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Finger and penile tactile sensitivity in sexually functional and dysfunctional diabetic men

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Summary Tactile sensitivity of the penis is related to sexual functioning, however its role in diabetic erectile problems is unclear. We evaluated penile sensitivity in 10 diabetic men with erectile dysfunction, 17 sexually functional diabetic men and 14 control subjects. Finger and penile thresholds and ratings of intensity and pleasantness for finger and penis were assessed using vibrotactile stimulation. Glycosylated haemoglobin and total and bioavailable testosterone measurements were determined and subjects completed self-reports on sexual function. Diabetic men with erectile problems had higher values of glycosylated haemoglobin than sexually functional diabetic men ($p = 0.02$) and both groups had lower bioavailable testosterone than control subjects ($p \leq 0.05$). Sexually dysfunctional diabetic men had a higher finger threshold than the other two groups ($p < 0.01$). Penile threshold for the sexually dysfunctional group was also marginally higher compared with the functional diabetic group ($p < 0.052$) but did not differ from control subjects ($p = 0.09$). Diabetic men with erectile dysfunction exhibited different response patterns than sexually functional men on dimensions of intensity and pleasantness to penile stimulation. Although these data do not directly implicate subjective response to penile stimulation in diabetic erectile problems, they suggest such anomalous response could be one contributing factor. [Diabetologia (1999) 42: 336–342]

Keywords Diabetic erectile dysfunction, penile sensitivity, penile threshold, glycosylated haemoglobin, testosterone.

Although not all men with diabetes mellitus report difficulty achieving and maintaining erections, factors that differentiate sexually functional from dysfunctional diabetic men have not been explored extensively. Previous research has shown that penile vibratory thresholds are related to male sexual functioning [1]. Furthermore, ageing and pathophysiology related to vascular function have been associated with decreased penile sensitivity and diminished ability to achieve and maintain erections [2]. Although not presumed to be the primary cause of erectile problems, such diminished sensitivity could compound the ischaemic, metabolic and other effects of various pathophysiological states such as diabetes. Diabetic men with erectile dysfunction have been shown to have higher penile thresholds (i.e., decreased sensitivity) than young non-diabetic men [3]. Subjective cutaneous thresholds, however, represent only the most basic of sensory processes. Equally important to sexual functioning is the perceived intensity and pleasantness of penile stimulation.

Endocrine factors could also be involved in diabetic erectile dysfunction. Varying methodologies have yielded conflicting results regarding the association between testosterone concentrations and diabetic erectile capacity [4–7], with at least one study indicating lower testosterone in men with diabetes. Because testosterone concentrations have been implicated in

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Abbreviations: NPT, Nocturnal penile tumescence.

penile thresholds, with testosterone deficiency associated with penile hypersensitivity [8], perception of penile stimulation in both diabetic and non-diabetic men might be modulated by circulating testosterone.

In this study we 1) determined penile and finger vibrotactile thresholds, 2) assessed finger and penile intensity and pleasantness to seven suprathreshold vibratory levels of stimulation, and 3) determined total and bioavailable testosterone concentrations. We examined these variables in men of similar age: sexually functional diabetic men, diabetic men with erectile dysfunction and healthy control subjects. We hypothesized sexually dysfunctional diabetic men would exhibit higher thresholds than men in the other two groups and give lower ratings of intensity and pleasantness. We also investigated the extent that total and bioavailable testosterone vary according to diabetic status to explore their possible role in differences to our response variables.

Subjects and methods

Subjects. We studied 41 men (Table 1): 10 diabetic subjects with erectile dysfunction, 17 sexually functional diabetic subjects and 14 control subjects. The protocol was approved by our institutional review board. Selection criteria included: age range of 29–52 years and diagnosis of diabetes for a minimum of 4 years (diabetic subjects). Exclusion criteria were: obesity (greater than 20% over ideal body weight for height according to the Metropolitan Life Insurance Tables); mild-moderate to severe depression scores on the Beck Depression Inventory [9]; medication (prescription, over-the-counter and illicit), surgery or history of medical conditions (except diabetes for the diabetic groups) that could affect sexual function: both low total and bioavailable testosterone; glycosylated haemoglobin values above 13%; retarded or premature ejaculation; and substance abuse.

