors produce reliable differences in the ability to sense lower and high frequency vibrations. For example, vibrations at low frequencies (e.g., 25 Hz) are detected more easily over glabrous (hairless, e.g., fingertips) than sebaceous (hairy) skin, but higher frequency vibrations do not show this difference by type of skin (e.g., 200 Hz: Mahns, Perkins, Sahai, Robinson, & Rowe, 2006). This greater sensitivity (lower threshold) to higher frequencies tends to persist even under intradermal lidocaine (Mahns et al., 2006). Interobserver assessment of vibratory threshold in globulous skin after only a 15 minute lag only ranges from low to moderate (ICC = .32 to .88: Peters, Bienfait, de Visser, & de Haan, 2003). Intraobserver reliability is much higher, so distinctions within an individual probably can be made. However, low-interobserver reliability means that different clinicians measuring patients probably cannot use this information to make meaningful clinical distinctions. The clitoris is comprised largely of Merkel disk receptors (Berman, Adhikari, & Goldstein, 2000), mechanoreceptors that are most sensitive to vibrations between 5 and 15 Hz. In contrast, penile dermis has scattered Pacinian and Ruffini mechanoreceptors (Halata & Munger, 1986), which are sensitive to high frequency (250 Hz) and stretch, respectively. While vibratory threshold studies in non-genital regions suggest that men and women do not differ in their general sensitivity to vibratory stimulation (Bikah et al., 2008), physiology suggests that their genital vibratory thresholds should differ.

A vibrator, simply put, is a vibrating motor. Placed inside a housing, a vibrator can provide stimulation that induces sexual arousal. The housing material varies widely, but typically is some form of plastic in vibrators designed for sexual stimulation.

The vibrating motor is made of an external ring or bearing fastened on a shaft, which provides a rotational motion when provided with current (Ragulskis, Jonusas, Kanapeckas, & Juzena, 2008). As the shaft spins, the weight generates centrifugal force, causing it to vibrate around the shaft location (see Figure 1). In addition to weight and housing characteristics, the voltage supplied to the motor affects the strength of the vibration that is transferred to the housing (Ragulskis, Jonusas, Kanapeckas, & Juzena, 2008). Battery-powered vibrators typically have smaller, lighter motors designed to operate on the relatively low current of batteries. Vibrators that take power from a wall outlet receive 120V in the United States (220V in Europe), so they may sustain less variable, higher rate and/or greater displacement vibration. Vibrators can be characterized in terms of their frequency, displacement and velocity. *Frequency*, the number of revolutions of the weight per unit time, is usually quantified in hertz (Hz, cycles per second: Giancoli, 1988). *Displacement* refers to the change in position of a point in reference to a previous position. Thus,

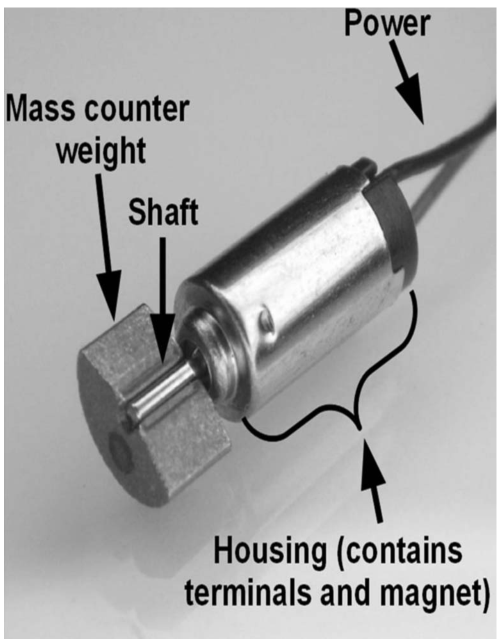

Figure 1. Common vibratory motor showing counterweight that displaces housing when shaft is rotated. Used with permission from Precision Microdrives.

