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CONTRIBUTION OF TACTILE DYSFUNCTION TO MANUAL MOTOR DYSFUNCTION IN TYPE II DIABETES

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Abstract

Introduction: Changes in sensory and motor functions of the hand in Type II Diabetes (T2D) patients have been reported; there is speculation that these changes are driven by tactile dysfunction. The purpose of this study was to evaluate the effects of tactile feedback on manual function in T2D patients.

Methods: T2D patients and healthy controls underwent median nerve blocks at the wrist and elbow. All participants underwent traditional timed motor evaluations, force dynamometry, laboratory-based kinetic evaluations, and sensory evaluation.

Results: Tactile sensation in the T2D group at baseline was found to be equivalent to tactile function of the control group after median nerve block. Traditional timed evaluation results were negatively impacted by anesthesia, while more sensitive kinetic measures were not.

Discussion: These data suggest mechanisms outside of tactile dysfunction play a significant role in motor dysfunction in T2D.

Keywords

tactile; hand; finger; type II diabetes; motor; sensory function

Introduction

In daily interactions, tactile sensation provides important information ranging from personal safety to intimate touch. An individual's association with the external environment relies on sensory cues that, if missing, may generate lead to an inability to perform basic self-care activities such as daily blood glucose monitoring, bathing, grooming, and dressing. An important link for these interactions is the human hand. Damage to sensory innervation of the hand can lead to improper efferent commands and result in reduced fine motor function.

Recent evidence suggest that fine motor function is impaired in patients who have type II diabetes (T2D), even though they do not notice such deficits. Recent studies have indicated that adults with T2D exhibit subtle yet significant differences in hand function in kinetic evaluation but not in assessments with clinical evaluation tools¹⁻⁴. As all manual tasks are performed by the application of force through the hands or fingers, evaluation of kinetics yields a wealth of information regarding fine motor disability⁵⁻¹⁰. Reduced maximal force produced by T2D patients has not previously correlated with changes in tactile function, disease severity, or diagnosis of peripheral neuropathy (PN); however, changes in submaximal force production have correlated with poorer tactile function^{1,2}. Together, these results suggest that tactile deficits may be responsible for some, but not all, manual deficits exhibited by T2D patients.

Previous work has shown the importance of cutaneous information for motor control of the fingers in healthy individuals. In these studies, forearm proprioception and tactile function of the palm were preserved, while tactile function of the fingertips was temporarily diminished¹¹⁻¹⁵. These temporary sensory deficits were achieved primarily through subcutaneous injection of anesthesia at the metacarpophalangeal joints to digital nerves of digits 2-5 ("ring blocks"). These studies identified significant decrements in maximum voluntary force production after the application of anesthesia via ring blocks. Based on this work, we suggest that altered force production in healthy control subjects is due to diminished cutaneous sensory feedback of the fingertips. In contrast, recent evidence indicates that diminished tactile function alone may not account for motor function changes in the hand in the presence of a systemic metabolic disorder such as T2D^{1,2}. In order to better understand how actions of the hands are affected by the presence of systemic neural damage that is presumed to target sensory neurons in the early stages of neural degeneration, more work is needed to understand the contribution of tactile function to manual disability.

The focus of this project is to investigate the contribution of tactile feedback to fine motor dysfunction in T2D patients compared to healthy control subjects. This was achieved by mimicking the effects of cutaneous deficits observed in T2D patients in healthy control participants via the use of subcutaneous anesthesia to the median nerve. We hypothesized that if tactile dysfunction is the primary deficit affecting pre-anesthesia finger function in T2D patients, then anesthetization of healthy control subjects will reveal equivalent motor behavior deficits in post-anesthesia evaluations of the control group as compared to pre-anesthesia function of T2D patients. The T2D cohort also underwent the anesthesia conditions; however, no hypotheses regarding changes in T2D function with anesthesia were developed *a priori*, as this portion of the experiment was exploratory.

