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Sexual Function after Spinal Cord Injury: Innervation, Assessment, and Treatment

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Abstract Sexual function is a high priority quality of life issue among the spinal cord injury (SCI) population. Over 12,000 new cases are reported in the USA annually, with males being twice as likely to incur a SCI compared to females. SCI males may suffer from erectile and ejaculatory dysfunction and infertility, while SCI females may suffer from dysfunctions of sexual arousal and orgasm. Assessment of sexual dysfunction in SCI individuals relies on questionnaires and reflex circuitries, highlighting the need for better quantitative assessment and outcome measures. Treatments for SCI males include pharmacotherapy, physical aids, and surgical interventions; however, treatments for SCI females is severely lacking. Advancements in assessments and treatments in both animal models and humans will pave the way for greater sexual dysfunction intervention in SCI individuals.

Keywords Spinal cord injury · Erection · Ejaculation · Pudendal · Pelvic · Fertility

Introduction

Over 1.2 million Americans live with paralysis from spinal cord injury (SCI) with approximately 12,500 new cases reported annually. The majority of SCI individuals are males (80.7 %) who are twice as likely to incur a SCI compared to females [1]. Among SCI individuals, sexual function is rated a top priority due to the impact on quality of life (QoL) [2, 3]. High scoring on either the Sexual Interest and Satisfaction Scale (SIS) or the Sexual Adjustment Scale (SAS) has been shown to correlate to higher QoL scores using a visual analogue scale [4, 5]. About 61 % of both male and female SCI individuals rate their sexual life as satisfactory, with men being less satisfied than women [6, 7]. Despite the high priority, only a limited number of experimental animal studies have focused on sexual dysfunction post-SCI [3, 8].

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Males

Erectile Function

Spinal shock immediately post-SCI severely depresses or eliminates male genital reflex function. Spinal shock may last from several hours to several weeks after injury, making predictions of sexual recovery difficult [9]. Once the spinal shock period has ended, reflexogenic, psychogenic, and mixed erections (both reflexogenic and psychogenic in origin) can be induced [10, 11]. Erection stems from the activation of the autonomic nervous system, with parasympathetic input being pro-erectile and somatic input assisting with erectile function. Parasympathetic outflow originates in the sacral parasympathetic nucleus (SPN) of the S2-S4 spinal cord in humans (L6-S1 in rodents) and reaches the penis via the pelvic plexus and cavernous nerves [12–15]. Parasympathetic excitatory input to the penis via these nerves is responsible for vasodilation of penile vasculature, increased penile volume, and increased intracavernous pressure [15–20].

The 2014 NSCISC database indicates that most SCI lesions are above the sacral level [1, 21]. Sensory input from the penile skin, glans, and prepuce project to pudendal motoneurons of

Onuf's nucleus within the sacral cord (human; dorsomedial and dorsolateral nuclei in the rat) to cause contractions of the bulbospongiosus (BS) and ischiocavernosus (IC) muscles, which aids in rigidity and maintenance of erection [12, 15, 22, 23]. Loss of descending inhibition from the brain after SCI allows for reflexogenic erections in response to cutaneous stimulation of the genital region as sacral circuitries remain intact. However, these reflex types of erections are often short-lived and lack sufficient rigidity for penetration [11, 24]. Studies in the rat indicate that lesions of several different supraspinal sites, including the median and pontine raphe nuclei, lateral paragigantocellular nucleus, and nucleus of the medial amygdala, significantly increase the occurrence of reflexogenic erections, suggesting an inhibitory role and potential sources of the damaged projections (either direct or indirect) after SCI [25–27]. In human studies using positron emission tomography to measure regional cerebral blood flow, deactivation of the amygdala and ventral temporal lobe has been shown to coincide with genital stimulation, which is hypothesized to be associated with decreased vigilance during sexual performance [28].