a vibrator with high displacement values is swinging farther through space with each revolution. *Acceleration*, or the rate of change of position, is calculated using displacement, speed and direction. Generally, vibrator motor specifications are available from the motor manufacturer. However, motor specifications are problematic to be used as a direct indicator of vibrator characteristics for sexual stimulation for several reasons. First, the vibratory motor manufacturer was not indicated on any of the devices examined for this study, suggesting it would be difficult to find the specifications. Second, the motor specifications depend on the power supplied, which may vary from the power actually available from batteries in the particular device. Finally, the housing in which the motor is placed will alter vibrator characteristics. For example, a heavy housing would not be displaced as far as a lighter housing. This study specifically investigated the vibratory properties within the particular housing powered by a controlled energy source to mimic the source to be used by consumers if it could be consistently applied. An *accelerometer* is a device to measure absolute motion, based on the force required to accelerate the mass (Doeblin, 1966). An accelerometer indirectly measures parameters of vibration. The accelerometer used in this study was a piezoelectric accelerometer, which records the electricity generated by a latticed substance when it is put under the force of vibration. The electric output produced is a marker of the amount of vibratory force.

Clinical and common use of vibrators

Clients may report concerns about vibrators becoming a sexual ‘‘crutch’’ or decreasing their sensitivity (Heiman & LoPiccolo, 1988). Some of these fears appear partially justified. Short-term adaptations do occur to vibratory stimulation, such that stimulation 15 seconds after a constant vibratory stimulus cannot be discriminated as well as prior to the vibratory stimulation (Tommerdahl et al., 2005). However, vibrators may be no different than manual stimulation in decreasing subsequent sensitivity. Manual massage of the anterior thigh in athletes exerts a similar dampening of sensitivity by increasing presynaptic inhibition of spinal alpha motoneurons (Povareshchenkova & Petrov, 2008). In other words, vibrators do dampen sensitivity to subsequent stimulation at the same site, but manual stimulation exerts a similar effect.

The greatest challenges to clinical use of vibrators may arise from client expectations. New users can feel the vibrator is unnatural and may have to negotiate its use with a sexual partner who is not supportive (Marcus, 2011b). Also, any ‘‘success’’ in self-stimulation to orgasm may not transfer to being able to orgasm in the presence of a partner (Meston, Hull, Levin, & Sipski, 2004), although it is unclear whether or not this problem is related to the use of a vibrator in self-stimulation. By report, using a vibrator during masturbation did not impair sexual satisfaction with a partner (Davis, Blank, Lin, & Bonillas, 1996). Vibrator use for genital self-stimulation alone and with a partner is much more common in women than men (Herbenick et al., 2009). Although 44.8% of men report having used a vibrator for sexual stimulation in their lifetime, only 6.8% of that sample initially started using a vibrator to facilitate their own orgasm (Reece et al., 2009). In contrast, 32.3% of women started using a vibrator to facilitate their own orgasm (Herbenick et al., 2010). Whether men are preferentially stimulating a female partner or identify it only as co-occuring (not causing) orgasm (e.g., Merino-Salas, Arrabal-Polo, & Arrabal-Martin, 2009) is unclear.

Men

One of the first laboratory studies to use vibratory stimulation in men used a "commercially available" device oscillating at 120 Hz with an amplitude adjustable between 5 and 50 μm covering a 1.5 by 2.0 cm area (Rowland & Slob, 1992). Erectile responses were highest to a combination of vibration and visual stimulus. Later studies used a Biothesiometer with a lower 60 Hz motor (Rowland, Cooper, & Slob, 1996). The "preferred" intensity/displacement did not differ by clinical groups (e.g., early ejaculation versus erectile dysfunction) on average. Subsequent studies found similar effects wherein visual stimuli with vibration increased penile response and, to a lesser extent, self-reported sexual response in men without sexual difficulties (Rowland, Keeney, & Slob, 2004; Rowland & Slob, 1992).