Materials and Methods

Participants

Nine individuals with T2D and 9 healthy age- and gender-matched individuals were recruited. T2D patient information can be found in Table 1. The average age of the participants was 55 ± 5 years and 56 ± 5 years for the T2D and healthy cohorts, respectively. The average glycated hemoglobin (A_{1c}) for the T2D and healthy groups were $8.9 \pm 1.3\%$ and $5.8 \pm 0.4\%$, respectively. All subjects with the exception of 1 from each group were

strongly right-handed (laterality quotient (LQ) average = +98), and the exceptions were strongly left-handed (LQ average = -100) assessed via the Edinburgh Handedness Inventory¹⁶. Participants were recruited from our database from previous study participation. T2D participants had a confirmed T2D diagnosis either with or without diagnosis of PN made by collaborating physician; diagnosis was made via clinical examination and electrodiagnostic studies. Healthy individuals recruited to participate in this study did not have a clinical diagnosis of T2D, Type I Diabetes, or pre-diabetes. Study participants were excluded if they reported a history of neurological disorders (Parkinson disease, stroke, multiple sclerosis, or other neurological disorders), chemotherapy treatments, or hereditary or compression neuropathies, including carpal tunnel syndrome. The protocol was approved by the Committees established for the Protection of Human Subjects (CPHS) at the University of Houston. In accordance with the Declaration of Helsinki, participants provided informed consent according to the regulations established by University of Houston CPHS.

Experimental Procedures

All participants were evaluated with each test prior to the injection of anesthetic. Participants were re-evaluated after each nerve blocks [first block: median nerve at the wrist (WB); second block: median nerve at the elbow (EB)]. The protocol for each evaluation was completed within 20 minutes. The average time between the WB and EB injections was 27 ± 3 minutes, inclusive of the 5–10 minute waiting period post-injection to confirm block efficacy.

Administration of Median Nerve Blocks—Median nerve block at 2 anatomic levels was performed on the dominant hand of each participant using 1 mL of 2% lidocaine hydrochloride without epinephrine. At this volume and concentration, a short-acting (90 minute) sensory block without concomitant motor block can be reliably achieved¹⁷. The blocks were performed under aseptic conditions using a 1 mL syringe and 25 gauge sterile, single-use needle. The WB was performed between the palpated flexor carpi radialis and palmaris longus tendons at the level of the distal wrist crease, in line with the fourth metacarpal bone, evidenced by the direction of the fourth digit. The median nerve block at the elbow (EB) was performed in the antecubital fossa at the level of the volar elbow crease, just medial to the biceps tendon and the brachial artery. For accuracy, Doppler ultrasound was used to locate the brachial artery. The syringe was aspirated prior to instilling the lidocaine to confirm no occurrence of vascular puncture. The anticipated effect of EB was to maintain the suspension of tactile and proprioceptive block as well as to induce afferent blockade of the extrinsic flexor muscles of the forearm innervated by the median nerve. Given this anticipated effect, randomization of the evaluation schedule with respect to nerve block order could not be implemented.

Sensory Evaluations—The Semmes-Weinstein monofilament test was used to evaluate tactile sensation of the hands. Monofilament testing sites were the tips of the thumb (digit 1) and digit 5. Testing of a non-median sensory nerve innervated site (digit 5) was used as a control to confirm the anatomic distribution of the block. During evaluation, participants kept their eyes closed and indicated verbally if and where they perceived monofilament

touch. The monofilament size was increased until the subject was able to detect its touch a minimum of 2 consecutive times at the same location.

Proprioception was evaluated via a kinesthesia examination in which the testers produced the following movements in the non-anesthetized hand: (1) tip-to-tip pinch between digits 1 and 2, (2) tip-to-tip pinch between digits 1 and 5, (3) abduction and adduction of digit 1. Proprioception was assessed at all 3 time points; results were reported across all subjects as number of errors per condition.

Clinical Motor Evaluations

Jebsen-Taylor Hand Function Test (JTHFT)—The JTHFT is a performance-based evaluation used to assess common daily motor skills^{1,18}. It consists of 7 timed tests of manual activities: writing a 24 letter sentence, card turning ability, lifting small common objects, stacking checkers, simulated feeding, lifting large light objects (empty cans), and lifting large heavy objects (lifting 0.45 kg cans). Participants were instructed to perform the tasks as rapidly and accurately as possible. Times for the participants are reported in seconds.

Functional Dexterity Test (FDT)—The FDT is designed to assess 3 components of functional dexterity: speed, accuracy, and in-hand manipulation¹⁹. Participants were instructed to perform the task as rapidly and accurately as possible. Times for the participants are reported in seconds. Ten-second penalties were added to total performance time for each instance of dropping a peg, using the board for assistance in rotation of the peg, or for supination of the hand during rotation of the peg.