Psychogenic erections require an intact thoracolumbar sympathetic pathway for activation via visual and auditory stimuli, along with memories and fantasies [10, 11]. The capacity for psychogenic erections post-injury is likely low, as only 5.9 % of SCI individuals have lesions below L2 [1]. Sympathetic innervation of the penis arises from two distinct spinal areas: the intermediolateral cell column (T12-L2) and the dorsal grey commissure (L1-L2). The intermediolateral cell column contains neurons that reach the penis via the lumbar paravertebral sympathetic chain and the hypogastric nerve, while the dorsal grey commissure sends axons via the hypogastric nerve alone [13, 29]. The role of the hypogastric nerve in penile erection has been a topic of debate. Depending upon the author and animal model studied, the hypogastric nerve may have anti-erectile effects, pro-erectile effects, or no effect at all, suggesting the possibility of efferent fibers with differing roles [18, 30, 31]. Psychogenic erections persist when descending pathways from brain nuclei projecting directly to the sacral cord remain intact, suggesting a common white matter location of sympathetic and parasympathetic descending axons. Supraspinal regions that have been implicated in animal models for controlling non-contact erections include the hypothalamic paraventricular nucleus, bed nucleus of the stria terminalis, and medial nucleus of the amygdala [25, 27, 32, 33]. Additionally, the ventral putamen and the hypothalamus have been suggested to aid in maintenance of psychogenic erection [34].

Ejaculation

In addition to erectile dysfunction, SCI males have adversely affected ejaculatory function. An ejaculation affects a significant portion of SCI males [8, 10]. Approximately 95 % of SCI men with lesions caudal to T10 have severe impairment of ejaculation, with ejaculation occurring during self-stimulation or coitus at very low rates [35–37]. Fertility is also negatively affected due to necrospermia (non-viable sperm with low motility), hypogonadism, and hypospermatogenesis [38–41].

Ejaculation consists of two successive events: emission and expulsion [42, 43]. An ejaculation in SCI males may be due to a lack of emission of seminal fluid into the urethra [44]. During the emission phase of a healthy male, ejaculate fluid enters the posterior urethra as sensory penile afferents signal the emission center of the T10-L3 spinal cord. [45] Efferent autonomic signals dominated by sympathetic nerves of the hypogastric plexus then cause contractions of the vas deferens, prostate, bladder neck, and seminal vesicles. Seminal fluid is released into the posterior urethra, with the contracted bladder neck preventing the fluid from retrogradely entering the bladder [46, 47]. However, impairment of bladder neck musculature control in SCI may lead to retrograde ejaculation of seminal fluid into the bladder [48, 49].

During expulsion, seminal fluid is released from the glans meatus [50]. Impulses within somatic efferents from Onuf's nucleus and parasympathetic efferents from the SPN of the S2-S4 spinal cord propagate via the pudendal and pelvic nerve, respectively, to cause pulsatile contraction of the urethralis, BS, and IC muscles. Rhythmic contraction of these muscles forces seminal fluid to exit the urethra to the exterior [47, 51, 52]. In SCI men where this somatic-parasympathetic coordination is impaired but ejaculation is possible, the ejaculate is not forcefully expelled but dribbles out the urethra [53].

Preclinical models that have mapped pathways mediating the control of ejaculation include supraspinal projections from regions such as the medial preoptic area, the paraventricular nucleus, the lateral hypothalamus, and the lateral paragigantocellular nucleus [54–57]. Descending projections include the medullary reticular formation (MRF) whose nuclei have been shown to be critical in male ejaculation, along with both receiving and sending projections to other brainstem nuclei that receive pelvic visceral input, such as the gracile and solitary nuclei [58–67]. Human imaging studies using positron emission tomography indicate that the mesodiencephalic junction, striatum, cerebral cortex, and cerebellum are activated during ejaculation [68]. Despite the loss of supraspinal connections in many SCI males, ejaculatory reflexes have been activated in the SCI male via electro ejaculation (EEJ) and penile vibratory stimulation (PVS) suggesting a spinal generator for ejaculation [42, 69, 70]. Support for such a generator comes from pre-clinical studies by Truitt and Coolen who identified a population of lumbar spinothalamic cells located in laminae VII and X in the L3-L4 rat spinal cord which, when inactivated, cause disruption of the ejaculatory

process. Additionally, these cells were shown to have projections to neurons of the intermediolateral cell column and the SPN as well as ascending projections to the parvocellular subparafascicular nucleus of the posterior thalamus [71]. As ejaculation requires coordination between somatic, sympathetic, and parasympathetic input and output, the location and projections of lumbar spinothalamic cells implicate them as major components of the spinal ejaculation generator.