A number of studies have used vibratory stimulation in an effort to better assess and treat both erectile and ejaculation (premature/rapid or inhibited/delayed/retarded) difficulties. Men with erectile difficulties specifically exhibited lower penile circumference to vibration alone as compared to a non-patient group, although the groups of men did not differ in their penile circumference to erotic film or film and vibration together (e.g., Janssen, Everaerd, van Lunsen, & Oerlemans, 1994). Latency to ejaculation or orgasm is almost always defined by the time elapsed until the participant indicates with a button press (or similar) that they feel they have reached orgasm. It is possible to record the contractions associated with orgasm electromyographically. However, this often is measured from the anus to keep primary areas of stimulation available (e.g., Carmichael, Warburton, Dixen, & Davidson, 1994), which may be less acceptable to some volunteers or introduce confounds of additional anal stimulation or discomfort. Generally, men with lifelong premature ejaculation exhibit *higher* vibratory thresholds across genital and non-genital sites (Salonia et al., 2009; Xin et al., 1997). However, vibratory thresholds determined in the laboratory appear unrelated to ejaculatory latency in the laboratory or home (Brouke et al., 2007), which is usually the variable of more clinical interest. Some have argued that sensory thresholds must be *lower* in men with premature/rapid ejaculation because topical desensitizing agents tend to increase latency to ejaculation (Wyllie & Hellstrom, 2011), but the sensory data do not generally support this interpretation. More data support the possibility of using vibrators to assess premature/rapid ejaculation as evidenced by a shorter latency to ejaculation in those who report difficulty (Rowland, 2010). There is a patent on file (US 6814695: Wyllie & O'Leary, 2004) using a vibratory device to diagnose rapid ejaculation. This bullet-type vibrator is strapped over the frenulum and, while the stimulation level can be changed, 60 Hz was shown to reliably discriminate patients from non-patients using latency to ejaculation (Dinsmore et al., 2006). The addition of vibratory stimulation in a study including men with rapid or delayed ejaculation did not help discriminate patient groups from non-patients (Rowland, Keeney, & Slob, 2004). In fact, in a review of clinical outcome measures for studies of premature ejaculation treatments, vibrators were not mentioned (McMahon, 2008).

Vibratory stimulation has been tested for its therapeutic efficacy, or to test the therapeutic efficacy of related methods, in men. Vibratory stimulation does enhance erections in men with premature ejaculation and erectile dysfunction (Rowland, den Ouden, & Slob, 1994). Using the FertiCare vibrator (Multicept A/S, Denmark) applied to the frenulum (frequency = 100 Hz; amplitude = 2.5 mm) vardenafil was tested as a treatment for premature ejaculation (GökÇe, Demirtas, Halis, & Ekmekcioglu, 2010). Vardenafil significantly delayed ejaculation latency over placebo during laboratory vibratory stimulation. Vibratory stimulation helped distinguish between topical treatments for premature ejaculation (Xin, Choi, & Lee, 2000). Vibrators also may be helpful in facilitating orgasm in men with inhibited/delayed ejaculation. Thirty-four men reporting ejaculation difficulty used a commercially available vibrator (Pin Point Massager, Brookstone, Merrimack, NH) applied in one minute on/one minute off pattern three times in each session to the frenulum (Nelson, Ahmed, Valenzuela, Parker, & Mulhall, 2007). The study was not controlled or blinded, but men reported improved orgasm and satisfaction at three and six months of regular use. However, in a summary document on the treatment of inhibited/delayed ejaculation, Richardson and Goldmeier (2006) found the evidence for the efficacy of vibrators in this clinical group weak. Vibrators may still be most helpful in research to better characterize the mechanism of efficacy in treatments for orgasm difficulties. For example, vibrators helped demonstrate that alpha-stimulating midodrine may be effective treating inhibited/delayed ejaculation because it lowers sensitivity thresholds, which, in turn, lower ejaculatory thresholds (Courtois et al., 2008). While relatively less common for men to use vibrators for their own pleasure, possibly due to stigma attached to using a ''woman's'' stimulation device, new studies are emerging that investigate men's use of vibrators for their own pleasure (Reece, Herbenick et al., 2010; Reece, Rosenberger et al., 2010).