Laboratory-based Kinetic Evaluations

Maximum Force Production—Maximal grip and pinch strengths were evaluated using Biometrics Digital Hand and Pinch Dynamometers with wireless DataLOG system (G200, P200, and DataLOG model MWX8, Biometrics Ltd., Newport, UK). Three trials were collected with the dominant hand, and average maximal force production values (MVC) were calculated. During testing, dynamometers were placed 16 inches anterior to the patient torso, 6 inches away from the midline of the body towards the dominant hand. The wrist orientation was such that the hand was in a neutral position during testing^{1,2}. For pinch testing, the P200 device was held vertically with the non-dominant hand.

Submaximal Force Production Task (Submax)—Briefly, the task involved using the index finger and thumb in a pinch grip to produce a constant level of grip force, with feedback from a computer screen. All forces and moments of force produced were recorded simultaneously using 2 identical 6-component force-moment transducers (Nano-25 transducers; ATI Industrial Automation, Garner, NC, USA). Instrument details have been published^{1,2}. No contact of either transducer was permitted prior to trial onset. Up to three practice trials were offered to each subject. On average, each subject performed 1 practice trial prior to the onset of data collection for a given condition. Two different force production levels were tested: 20% and 40% MVC. MVC values for pinch forces were

determined from dynamometry testing. Each participant performed 3 trials for each condition, lasting 15 s each. Data of the 3 trials per condition were averaged.

Transducer signals were amplified and multiplexed using ATI hardware prior to being routed to an analog to digital converter (via cDAQ-9174 chassis and NI-9205 input modules, National Instruments, Austin, TX, USA). A customized Labview program (National Instruments, Austin, TX, USA) was used for data acquisition and customized MATLAB (Mathworks Inc., Natick, MA, USA) programs were written for data processing. Signals were sampled at 100 Hz and low-pass filtered at 10 Hz using a second-order, zero-lag Butterworth filter^{1,2}. The region of interest in the force data consisted of the final 10 s of each trial^{1,2}. Participants were required to reach and maintain the indicated force production level within the first 5 s of each trial.

Kinetic Analyses—Submaximal data were analyzed with respect to both linear and non-linear measures. Linear measures of performance included root mean square error (RMSE) of the force output relative to the target and the coefficient of variation (CV). The structure of force output variability was quantified via Approximate Entropy (ApEn) and Detrended Fluctuation Analysis (DFA).

Statistics

The data are presented as means $\pm$ standard errors. Repeated measures analyses of variance (RM-ANOVAs) were performed with the factors of: *Group* (2 levels: T2D or Control) and *Condition* (3 levels: baseline, WB, and EB). Evaluation of additional factors were included in test-specific RM-ANOVA analyses: *Site* (2 levels for the monofilament test), and *Level* (2 levels for the submaximal force production test). In order to evaluate our hypotheses regarding motor function, 95% confidence intervals (95% CI) were computed for motor performance of the control *Group* in the anesthesia *Conditions*. Baseline performance of the T2D *Group* was compared to 95% CI values of the control *Group* in the anesthesia *Conditions*. Subsequent ANCOVAs were performed using A_{1c} , duration of diagnosis, diagnosis of PN (via indicator variable), and monofilament data as co-variables to determine the strength of the relationship between disease indicators and motor function. *Monofilament* data were log transformed prior to analyses due to non-linearity and heteroskedasticity. Non-transformed data are shown in the Figures. As the data from the kinesthesia examination were in true/false format, these data were evaluated via Kruskal-Wallis tests.

Results

Data regarding the 95% CIs for each motor task in *Conditions* of interest for each *Group* can be found in Table 2.