Females

Sexual Arousal

Sexual function is also rated a top priority for females living with paralysis. Like males, after spinal shock subsides, SCI women can experience sexual arousal via reflexive and psychogenic pathways [41, 72–74]. Reflexive arousal has been shown in women with upper motor neuron damage affecting supra-sacral segments and lower motor neuron incomplete injuries [75]. Parasympathetic fibers originating from the S2-S4 spinal cord are responsible for the female sexual arousal reflex, which consists of vulvar swelling, vaginal lubrication, tenting, vasocongestion, and clitoral erection [76, 77]. In reaction to genital stimulation, pudendal afferents innervating the clitoris, perineum, and urethra participate in a polysynaptic reflex with the cavernous nerve to lengthen and increase blood flow to the vagina and increase blood flow and intracavernosal pressure in the clitoris, allowing for clitoral erection [77, 78]. Additionally, pudendal sensory fibers activate pudendal motor neurons that contract the striated perineal muscles, allowing for persistence of clitoral erection [23]. During vaginal tenting, the cervix, innervated by both the hypogastric (sympathetic) and pelvic (sensory) nerves, retracts and softens [76, 79, 80]. At this stage, the uterus (innervated by hypogastric and pelvic nerves) moves upward [80–82]. The movement of the cervix and uterus are believed to be initiated by pelvic muscle contraction and maintained by the smooth muscle contractions of the parametrial sheaths attached to the uterus [81, 83, 84].

Psychogenic arousal via audiovisual cues has been shown to occur in women with intact sensory perception of the T11-L2 dermatomes, and evidence for sympathetic elucidation of psychogenic genital arousal exists in SCI females [73, 85]. Both reflexive and psychogenic arousal is seen in SCI women with incomplete injuries; however, it has been suggested that neither reflexive nor psychogenic arousal is seen for a lesion between T10-T12 [72, 74, 86, 87].

Orgasm

The female orgasm consists of rhythmic contractions of the striated perineal muscles controlled via motor pathways of the pudendal nerve, including the BS and IC muscles, and external anal and urethral sphincters [76]. Though arousal is dependent on the level of injury, Sipski et al. reported no statistically significant differences in the ability to reach orgasm in the laboratory setting when comparing between lesion levels, completeness of injury, or upper or lower motor neuron injury. In one study, 55 % of SCI women reported being able to achieve orgasm post-injury though latency to reach climax was significantly longer than able-bodied females [86]. These data suggest that neurological ability to orgasm remains intact; however, psychological and/or extrinsic variables, such as medication or misinformation concerning sexual ability, may inhibit an individual from reaching climax [87].

Menstrual cycles, if affected, return to normal within a year of injury for 90 % of individuals [88, 89]. Thus, SCI women are able to conceive and carry to full term with no increases in rates of spontaneous abortion relative to the general population [88, 90]. Close observation by an obstetrician is necessary due to increased complications from urinary tract infections (UTI), decreased gastric mobility resulting in severe constipation, thrombophlebitis, and autonomic dysreflexia for lesions above T6 [74, 88, 90]. No extraneous delivery complications are known to solely effect the SCI population, with the exception of the requirement to control severe hypertension for medically unmanaged autonomic dysreflexia [90].

It is important to note that women with clinically complete (according to criteria of the International Standards for Neurological Classification of SCI by the American Spinal Injury Association—ASIA) and anatomically complete injuries can sense cervical and vaginal stimulation, menstrual discomfort, and orgasm. These reported sensations implicate an alternate non-spinal pathway, the vagus nerve, as a potential source of input to the brain [91]. Nucleus tractus solitarius neurons, which receive direct vagal input [92, 93], have been shown to be responsive to stimulation of the cervix, vaginal canal, and uterus in animal models [94, 95]. However, while a bilateral vagotomy was shown to affect the responsiveness of these brainstem neurons, only a complete transection of the spinal cord eliminated responses in the nucleus tractus solitarius [95, 96]. Neurons in the nearby nucleus gracilis have also been shown in rats to respond to the stimulation of the clitoris and internal female reproductive organs, with responses varying throughout the estrus cycle [97–99], as well as in their subsequent target, neurons in and around the ventrobasal complex of the thalamus [100, 101].