Women

Most studies of women that use vibrators are testing sensitivity, but some researchers have asked participants to self-stimulate with the vibrator and, far less frequently, controlled the vibrator automatically. The vibrators used for these different purposes also varies systematically, as sensitivity testing requires greater precision over location and vibratory parameters. The first vibratory threshold study in women identified the threshold of a 100 Hz device placed on the clitoris in women without known pathology to be .27 μm (amplitude) on average with a range of .09 to .48 and standard deviation of .10 (Helström & Lundberg, 1992). The threshold was slightly higher in the hands of the same women and in women who had a hysterectomy. A subsequent study tested intravaginal and clitoral stimulation at 100 Hz with a range of 0–130 μm (Vardi, Gruenwald, Sprecher, Gertman, & Yartnitsky, 2000). On an ascending test of limits, clitoral thresholds averaged 1.75 μm and vaginal thresholds averaged 7.38 μm, consistent with the dense innervations of the clitoris (Martin-Alguacil, Pfaff, Shelley, & Schober, 2008) and self-reported areas of sensitivity (Schober, Meyer-Bahlburg, & Ransley, 2004). Thresholds may be lowered by vasoactive agents (Berman et al., 2001) and sexual arousal and orgasm (Gruenwald, Lowenstein, Gartman, & Vardi, 2007). Thresholds are higher in regular bike riders as compared to runners (Guess et al., 2006) and in women with sexual dysfunction (Esposito et al., 2007). Multiple studies support that women's vibratory thresholds to increase as they get older (Connell et al., 2005; Guess et al., 2006; Vardi et al., 2000).

Methods

The decision to test vibrators mechanically, rather than *in-vivo*, was primarily made for the greater level of control available in the mechanical environment. Of course, users may hold the devices at different locations, press with different force, different grip force, have more or less pubic hair or fat, use some of the devices internally preferentially or have clitoral glans less sensitive to particular testing ranges. Rather than attempt to control dozens of unknown material and physical variables, this pilot study represents a first attempt to work from stimulus preference ''backwards'' to allow the development of likely more appropriate stimulation devices for research and some guidance for clinicians in the future.

Vibrator models were selected using three methods: (1) searches conducted in spring of 2009 for highly-rated vibrators across multiple Internet sites selling sexual aids, (2) recommendations of colleagues in clinical practice performing sex therapy and (3) two additional vibrators with atypical housing. Since most clinical and research applications to date with women have not used devices that insert into the vagina, and to maximize potential comparability with male stimulation, only vibrators designed to be used externally were considered. To meet criterion (1) the popularity/sales of stimulation devices on Internet sites selling vibrators characterized as ''for sexual stimulation'' (e.g., Amazon.com) were used to rank order the devices. The top five selling vibrators from each website in Spring 2009 were cross-examined and the three vibrators that occurred most frequently on these top-seller lists were included. Two additional models were selected based on input from colleagues in clinical practice from professional listservs (e.g., SexLab). One vibrator was added at the author's discretion due to its atypical thin ''petal'' stimulation area that might have vibratory characteristics distinct from the other vibrators.

Accelerometer

A quartz piezoelectric accelerometer (PCB Piezotronics) with 10.46 mV/g sensitivity at 100Hz was used. It weighed .05 oz, which should minimize reactive vibrations of the accelerometer back against the vibrating motor. Its sampling range from 1 to 1000 + Hz very adequately covers the likely range of vibrator parameters based on published studies. The output of the piezoelectric transducer is a continuous, time-varying voltage that is measured as a discrete voltage at the sampling rate and then converted to acceleration (m/s^2) by a proportionality factor specified with the sensor's manufacture calibration.

Procedure

Flat, even surfaces are ideal for mounting the accelerometer, but none of the vibrators tested had a flat surface. Identical washers were affixed to each vibrator with ceramic epoxy. The width of each washer was just sufficient to accommodate the accelerometer width to minimize additional weight. The washer was mounted as close to the area used for sexual stimulation as possible, on the plane at which vibration would be applied to the genitalia. The exact mount position of the washer on each vibrator is described in Table 1. The accelerometer then was mounted on the washer using wax to improve vibration transmission and reduce electrical interference per the manufacturer's recommendations. Each vibrator was mounted in rigid, rounded clamp held aloft by a metal stand. The stand was cushioned and held firmly against a table by c-clamps identically for all vibrators to damp resonance from the mount. The accelerometer cord also was held by a cushioned arm to reduce reverberation from the accelerometer cord. Any vibratory testing (e.g., of dental instruments) will be somewhat contaminated by the testing situation (e.g., attachment of instrument) and these are standard procedures to reduce such contamination in engineering applications.