Sensory Evaluations

Significant impairment in tactile function was detected in the T2D group as compared to controls (Figure 1A,B) (*Group*: $F_{1,88} = 48.40$, $P < 0.001$). Tactile threshold detection values increased with anesthesia, such that baseline < WB < EB EB confirmed with Bonferroni

post hoc analysis (*Condition*: $F_{2,88} = 21.66$, $P < 0.001$). Tactile detection values were preserved in the ulnar-innervated digit but significantly altered in the median-innervated digit (*Site*: $F_{1,88} = 12.66$, $P < 0.001$). Interactions signal poorer tactile detection thresholds in the T2D *Group* across all testing sites and all anesthesia *Conditions* (*Group x Condition*: $F_{2,88} = 3.71$, $P < 0.05$; *Group x Site*: $F_{1,88} = 10.05$, $P < 0.005$; *Condition x Site*: $F_{2,88} = 3.71$, $P < 0.05$; and *Group x Condition x Site*: $F_{2,88} = 3.13$, $P < 0.05$). ANCOVA indicated worsened tactile function as disease duration increased and if patients presented with a clinical diagnosis of PN (*Duration*: $F_{1,76} = 5.96$, $P < 0.05$; *PN*: $F_{1,82} = 5.19$, $P < 0.05$).

No significant differences were noted between *Groups* across kinesthesia tasks. No *Condition* differences were noted in the digit 1 abduction/adduction task; however, *Condition* differences were found in the opposition tasks: tip-to-tip digit 1 to digit 2 task and tip-to-tip digit 1 to digit 5 task ($H_2 = 11.5$, $P < 0.005$; and $H_2 = 7.85$, $P < 0.05$, respectively). In opposition tasks, the anesthesia conditions were associated with more kinesthesia errors in both tested *Groups* as compared to baseline (Table 3).

Clinical Motor Evaluations

JTHFT—Overall, T2D patients were significantly slower in all JTHFTs compared to controls (*Group*: $F_{1,48} = 24.38$, $P < 0.001$) (Figures 2A-G). The WB *Condition* was associated with longer task times as compared with baseline and EB *Conditions* confirmed via *post hoc* analysis ($F_{2,48} = 7.96$, $p < 0.001$). Significant *Task* differences were noted among evaluations. T2D patients had pronounced increases in completion times across all *Tasks* (*Group x Task*: $F_{1,9,88,8} = 5.12$, $P < 0.01$). No changes in completion time across *Conditions* were found in JTHFT6 and JTHFT7 for the control *Group*, in contrast to the T2D *Group* indicated by the *Group x Condition* interaction ($F_{1,48} = 3.33$, $P < 0.05$).

FDT—T2D patients were significantly slower in the FDT as compared with controls (*Group*: $F_{1,8} = 12.55$, $P < 0.01$). Completion time increased with *Condition* with a *Group x Condition* interaction ($F_{2,16} = 11.24$, $P < 0.001$ and $F_{1,8,14,2} = 4.18$, $P < 0.05$, respectively). *Post hoc* analysis indicated that both *Groups* were similar at baseline, but the time for task completion increased significantly in the T2D group for the EB and WB *Conditions*, but not for controls (Figure 2H).

Laboratory-based Motor Evaluations

Maximal Force Production—Between *Group* differences indicated reduced grip strength in T2D patients ($F_{1,8} = 7.89$, $P < 0.05$). *Condition* differences were found in both tasks such that reduced strength was noted in both anesthesia conditions as compared to baseline (Figure 1C,D) (Grip: $F_{1,9,15,7} = 5.65$, $P < 0.05$; Pinch: $F_{1,9,9,5} = 12.76$, $P < 0.005$). Some decrements in pinch strength in the T2D *Group* were accounted for by clinical diagnosis of PN via ANCOVA while the main effects of *Group* and *Condition* remained significant (*PN*: $F_{1,38} = 16.99$, $P < 0.001$; *Group*: $F_{1,38} = 9.48$, $P < 0.005$; *Condition*: $F_{2,38} = 4.94$, $P < 0.05$).

Submaximal Force Production (Submaximal)—Linear evaluation of Submaximal tasks indicated *Condition* effects with *Group* effect interactions (Figure 3A-3D). RMSE values dropped in anesthesia *Conditions* for controls while RMSE values stayed