Men were recruited via media announcements, a diabetes newsletter, local diabetologists and word of mouth. Over a 26-month period, 178 subjects volunteered. During a telephone screening, 75 subjects failed to meet the criteria (e.g. age, obesity) and 16 declined to participate. We screened 87 subjects in person: they gave informed consent and completed the Beck Depression Inventory, a demographics questionnaire, a health and sexual function questionnaire and a semistructured interview. One blood sample was drawn to determine glycosylated haemoglobin and two additional samples were drawn, approximately 1 week apart (between 0900 and 1700 hours), to assess total and bioavailable [10] testosterone concentrations. For gonadal hormones, the mean value of the two samples was used for statistical analysis.

Screenings resulted in the rejection of 26 volunteers, mainly because of glycosylated haemoglobin values above 13% or self-reports of erectile functioning not confirmed by nocturnal penile tumescence (NPT) testing; 18 other subjects declined after learning more about the study or failed to appear for the screening. Two control subjects dropped out for personal reasons unrelated to the study.

We interviewed diabetic subjects to obtain details of the diabetic history and to look for causes of erectile dysfunction other than diabetes. History of anxiety, depression and sexual function were also obtained. The physical examination included heart, lung, thyroid, skin, arterial pulses by palpation and auscultation, abdomen, deep tendon reflexes, proprioception, light touch, and capillary filling of toes. The genital examination included palpation of the penis for plaques or fibrosis, palpation of the testes for size and irregularity, sensory exam of the perineum, rectal sphincter tone, palpation of the prostate, and tests of anal wink and bulbocavernoses reflexes.

Assignment to the diabetic erectile dysfunction group was based initially on self-reported inability to achieve and maintain an erection in 75% or more of intercourse or masturbation or both in the preceding month and a diagnosis of diabetes preceding erectile dysfunction. Sexually functional diabetic and control subjects were those reporting no erectile dysfunction in 25% or less of sexual activity in the preceding month. To objectively confirm erectile functioning, NPT [11–12] was assessed for 1 to 3 nights using either the RigiScan or Penile Tumescence portable home monitors (Dacomed Corp., Minneapolis, Minnesota, USA; Event Systems, Moorestown, New Jersey, USA, respectively). Subjects were considered sexually functional when NPT data showed three or more erections a night with a 15 mm increase above baseline for a minimum of 15 min and penile rigidity (RigiScan only) of 60% or greater. Subjects not meeting these criteria were confirmed as sexually dysfunctional. No subject was reclassified into a different group because of NPT results.

Assays. Glycosylated haemoglobin was determined by affinity chromatography using the Isolab (Akron, Ohio, USA) minicolumn method (normal range, 4.0–8.0%; slightly increased, 8.1–10.5%; mildly increased, 10.6–13.0%; moderately increased, 13.0–15.5%; greatly increased, 15.6% and above).

Testosterone was measured by radioimmunoassay as described by Anderson et al. [13] (normal values: mean = 21.11 nmol/l; range = 12.24–38.1 nmol/l). Bioavailable testosterone was measured using the method of Tremblay and Dube [14] (normal values: mean = 7.87 nmol/l; range = 3.4–12.93 nmol/l). Intraassay coefficients of reliability for total testosterone and bioavailable testosterone were 3.0% and 5.8%, respectively. Interassay coefficients of reliability were total testosterone, 5.0% and bioavailable testosterone, 6.0%.