Table 1. Tested vibrators with specifications (links to specific device photographs).

Vibrator	Description[a]	Specifications
A	"Magic Wand" by Hitachi	Batteries: NONE Settings: OFF/ON(low, high) Operating V: 110V Sample point: Mounted on side of device "head" measured normal to axis of symmetry of device Morphology: 4 in by 1 in; tip is flattened with a number of small firm projections
B	Hard plastic, straight insertable	Batteries: 2x1.5V "C" Settings: OFF/ON(variable) Operating V: Low V = 1.0V, High V = 3.0V Sample point: Mounted on side of device normal to axis of rotation of DC-motor Morphology: Tip is formed into a concave depression with rounded, ridged edges
C	Hard plastic, wavy with clitoral "cup" on side of terminal	Batteries: 2x1.5V "AA" Settings: OFF/ON(variable) Operating V: Low V = 0.8V, High V = 3.0V Sample point: Mounted on side of device normal to axis of rotation of DC-motor Morphology: Inch-long flexible tapered tip with flagellar-type movement, which could not be mounted by the accelerometer
D	Soft plastic egg	Batteries: 2x1.5V "AA" Settings: OFF/ON(variable) Operating V: V = 2.8V [other settings just OFF/ON variations] Sample point: Mounted on side of device normal to axis of rotation of DC-motor Morphology: 4 in by 1 in; tip is flattened with a number of small firm projections
E	"Pocket Rocket"	Batteries: 1x1.5V "AA" Settings: OFF/ON Operating V: V = 1.5V Sample point: Mounted on side of device normal to axis of rotation of DC-motor Morphology: 3 in by 1 in at the widest point
F	Soft plastic, flower appearance with long pistol as stimulation point	Batteries: 4x1.5V "button cell" Settings: OFF/ON(variable) Operating V: Low V = 1.65V, High V = 2.6V Sample point: (1) tip of device; (2) periphery of device (petal) Morphology: Central body houses the vibrating motor; "nose" at clitoris used for accelerometer mount
G	Butterfly with thigh straps	Batteries: 3x1.5V "AA" Settings: OFF/ON(variable) Operating V: Low V = 1.44V, High V = 4.1V Sample point: Mounted on (1) main device housing normal to axis of rotation of DC-motor; (2) periphery of device covering (nose) Morphology: Vibrating motor is housed within the head

Note: [a]Online links to specific device photographs: A – http://tinyurl.com/yz39bzd; B – http://tinyurl.com/2egeg9z; C – http://tinyurl.com/2fw84ua; D – http://tinyurl.com/277n3fw; E – http://tinyurl.com/25lzvnl; F – http://tinyurl.com/2arqveb; G – http://tinyurl.com/25lzvnl

Six of the devices were battery (DC) powered and one was mains (AC) powered (Vibrator A). To determine the operating voltages of the DC-powered test devices, new batteries were installed and the potentials between the DC-motor terminals were measured. The devices were operated within the range of their design and intended use. If the devices had more than one speed setting, the operating voltages were taken to be those that generated the minimum and maximum speed of the DC-motor based on the applied battery voltage allowed by the device settings. The operating voltages for each device were then recorded.

Then, the batteries were removed. Small holes were drilled into the device housings and 28 AWG lead wires were soldered to the motor terminals. The lead wires were then affixed to the device housings with electrical tape. The batteries were insulated at the terminals and placed back into the devices to provide the same weight loading present during normal device operation. To standardize and maintain consistent control of the operating voltage applied to the devices, a DC power supply was used for each trial. In other words, vibrators typically use speed-varying potentiometers that could contribute to signal variability over time, so a consistent power supply was used to reduce such variability.