approximately the same for the T2D *Group* (*Condition*: $F_{1,3,9,4} = 5.60$, $P < 0.05$; *Group x Condition*: $F_{1,2,8,1} = 5.91$, $P < 0.05$). RMSE increased as force requirements increased for the control *Group* but decreased for the T2D *Group* (*Group x Level*: $F_{1,7} = 8.53$, $P < 0.05$). CV values also indicated differences across *Level* such that larger force requirements resulted in smaller CV values (*Level*: $F_{1,7} = 20.67$, $P < 0.005$). A *Group x Condition* interaction emerged in the CV data, indicating the CV was relatively unchanged in the T2D *Group* across *Conditions*, while CV declined notably in the control *Group* in the anesthesia *Conditions* ($F_{1,4,9,6} = 5.71$, $P < 0.05$). Nonlinear analysis revealed *Group* effects that became stronger when a clinical diagnosis of *PN* was accounted for via ANCOVA (Figures 3E,F) (*Group* ApEn: $F_{1,45} = 15.33$, $P < 0.001$; *Group* DFA: $F_{1,45} = 18.84$, $P < 0.001$; *PN* ApEn: $F_{1,45} = 16.31$, $P < 0.001$; *PN* DFA: $F_{1,45} = 9.54$, $P < 0.005$).

Discussion

We hypothesized that T2D patients at baseline would display similar deficits in motor function to the control group under the anesthetized conditions, given the assumption that tactile deficits were the primary source of manual deficits in T2D. Most of the timed clinical evaluations supported the hypothesis, whereas the kinetic evaluations did not.

Use of Anesthesia to Mimic T2D Tactile Deficits

The use of injected lidocaine in this study provided a consistent targeted anesthetic to the median nerve at 2 locations for over 60 minutes. No injection-related complications (irritation at the injection sites, lightheadedness, infection, or cardiac dysrhythmias) were reported, and the patients tolerated the injections well. Tactile function of ulnar-innervated digits remained consistent across all 3 tested conditions, indicating successful targeting of the median nerve. Some evidence of impaired proprioception was found in kinesthesia evaluations in both groups, suggesting that the density of anesthesia administered may have successfully targeted smaller afferent nerve fibers of the hand associated with tactile function.

Kinesthesia error rates and timed evaluations worsened with the WB condition as compared to the baseline and EB conditions, particularly for the T2D group. These behaviors were observed despite the consistent tactile function impairment throughout the duration of each nerve block as measured by monofilaments. Tactile function of the median nerve was further impaired in the EB condition. The improvement in timed performance and kinesthesia in the T2D group in the EB condition was an unexpected finding. Similar effects of much smaller amplitude were echoed by the control group indicating that this response was not entirely pathological in nature. It is possible that the discrepancy in tactile feedback of the hand versus sensory feedback from the intact forearm muscle afferents in the WB condition led to magnified dexterity errors in both groups in the WB condition. As forearm muscle afferents may have been altered in the EB condition due to the lack of specificity in the Na⁺ channel blocking anesthesia, the sensation discrepancies between the forearm and the hand may have been muted in the EB condition, leading to fewer motor errors.

Pilot testing of this project indicated other dosage amounts of 1% and 2% lidocaine were not effective in producing consistent tactile deficits comparable to those found in T2D patients.

The injections may have contributed to some reduction in pinch force production; however these effects were found across all conditions for all participants.

Use of Timed Evaluations versus Kinetic Evaluations and Mechanisms Responsible for Behavior

Timed clinical measures of motor function were utilized to assess differences in manual dexterity. In the majority of instances, timed performance was consistent between the T2D group at baseline versus the control group in the anesthesia conditions, supporting the hypothesis. However, JTHF6 and JTHF7 were associated with larger functional declines in the T2D group at baseline versus the control group with anesthesia, indicating that T2D-related declines may not be attributed solely to tactile dysfunction in T2D. As suggested previously¹, the vast majority of clinical timed tests may not be sensitive to subtle changes in sensorimotor behaviors induced by metabolic diseases such as T2D. While the majority of the timed findings superficially display evidence that tactile dysfunction may be responsible for motor changes in the T2D group, more sensitive measures of motor change features should be analyzed to reveal a clearer picture of the extent of damage with T2D.

Similarly, basic force dynamometry did not reveal differences between the T2D group at baseline versus the control group in the anesthetized conditions, suggesting that the administration of anesthesia was adequate to negate group effects found in the absence of anesthesia, seen previously^{1,2,20} and at baseline evaluation, supporting the hypothesis. As in the timed clinical evaluations, since basic force dynamometry assesses only maximal strength, any underlying changes in force production are not probed.