Table 1. Demographic characteristics of subjects

	Diabetic subjects		Control subjects	Kruskal-Wallis Test
	Erectile dysfunction ($n = 10$)	No erectile dysfunction ($n = 17$)	($n = 14$)	p
	Median (range)	Median (range)	Median (range)	
Age (years)	45.4 (30.2–52)	42.1 (30.3–51.6)	41.3 (29.7–51.5)	NS
Ethnic identity				
Asian	0	1	1	NS
Hispanic	1	0	0	NS
White	9	16	13	NS
Marital Status				
Single	1	2	5	NS
Married	8	10	8	NS
Separated/ divorced	1	5	1	NS
Duration of diabetes (years)	12 (6–19)	12 (4–42)	Not Applicable	NS

Table 2. Testosterone and glycosylated haemoglobin values by group

	Diabetic subjects		Control subjects	Kruskal-Wallis Test
	Erectile dysfunction ($n = 10$)	No erectile dysfunction ($n = 17$)	($n = 14$)	p
	Median (range)	Median (range)	Median (range)	
Total testosterone (nmol/l)	19.53 (12.57–26.15)	23.19 (10.06–38.05)	15.57 (7.67–26.82)	NS
Bioavailable testosterone (nmol/l)	4.96 (3.05–9.48)	6.17 (1.98–8.79)	7.37 (4.28–10.88)	0.02
Glycosylated haemoglobin (%)	11.5 (8.2–12.7)	8.9 (6.8–12.6)	5.3 (4.9–5.9)	0.0001

Daily logs. To measure self-reported frequency of sexual behaviour and function, subjects completed one-page daily logs for 1 month, typically concurrent with laboratory testing. The content has been described previously [15]. To minimize retrospective reporting, subjects were given logs for 1 week at a time.

Laboratory testing

Vibrotactile thresholds. Vibrotactile stimulation was used to assess finger and flaccid penile thresholds, as described previously [3]. Briefly, the left index finger or underside of the flaccid penis (≤ 10 mm from the coronal ridge) was placed on a concave plastic pad at the end of an acrylic rod attached to a Bio-Thesiometer (Bio-Medical Instrument Company, Newbury, Ohio, USA). The instrument was modified with a vernier rheostat to control stimulus intensity. Vibration was measured in microns of movement with a frequency of 120 cycles per second; increments and decrements of stimulus intensity were between 0.04–0.06 microns and duration was 500 msec. Stimulus initiation and duration were computer controlled. An approximate threshold was first determined using the method of limits [16] followed by the more precise forced choice method [17], requiring subjects to report after which of two tones the stimulus was presented.

Vibrotactile intensity and pleasantness. For ratings of intensity and pleasantness to vibrotactile stimulation, subjects were presented a series of individual suprathreshold vibrotactile stimuli at the finger or penile sites, separately and asked to rate each from a given list. The list consisted of seven descriptors from "faint" to "extremely intense" or "extremely pleasant." Subjects could repeat descriptor ratings. Subjects were blinded to the stimulus presentation: seven voltages, ranging from 20 to 38, at 3-volt increments. Each voltage was paired with a verbal descriptor, with increasing voltages corresponding to verbal descriptors of increasing magnitude. Intensity ratings using these descriptors were based on a validated ratio scale [18]. Each voltage was presented six times in random order and the mean for each voltage was recorded.

Subjects visited the laboratory for four test sessions, approximately 1 week apart. Finger and penile thresholds were measured twice, once in each of the first two sessions, with penile testing following finger testing. Finger intensity and pleasantness ratings were also recorded in the first two sessions, one per session; the order alternated with each new subject. Penile intensity and pleasantness were recorded in the third and fourth sessions, using the same protocol as the finger testing.

Statistical analysis. For single factor analyses where distributions were heterogeneous, data were analysed using the nonparametric Kruskal-Wallis analysis of variance (ANOVA), followed by Mann-Whitney post-hoc comparisons. For analyses involving multiple factors, data were first log-transformed to achieve homogeneity and then subjected to factorial ANOVA. Post-hoc analyses used a one-sided Dunnett's test, selected because it enables comparison of a single group (diabetic men with erectile dysfunction) with the other two groups while maintaining an overall alpha of .05. Chi-square was used for demographic data analysis; Fisher's exact probability test for percentage data.