Vibrators were run for 30 seconds, then the signal of the next 30 seconds was recorded. If a high and low setting was provided, the vibrator was tested at the lowest and highest available setting in separate trials. LabVIEW (National Instruments, 2009) was used to record the signal, which was sampled at 2000 Hz. Motors powered in this way are extremely regular (cp. Figure 2) and reliable.

Data analysis

Data were processed using Matlab R2009A (The Mathworks Inc., 2009). The piezoelectric voltage recorded between 15 and 16 seconds (of the 30 second sample) were used for calculations as motor rotation would be stable across this interval. Vibratory motors, unless at fault, are highly regular (see Figure 2) and do not require

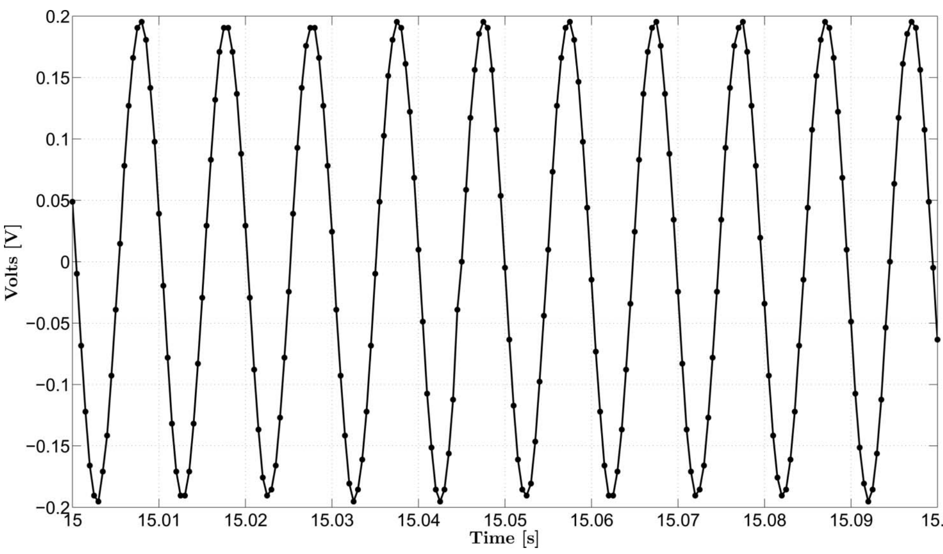

Figure 2. Signal from vibrator A from second 15 to 15.1 (high setting).

additional samples beyond one second (see Figure 3). Calculations were made for period (Hz), displacement (μm) and acceleration (m/s^2) from this sample.

To calculate these values, an FFT was performed on the acceleration-transformed data. This frequency was then input as the cutoff-frequency of a first-order, low-pass Butterworth filter. Having removed the frequency components of the signal greater than the operating frequency, the amplitude of the filtered signal was scaled to the amplitude of the original signal using a peak-picking method. A two-term Fourier fit [A*sin() + B*cos()] was then performed to produce a functional representation of the waveform.

The maximum *acceleration* of the device at the point measured by the accelerometer was taken as a local maxima (also equal to the global maximum) of the resulting function. After integrating the function twice, the maximum *displacement* of the device was measured as the maximum value of the signal.

Results

Results from the sample and transformations and calculations are shown in Table 2. Vibratory frequency ranged from 43 to 148 Hz, displacement from 37 to 783 μm and acceleration from 18 to 311 m/s^2. As expected, lower settings decreased the oscillation frequency and acceleration. However, the displacement at higher and lower setting was dependent on the device housing. For instance, the lower speed setting resulted in greater displacement for vibrator B, but higher displacement for vibrator C.