Assessment of Sexual Function after SCI

Assessment of Males with SCI

Currently, the most widely used method of assessing sexual function in human males is the International Index of Erectile

Function (IIEF) [102–104]. The IIEF is a self-administered questionnaire consisting of 15 questions divided among five domains, including erectile dysfunction, orgasmic function, sexual desire, intercourse satisfaction, and overall satisfaction. The six questions concerning erectile function, for example, are assigned a score of 0 to 5, for a total of 30 possible points. Scores 25 to 30 indicate no dysfunction, 19 to 24 indicate "mild" dysfunction, 13 to 18 "mild to moderate dysfunction, " 7 to 12 indicate "moderate" dysfunction, and 0 to 6 indicate "severe" dysfunction. Important to studying a SCI population, the IIEF examines the ability to achieve versus maintain erection as two distinct entities [102]. However, the IIEF lacks consideration of psychogenic versus reflexive erections, as well as anejaculatory orgasm in SCI men. In 2009, the Autonomic Standards Committee validated the IIEF as an appropriate tool for assessing sexual function after SCI in clinical trials and recommended considerations to include when using the IIEF in this population [105]. Many of the questions do however rely on the subject having a partner at the time when the survey is given, which often may not be the case given the generally young age of the SCI male population. Another assessment developed for use in several drug studies is the Erection Hardness Grading Scale, which is a descriptive measure on a four-point scale [104].

Currently, no questionnaire exists solely to measure ejaculatory ability in SCI men. Clinically, however, our knowledge of reflex circuitries allows researchers and physicians to determine intact sexual pathways and predict ejaculatory ability [105]. The bulbocavernosus reflex can be visualized by stimulation of the glans penis and recording responses of the BS muscle or anal sphincter via EMG [106]. The bulbocavernosus reflex has been shown to indicate an intact S2-S4 spinal cord. [107•] The hip flexor response is a pathogenic reflex initiated by stimulating the sole of the foot leading to flexion of the hip that is typically seen in SCI individuals. This reflex, if present, suggests an uncompromised spinal cord immediately superior to S2-S4. The presence of both the bulbocavernosus reflex and hip flexor response indicates the individual is likely capable of ejaculation with assistance of PVS. [108] These spinal reflex assessments are therefore useful clinically as indicators of sexual prognosis and as a tool to aid in the selection of future treatment plans (e.g., PVS or EEJ).

The International Spinal Cord Injury Male Sexual Function Basic Data Set was created in response to the need for easily comparable international sexual function data pertaining specifically to SCI men. This data set is collected by the clinician and assesses interest in discussing sexual issues, sexual problems unrelated and related to SCI, psychogenic erection, reflex erection, ejaculation, and orgasmic function [109]. The data set includes a section regarding the use of medications for sexual function. It is necessary to know if survey questions are being answered with drug or device usage to enhance sexual function as this can influence interpretation of the degree of dysfunction.

Assessment of Females with SCI

The two most common tools used to assess female sexual function are the Female Sexual Function Index (FSFI) and the Sexual Function Questionnaire (SFQ) [103]. The FSFI consists of six domains including desire, arousal lubrication, orgasm, satisfaction, and pain. Nineteen questions are posed with scores ranging from 0 or 1 through 5, with the lowest score possible being 2 and the highest being 36 [110]. Though the FSFI's use in SCI clinical trials has been limited, the Autonomic Standards Committee has endorsed its use for sexual function assessment in SCI women [105, 111–114, 115•]. The SFQ consists of eight factors including desire, lubrication, cognitive desire, sensational desire, orgasm, pain, enjoyment, and partner ratings among 28 questions [116]. This questionnaire may be beneficial in assessing SCI women as it considers both reflexive (sensation) and psychogenic (cognitive) arousal; however, the SFQ's use has also been limited in SCI [117].

Another method for sexual function assessment approved by the Autonomic Standards Committee for SCI women is the use of vaginal photo plethysmography to measure vaginal vasocongestion [105]. This physiological measurement is taken by using an intravaginal probe emitting infrared light that reflects off the vaginal wall and is captured via a phototransistor. The direct current received is believed to report total vaginal blood volume, where the alternating current signal reports vaginal pulse amplitude [118]. Current belief is that vaginal pulse amplitude is the preferred measurement for assessing vaginal responses to arousing stimuli [105]. Sipski and colleagues have utilized vaginal pulse amplitude to study sexual function in SCI women, including determination of the effects on vaginal vasocongestion in drug studies, on lesion level or completeness, and for multiple stimulation types [73, 75, 85, 86, 119–121].

The International Spinal Cord Injury Female Sexual and Reproductive Function Basic Data Set is similar to the Data Set for men discussed previously. This data set addresses the individual's interest in discussing sexual issues, sexual problems not related to SCI, sexual dysfunction related to SCI, psychogenic genital arousal, reflexive genital arousal, orgasmic function, and menstruation [122].