Table 3. Self-reported weekly frequencies and quality of sexual behaviours

	Diabetic subjects		Control subjects	Kruskal-WallisTest
	Erectile dysfunction ($n = 10$)	No erectile dysfunction ($n = 17$)	($n = 14$)	p
	Median (range)	Median (range)	Median (range)	
Sexual desire	5.9 (1.5–7)	5.8 (0.5–7)	6.4 (2–7)	NS
Non-coital partner sex	0.9 (0–3)	0.5 (0–2.8)	0.9 (0–4.1)	NS
Coitus	0.0 (0–2)	0.7 (0–3.4)	1.5 (0–3.8)	0.03
Masturbation	0.9 (0–2)	2.0 (0–9.8)	2.1 (0–8.9)	NS
Morning erection	0.0 (0–1.5)	1.8 (0.3–5.3)	3.7 (0.8–7)	0.0001
Spontaneous erection	0.0 (0–0.3)	0.8 (0–7)	1.8 (0–6.5)	0.002
Firmness of coital erections[a,b]	42 (25–61.3) (3)	83.5 (74.3–100) (13)	94.1 (76.4–100) (11)	0.02
Firmness of morning erections[a,b]	34.4 (22.8–44) (4)	70.2 (48–97) (17)	75.1 (47.9–100) (14)	0.005
Firmness of masturbatory erections[a,b]	37 (8.9–67) (7)	88.8 (62–100) (15)	89 (71–100) (11)	0.0004
Pleasure in coitus[a,c]	64.5 (49.3–66) (3)	74.5 (60.3–100) (13)	84.6 (63.5–97.6) (11)	0.054
Pleasure in masturbation[a,c]	54 (49.3–75.5) (7)	80.4 (51.8–99) (15)	78.9 (37.7–87) (11)	0.07

[a] Includes only those subjects reporting specified sexual activity. n in parenthesis.
[b] Based on 100 mm scale: 0 = totally limp; 50 = firm enough for penetration; 100 = totally hard.
[c] Based on 100 mm scale: 0 = no pleasure; 100 = extremely intense pleasure

Results

Clinical data. Diabetic subjects were classified as having Type I (insulin-dependent) diabetes mellitus on the basis of a history of ketoacidosis, C-peptide determination, or childhood onset and insulin dependence. Subjects were classified as having Type II (non-insulin-dependent) diabetes mellitus, if they were adult onset and never insulin dependent. One subject with erectile dysfunction could not be classified by the available information. Of the other nine diabetic men with erectile problems, eight were Type I and one was Type II; of the 17 sexually functional diabetic subjects, 14 were Type I and three were Type II. The two diabetic groups did not differ statistically in diabetes type ($p > 0.05$).

Sexually functional and dysfunctional subjects had the following diabetic complications, respectively: peripheral neuropathy (29%, 80%); peripheral vascular disease (0%, 10%); retinopathy (24%, 60%); nephropathy (0%, 10%). No complications were found for 47% of the sexually functional diabetic men and 10% of the dysfunctional men. No subjects had clinical findings of coronary artery disease or autonomic neuropathy. All subjects had at least a weakly present anal wink and bulbocavernosus reflex and all had intact rectal sphincter tone.

All groups showed normal concentrations of total testosterone (one sexually functional diabetic subject and two control subjects had low levels: 10.05, 7.66 and 10.05 nmol/l, respectively) and no differences occurred between groups (Table 2). For bioavailable testosterone a nonparametric ANOVA showed significant differences (Table 2). Post-hoc analysis showed both diabetic groups had lower concentrations of bioavailable testosterone compared with control subjects ($p \leq 0.05$). Three subjects (two with erectile dysfunction and one sexually functional diabetic man) had low bioavailable testosterone (3.22, 3.05 and 1.98 nmol/l, respectively). No participant had both low total testosterone and low bioavailable testosterone.

Differences among groups were also found for glycosylated haemoglobin (Table 3). Post-hoc analysis showed diabetic groups had higher levels than control ($p \leq 0.0001$) and diabetic subjects with erectile problems showed poorer control than the sexually functional diabetic group ($p = 0.02$).