Discussion

The purpose of this study was to evaluate the mechanical properties of common sexual stimulation devices. Results indicated that the frequency of vibration ranged from 43 to 148 Hz, displacement from 37 to 783 μm and acceleration from 18 to

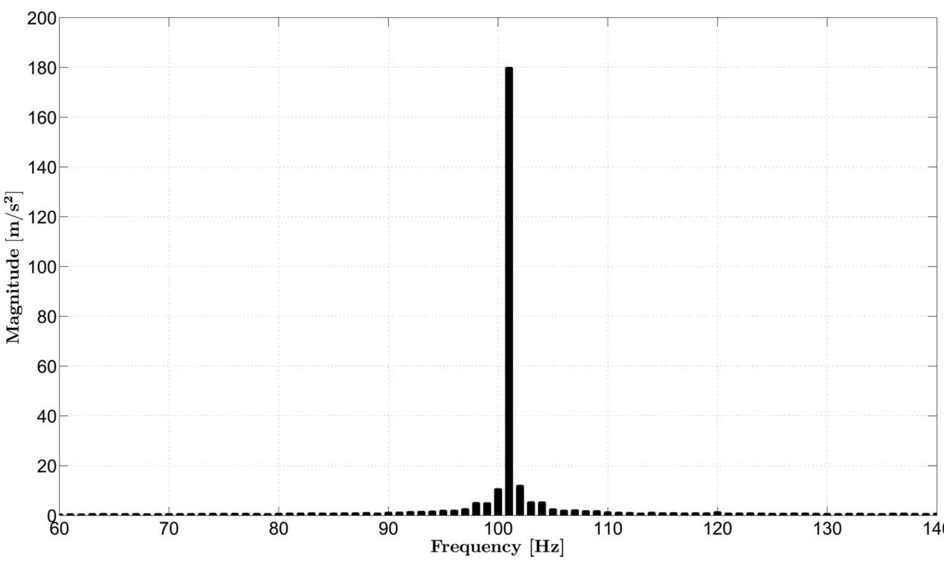

Figure 3. Discrete Fourier transform from vibrator A (high setting) showing clear frequency peak.

Table 2. Frequency, displacement, and acceleration of vibrators.

Vibrator	Setting	Highest-amplitude frequency (Hz)	Displacement (μm)	Acceleration (μg)
A	High	101	452.9	185.7
	Low	89	452.4	143.8
B	High	115	256.9	165.6
	Low	43	330.8	26.8
C	High	69	719.7	137.8
	Low	30	783.2	29.2
D		98	280.1	114.2
E	High	148	82.1	73.1
	Low	108	92.3	43.1
F	High	128	164.4	109.2
	Low	63	161.7	25.7
G		115	223.1	123.5

311 m/s^2. With the exception of acceleration, which is not reported in the psychological studies using vibratory stimulation, frequency and displacement vary from the stimulation parameters used in previous laboratory investigations for men and women. While the frequency generally was consistent with frequencies used in laboratory studies, the tested displacement was much higher (cp. 37 to 783) than the women's (2 μm) or men's (5 to 50 μm) studies to date. This may simply reflect that vibratory parameters are provided for studies of sensitivity and rarely in studies of stimulation. If displacement is similar for stimulation devices, this suggests that preferred vibratory stimuli displace at a much larger distance than laboratory instruments and could justify research devices with higher maximum displacement.

This information could aid clinicians in three ways. First, the vibratory acceleration of all vibrators tested exceeded the minimum detection threshold for both the vaginal and clitoral area in a sample of women averaging 40 years of age (Helpman, Greenstein, Hartoov, & Abramov, 2009). Thus, clients can likely be assured they are very unlikely to select a vibrator that is completely ineffective or undetectable. Similarly, clinicians could response to client concerns that their own genitals are not sufficiently sensitive. Specifically, clinicians could either help identify highly stimulating vibrator types based on these data or they could select weaker vibrators with less concern that the client actually would experience disappointment being unable to feel the device. To use the first strategy, hard clitoral cup on vibrator C on the high setting exhibited the highest displacement, but the "Magic Wand" vibrator A exhibits both high displacement and frequency. Second, clients with strong concerns about becoming "desensitized" by vibrators now have additional information. They can receive education that desensitization can occur from vibrator use, but desensitization is likely to be transitory. Also, the clinician can identify a low displacement device, such as the "Pocket Rocket" vibrator E, with evidence that it actually is a lower intensity device. Finally, these data may increase client acceptance of vibrator use by allowing more specific fit to client preferences. For example, if a client has become frustrated by the use of less intense vibrators in the past, but is reluctant to accept a vibrator that plugs in to the wall, a battery-powered variant that is more intense than his/her current vibrator can be identified. For example, a "butterfly" vibrator G has greater displacement than a "Pocket Rocket" vibrator E that the client already may have tried. Any clinical recommendations are still limited.