Assessment in Animal Models of SCI

Several methods have been used to assess sexual function in animal models of SCI. *Ex copula* reflexes to test sexual function in SCI male rats can be elicited by stimulation of the urethra, penile sheath retraction, or electrical stimulation of the dorsal nerve of the penis (DNP). The response to such stimulation includes penile engorgement, dorsiflexion, and glans cupping, with rhythmic contractions of the BS and IC muscles, with a much shorter latency than seen in intact

animals [123, 124]. In female SCI rats, this reflex can be generated by stimulation of the urethra, causing pudendal efferent and cavernosus nerve bursts and rhythmic vaginal contractions [123]. Pressure recordings from the corpus spongiosum during reflexes or mating paradigms in awake male SCI rats can be determined by use of telemetric pressure devices, giving a qualitative and quantitative assessment of penile erection [125]. Finally, in anesthetized animals, EMG of the perineal muscles, typically the BS, can be utilized to determine physiological responses in sexual reflexes [123]. A recent study that utilized BS EMG in a chronic contusion model determined the D3 dopamine receptor agonist 7-hydroxy-2-(di-*N*-propylamino)tetralin-facilitated ejaculatory reflexes [126••].

Treatment

Intervention for Males with SCI

Current therapies for treating sexual dysfunction in SCI men include pharmacotherapy, physical aids, and surgical interventions.

Pharmacotherapy

Pharmacotherapy interventions to assist erectile ability include intracorporeal (IC) therapy and phosphodiesterase type 5 inhibitor (PDE5I) oral medications. IC therapy consists of an intracavernosal injection of a cocktail including papaverine, phentolamine, and alprostadil [127]. However, IC therapy is expensive and can cause bleeding and scarring, and its use as a treatment option has waned with the introduction of PDE5Is [4]. PDE5I medications that have been assessed for use in SCI men include sildenafil (Viagra®), vardenafil (Levitra®), and tadalafil (Cialis®). In a clinical trial examining these three PDE5Is in SCI subjects, rigid erection sufficient for penetration was reached in 85 % of sildenafil users, 74 % of vardenafil users, and 72 % of tadalafil users with all three medications achieving mean persistent erection times of approximately 30 min. Individuals with upper motor neuron lesions responded best, while individuals with lower motor neuron lesions were poor responders. All three medications saw a significant increase in erectile function and intercourse and overall satisfaction when assessed with the IIEF-15, although only sildenafil significantly increased orgasmic function and ejaculation [128]. Alternative studies using the IIEF-15 have also shown significant improvement in ejaculation with both tadalafil and vardenafil [129, 130]. Additionally, tadalafil and sildenafil have been examined for long-term use and dose effectiveness in SCI males [131–133]. Recently, 4-aminopyridnine, or fampridine, an oral medication used in SCI individuals for spasticity control, was examined for its effect on sexual function. SCI men reported significant increases in two domains of the IIEF: erectile and orgasmic function, an effect secondary to the functionality of the medication [112].

Physical Aids

Physical aids currently utilized by the SCI population for sexual dysfunction include vacuum tumescence devices (VTDs) for erectile dysfunction and PVS/EEJ for an ejaculation. Previous studies of VTD use in SCI men reported increases in sexual satisfaction, with one study reporting 60 % of participants and 42 % of their partners seeing improvements [134, 135]. However, in a 2008 study where SCI men used VTD for 1 month followed by using sildenafil for 1 month, no men were satisfied with the VTD [136].

For an ejaculation after SCI, PVS is a first-line therapeutic approach performed by using a medical vibrator to activate the DNP which signals to the ejaculatory center activating the ejaculatory reflex. [69] The vibrator is placed either on the dorsal or ventral side of the glans penis, with the most effective amplitude and frequency being 2.5 mm and 100 Hz [137]. Studies indicate that 86 % of SCI men with lesions above T10 achieve ejaculation; however, with lower injuries approximately only 20 % succeed, as it is necessary for the sympathetic ejaculatory pathway to be intact [138]. Non-responders to a single vibratory device may respond to stimulation of both the dorsal and ventral glans penis, prompting the invention of the Viberect-X3 (Reflexonic, Frederick, MD, USA) that uses a single device to stimulate both the dorsum and frenulum of the penis [139, 140••]. A recent study using this device in ejaculatory SCI men with injury levels above T10 reported a 77 % success rate [140••]. If PVS is not a viable option, EEJ is the suggested next treatment option. EEJ is performed by rectally inserting a probe that uses electrical current to stimulate the smooth muscles of the seminal vesicles and prostate, which induces seminal emission. Since EEJ does not utilize the ejaculatory reflex, this method of sperm retrieval is appropriate for all injury levels [137]. EEJ has a high success rate, with the largest EEJ study to date reporting 91.9 % of SCI individuals achieving ejaculation [138].