Self-report of sexual functioning. In daily logs of sexual activities and sexual functioning reported prospectively for 1 month (Table 3), there were no group differences for frequency of sexual desire, non-coital partner sex or masturbation. There was a trend towards a difference among groups for pleasure in coitus and masturbation. Group differences were found for frequency of intercourse, morning erections, spontaneous erections, and firmness of coital, morning and masturbatory erections. Post-hoc comparisons showed erectile dysfunction subjects reported reduced frequency of intercourse compared with control subjects ($p < 0.02$); there was a marginal differ-

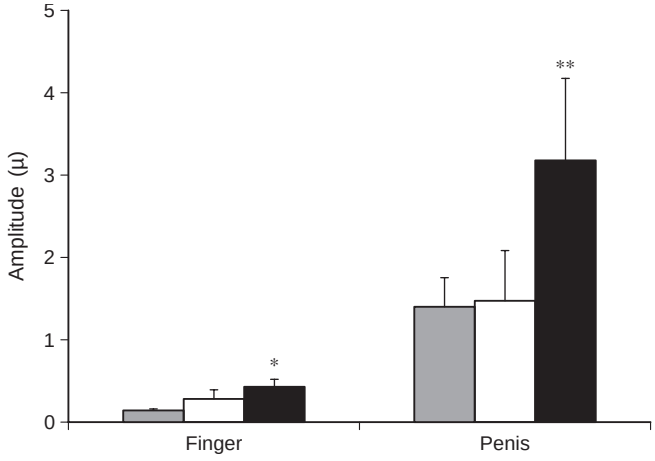

Fig. 1. Vibrotactile thresholds (means + SEM). ▒ Control subjects ($n = 14$); □ sexually functional diabetic subjects ($n = 17$); ■ diabetic subjects with erectile dysfunction ($n = 10$). * $p < 0.01$ compared with control and sexually functional diabetic subjects. ** $p = 0.052$ compared with sexually functional diabetic subjects

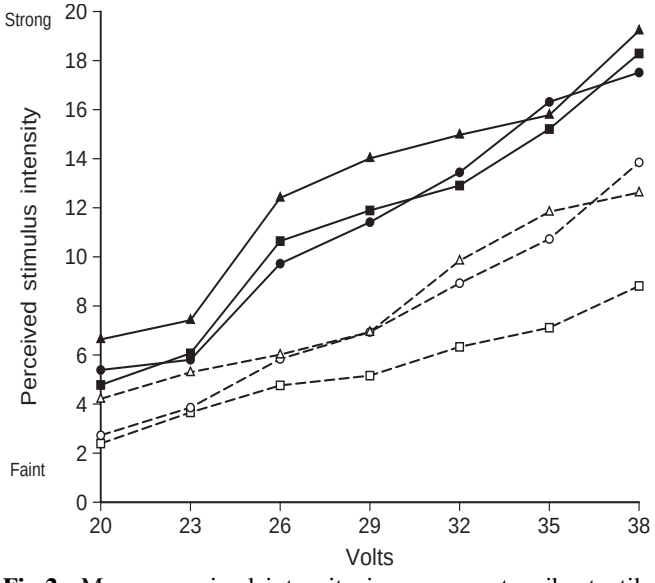

Fig. 2. Mean perceived intensity in response to vibrotactile stimulation. Stimuli were applied to the finger (black symbols) or penis (white symbols). ■ □ Diabetic men with erectile dysfunction ($n = 10$); ▲ △ sexually functional diabetic subjects (finger, $n = 17$; penis, $n = 16$); ● ○ control subjects ($n = 14$). See text for statistically significant results