Most of the vibrators published with sufficient mechanical information to compare with these new data represented sensory testing and were not used for stimulation. Also, the properties of the vibrators will be modified by actual use.

The displacement of these devices was much greater than the displacement of devices used in laboratories to date. It appears that researchers interested in using vibrators to maximize the sexual response in the laboratory may safely and effectively increase the displacement of their stimulation devices. As vibrators move into fMRI (functional magnetic resonance imaging) environments (Montant, Romaiguere, & Roll, 2009), the need to quickly induce high levels of sexual arousal for some designs may drive the use of higher displacement vibrators. A pneumatic vibrator design was extended from the Montant, Romaiguere and Roll (2009) design and currently is being used as the first genital vibratory stimulator in the MRI environment (see Figure 4). The appropriate pattern of stimulation to avoid desensitization also needs to be established.

There are several limitations to this study. First, the vibrators were not tested with a human population. For example, it is possible that the devices with lower displacement actually are experienced as more pleasurable or more pleasurable only early during use. Testing of these parameters in an experimental setting is an essential next-step to further develop appropriate devices for laboratory use.

Second, it is unclear how actual use may affect these machine characteristics. Use involves applying some force to hold or press the device against the desired area, which would change the vibratory characteristics of the devices. Thicker lubricants also could alter the intensity of the stimulation. Since actual use is likely to vary widely between individuals, the current approach represents an early study of device efficacy. Simple hand grip measures could assess typical force applied during vibrator use and perhaps help distinguish more and less effective levels of pressure. Effectiveness studies examining how actual vibrator use impacts their stimulation qualities should follow.

Whether cause or result, vibrator use is related to better self-perceptions of genitalia (Herbenick & Reece, 2010), greater relationship satisfaction amongst female vibrator users whose male partners like their vibrator use (Herbenick et al.,

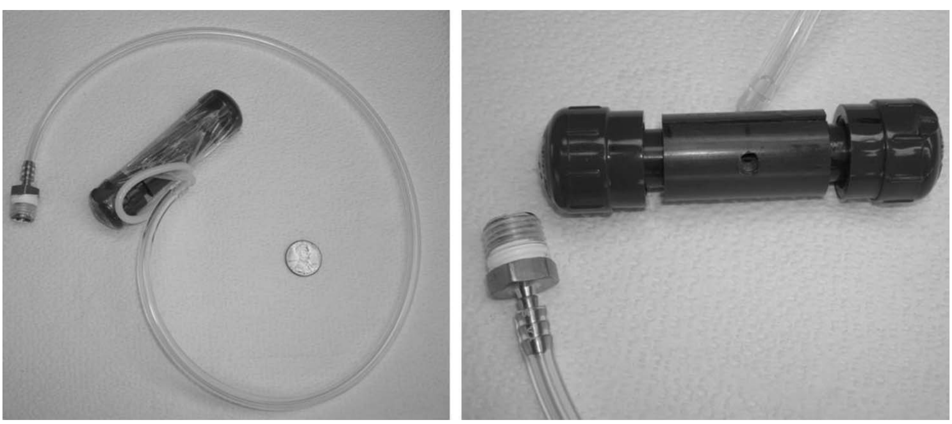

Figure 4. First MRI-safe genital vibrator. Fins are spun by compressed air to displace the counter weight and produce vibration.

2010) and increases the sexual arousal response in the laboratory over film alone (e.g., Janssen, Everaerd, van Lunsen, & Oerlemans, 1994). The range of specifications of common stimulation devices provided could aid in the appropriate selection of vibrators for improving sexual functioning and enhance researchers' ability to study high arousal states in the laboratory while minimizing risk of injury. The next step could entail human application to identify not only intensity, but also patterns of stimulation that results in orgasm. This may suggest how those who consistently experience orgasm pace their use and provide a window into the physiology involved in generating orgasm.

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