Surgical Intervention

Prosthetic penile implants to assist with erectile function can be inflatable, semirigid, flexible, or semiflexible. These devices have moderate satisfaction rates, with one study reporting 41 % of implanted SCI men seeing sexual function improvements [141]. A more recent study reported that 83.7 % of SCI participants with a penile implant could participate in sexual intercourse [142]. However, with the rise of less invasive alternative therapies and a high risk of complications, the use of these devices has slowed [143].

Surgical sperm retrieval is the remaining viable option if PVS and EEJ have failed. In this procedure, sperm is retrieved from the testis, vas deferens, or the epididymis by aspiration, biopsy, or open surgery. In vitro fertilization is almost always necessary with this method, as minimal amounts of spermatozoa with low motility are retrieved. Raviv et al. recently reported successful sperm retrieval using testicular sperm extraction in 89.6 % of 106 attempts, with 32 pregnancies of which 20 ended in live birth [144•].

A new procedure called TOMAX has been described as restoring tactile and erogenous sensation of the glans penis in SCI men with lesions below L2, as well as men with spina bifida. The TOMAX procedure uses microneurography to join the divided DNP to the sensory ilioinguinal nerve, which serves as a bypass to restore penile sensation. This procedure can be done either unilaterally or bilaterally; however, as the dorsal penile nerve is partially responsible for reflexive erections and ejaculation, bilateral TOMAX may jeopardize these reactions. In unilateral procedure, SCI and spina bifida men retained erectile and ejaculatory ability, with five subjects reporting reflexive erection, where previously only psychogenic erection had been present. A total of 80 % of individuals reported unilateral glans penis sensation, which originally reported as groin sensation but matured to real penile sensation in 33 %. Individuals also reported significant increases in penile rigidity and satisfaction during masturbation, along with a greater ease of maintaining an erection and reaching orgasm [145••].

Neuromodulation by sacral nerve stimulation (SNS) has seen a success in SCI individuals in regards to bladder and bowel function [146]. In addition to these results, further benefits in sexual function have been observed [147]. SNS involves the implantation of a neurostimulator device via the S3 foramen, which sends mild electrical impulses to the sacral plexus and affects the innervated pelvic viscera. Early studies of SCI individuals with complete lesions examining the efficacy of SNS on bladder control also found significant results in erectile function, with 29 of 33 men involved achieving a full erection with stimulator use [148]. Another study examining effects of SNS on concomitant pelvic dysfunction in incomplete SCI men reported median IIEF-5 (questions pertaining to erection) scores increasing from 15.6 pre-implantation to 22 post-implantation. While two individuals required re-implantation, their IIEF-5 scores returned to 22 at the 40-month follow-up [149].

Female Interventions

Current research in treatment of sexual dysfunction after SCI in women is sparse and has had limited success. One study examining SNS in 17 women with sexual dysfunction and neurologic lower urinary tract symptoms included five women with incomplete SCI. Of all 17 women, 36.3 % showed improvements of sexual function on both the FSFI and the Female Sexual Distress Scale after implantation. FSFI median scores increased from 22.7 pre-implantation to 26.02 post-implantation [111]. Another study examining the effects of sildenafil on sexual function in SCI women found no significant differences between sildenafil and placebo groups when assessed with SFQ, the Sexual Quality of Life Questionnaire—Female, a Sexual Distress Question, or a Global Efficacy Question, though a prior laboratory study saw benefits from sildenafil use [117, 119]. Similarly, the spasticity control medication fampridine had no effect on sexual function in SCI females [112].

Conclusions

Sexual function is a high priority QoL issue among the SCI population. The current state of research regarding sexual dysfunction after SCI reveals the need for better assessment and outcome measures geared toward dysfunctions specific to SCI populations. Additionally, the development of better assessment tools in animal research will allow more effective therapies to be developed. Finally, the lack of effective treatment options for the female SCI population should be addressed.

Compliance with Ethical Standards

Conflicts of Interest CJS and CHH declare that they have no conflicts of interest.

Human and Animal Rights and Informed Consent All reported studies/experiments with human or animal subjects performed by the authors have been previously published and complied with all applicable ethical standards (including the Helsinki Declaration and its amendments, institutional/national research committee standards, and international/national/institutional guidelines).

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