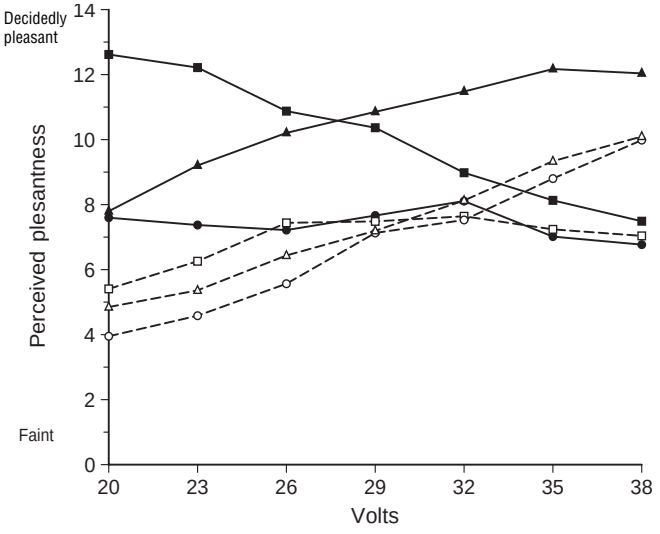

Fig. 3. Mean perceived pleasantness in response to vibrotactile stimulation. Stimuli were applied to the finger (black symbols) or penis (white symbols). ■ □ Diabetic men with erectile dysfunction ($n = 10$); ▲ △ sexually functional diabetic subjects (finger, $n = 17$; penis, $n = 16$); ● ○ control subjects ($n = 14$). See text for statistically significant results

ence between sexually dysfunctional and functional diabetic groups ($p = 0.053$). Diabetic subjects with erectile dysfunction reported fewer morning ($p \leq 0.0003$) and spontaneous erections ($p < 0.05$) and sexually functional diabetic men reported a lower frequency of morning erections than control subjects ($p < 0.05$).

Sexually dysfunctional diabetic men reported reduced penile rigidity in measures of erectile firmness compared with the other groups: firmness of coital ($p \leq 0.01$), morning ($p \leq 0.0003$) and masturbatory erections ($p \leq 0.0005$).

Finger and penile vibrotactile thresholds. A 3×2 mixed factorial ANOVA was applied to threshold data, using group (sexually functional diabetic men, diabetic men with erectile dysfunction and control subjects) as a between group factor and site of stimulation (finger vs penis) as a within group factor. Vibrotactile thresholds (Fig. 1) differed across groups ($F[2,38] = 3.65$; $p = 0.036$), and finger thresholds were lower (more sensitive) than penile thresholds ($F[1,38] = 100.87$; $p < 0.001$).

Post-hoc analysis carried out separately by site showed finger threshold for the sexually dysfunctional group was higher than the other two groups ($p < 0.01$); penile threshold for the dysfunctional group was marginally higher than that of the functional diabetic group ($p = 0.052$) but not different from the control subjects ($p = 0.09$).

Perceived intensity and pleasantness for finger and penile vibrotactile stimulation. For each analysis, a $3 \times 2 \times 7$ mixed factorial ANOVA was done, with group as a between group factor, and site of stimulation and stimulus magnitude (seven levels of intensity) as repeated measures factors.

Intensity ratings (Fig. 2) for finger and penis differed by site ($F[1,37] = 23.51$; $p < 0.001$) and over stimulus magnitudes ($F[6,222] = 88.09$; $p < 0.001$) but not across groups ($F[2,37] = 0.64$; $p = 0.534$). Subjects rated finger stimulation as more intense than pe-

nile stimulation and indicated increased subjective intensity with increasing levels of vibrotactile stimulation. A site by magnitude interaction ($F[6,222] = 7.72$; $p < 0.001$) indicated the greater increase in perceived intensity in the finger (vs penis) as stimulus magnitude rose, a difference most pronounced in the sexually dysfunctional diabetic group.

Pleasantness ratings (Fig. 3) also differed by site ($F[1,37] = 9.12$; $p = 0.005$) and over stimulus magnitudes ($F[6,222] = 3.17$; $p = 0.005$) but not across groups ($F[2,37] = 1.07$; $p = 0.354$). Group by magnitude and site by magnitude interactions were significant ($F[12,222] = 2.89$; $p = 0.001$; and $F[6,222] = 6.79$; $p < 0.001$, respectively). The group by magnitude interaction indicated that the sexually dysfunctional group responded with a slight decrease in pleasantness as stimulus levels increased, unlike the other two groups. The site by magnitude interaction reflected the increasing pleasantness ratings to increasing stimulation for the penis, contrasted with unchanged or mildly decreasing pleasantness ratings for the finger.

Spearman correlations showed significant correlations between penile vibrotactile thresholds and perceived penile intensity and pleasantness [$r(38) = -0.359$, $p = 0.023$; $r(38) = -0.450$, $p = 0.004$, respectively]. Finger thresholds were not related to these variables [$r(38) = -0.286$, $p = 0.074$; $r(38) = 0.033$, $p = 0.839$].

Discussion

This study found diabetic men with erection difficulties had higher penile vibrotactile thresholds than sexually functional diabetic men. In addition, compared with sexually functional healthy control subjects of similar age, a trend towards a higher penile threshold was seen for the dysfunctional diabetic group; the lack of clear-cut difference could be due to the relatively small group sizes. Although unlikely to be the cause of erectile problems, decreased penile sensitivity in sexually dysfunctional diabetic men could contribute to or worsen the dysfunction. As shown previously, we found that the finger is more sensitive to vibrotactile stimuli than the penis [3, 8, 19] and sensitivity at this site was lowest in diabetic men with erectile dysfunction. These results expand upon previous findings [3] specifying that diabetic men with erectile problems are at greater risk for loss of sensory function at both finger and penile sites than sexually functional diabetic and non-diabetic men.

All groups accurately perceived the relative intensity of the seven suprathreshold stimuli, regardless of body site. As expected, finger stimulation was generally perceived as stronger than penile stimulation but increases in stimulus intensity were also perceived more intensely when applied to the finger (vs the penis). Diabetic men with erection problems showed the least sensitivity to increasing stimulation (penis only) further emphasizing their potential vulnerability in genital sensory function.

Both the control subjects and sexually functional diabetic subjects perceived penile stimulation as more pleasant as stimulus intensity increased. But diabetic men with erectile problems rated higher intensities as less pleasant. A similar decrease characterized ratings of finger pleasantness. Although such disparate patterns in diabetic men with erectile dysfunction have yet to be explained, they suggest that these men are not only less sensitive to penile stimulation but that their subjective experience of that stimulation is different from that of sexually functional diabetic and control men. This study is the first to identify anomalous interpretation of sensory experiences in sexually dysfunctional men with diabetes. Such psychophysical differences are consistent with the trend towards lower self-reported pleasure during coitus and masturbation in diabetic men. Furthermore, penile thresholds are predictive of the subjective experience of intensity and pleasantness resulting from penile stimulation, although these variables appear somewhat independent of finger sensory threshold. These patterns, however, could also reflect their lower penile sensitivity and difficulty in getting full erections. The clinical relevance of these subjective experiences of pleasantness and intensity suggests that health providers might want to query diabetic men with erection dysfunction about their preferred type and intensity of penile stimulation to achieve maximum arousal and encourage them to communicate this information to their partners.

Other differences were also found: bioavailable testosterone concentrations (circulating free testosterone and albumin-bound testosterone) were lower for diabetic subjects compared with non-diabetic control subjects. Other research has suggested possible gonadal dysfunction in diabetic men [4, 7, 20–21] but this study emphasizes the potential importance of distinguishing between total testosterone, which did not differ across groups, and bioavailable testosterone. Despite the lower bioavailable testosterone in both diabetic groups, levels were within normal range and we did not find group differences on self-assessed sexual desire. Previous research suggests that decreased sexual desire is associated with much lower concentrations of testosterone [22–23], so the clinical relevance of low normal bioavailable testosterone remains to be determined. Whatever its role, variation in bioavailable testosterone across groups did not seem to affect penile or finger sensory thresholds. When variation due to bioavailable testosterone was controlled statistically (data not presented), neither the effects of this factor were significant ($p = .70$ for penis, $p = .21$ for finger), nor did the overall threshold differences change among groups.

As could be expected, both diabetic groups had higher values of glycosylated haemoglobin than control subjects. But we also found that diabetic men with erectile difficulties had increased values of glycosylated haemoglobin, indicating poorer metabolic control than sexually functional diabetic men. Others [24–26], but not all [27–28], have suggested such an association. One study found that poor metabolic control in diabetic men was associated with impaired NPT [29], suggesting subclinical erectile impairment and risk of future erectile dysfunction. It is possible that differences in glycosylated haemoglobin values could partly explain the differences in sensory data. The relation of diabetic erectile problems and poor metabolic control merits further research to assess 1) whether better control is associated with improved sexual function and 2) if subjects are matched for glycosylated haemoglobin values, how this effects finger and penile sensory perceptions.

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