In contrast, analysis of temporal components and signal complexity of the submaximal kinetic data did not support the hypothesis. Specifically, RMSE and CV were much larger in the T2D group across all conditions, indicating larger tracking errors by the T2D group, potentially related to the firing of motor units and their response to overall neural excitability via corticospinal changes. These values were not within the range of the healthy controls during either of the anesthetized states. These results indicate that damage beyond tactile dysfunction contributes significantly to motor dysfunction in T2D, and that T2D patients may not rely on tactile feedback during the performance of force production tasks. ApEn values were also noted to be lower in the T2D group while the values for DFA were larger than those for the control group, where both findings are similar to previous results^{1,2}. These directional changes in both values in the T2D group suggest higher signal predictability in T2D, indicating significant neural changes occurring with T2D. These between-group differences were magnified when the incidence of PN was controlled for in the data, suggesting that clinical diagnosis of peripheral nerve damage does not simply account for between-group differences^{21,22}. Implicitly, this suggests that changes to the corticospinal tracts and/or cerebral cortex maybe responsible for the behavioral differences exhibited in this and previous studies¹⁻⁴.

The premise of cortical change is plausible and supported by recent evidence of somatosensory cortex changes due to conditions previously considered to be only 'peripheral' in nature (eg. carpal tunnel syndrome)^{23,24}. It is also plausible that changes in motor units resulting in altered motor unit firing rates and or changes in motor unit size may

contribute to motor dysfunction in the T2D group²⁵. The mechanisms responsible are currently unknown, but the data presented in this study provide evidence to rule out tactile dysfunction as the sole contributor to manual dysfunction. In light of these findings, we are undertaking experiments to evaluate the contribution of potential cortical, corticospinal, and muscular changes to motor dysfunction in T2D patients. Results from these studies may be used to better understand the full scope of how self-care is impacted by systemic subtle neurological impairment in T2D patients.

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Abbreviations:

A_{1c}	percent glycated hemoglobin
ANCOVA	analyses of covariance
ApEn	approximate entropy
CV	coefficient of variation
DFA	detrended fluctuation analysis
EB	elbow block
FDT	functional dexterity test
JTHFT	Jebsen-Taylor hand function test
LQ	laterality quotient
MVC	maximal voluntary contraction
PN	peripheral neuropathy
RM-ANOVA	repeated measures analyses of variance
RMSE	root mean squared error
T2D	Type II Diabetes
WB	wrist block

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Figure 1.

Mean and standard error (SE) for tactile detection thresholds for the median and ulnar nerves and maximal force production. Note that in some panels SE bars are obscured by the symbols due to low variability across *Group*. **A:** *Group* and *Condition* averages for the tip of digit 1. **B:** *Group* and *Condition* averages for the tip of digit 5. **C:** Maximal grip strength. **D:** Maximal pinch strength.

Figure 2.

Mean and SE values for Jebsen-Taylor Hand Function (JTHF) test and Functional Dexterity test (FDT). All values are expressed in terms of task completion time (s) across all *Conditions*. **A:** Page turning. **B:** Stacking checkers. **C:** Picking up small common objects. **D:** Lifting large light objects. **E:** Lifting large heavy objects. **F:** Simulated spoon feeding. **G:** Handwriting. **H:** FDT.

Figure 3. Mean and SE of Root Mean Square Error (RMSE), Coefficient of Variation (CV), Approximate Entropy (ApEn) and Detrended Fluctuation Analysis (DFA) values. **A:** Group and Condition RMSE data. **B:** Group and Task RMSE data. **C:** Group and Condition CV data. **D:** Group and Task CV data. **E:** Group and Condition ApEn data, **F:** Group and Condition DFA data.

Table 1.

Clinical Characteristics of T2D Patients

Patient #	Age (years)	Gender	T2D Duration (months)	Glycated Hemoglobin (% A1c)
1	60	W	3	9.5
2	56	M	40	9.3
3	55	W	175	9.1
4	65	W	196	9.5
5	46	W	66	6.4
6 *	55	M	55	9.0
7	58	W	369	11.1
8	53	M	1	7.6
9 *	50	M	126	8.7
Mean	55	--	115	8.9
SD	6	--	118	1.3

* Indicates a clinical diagnosis of peripheral neuropathy (PN). W, women; M, men; T2D, Type II Diabetes; SD, standard deviation

Table 2.

Mean motor performance values for the T2D *Group* at baseline compared to the 95% confidence interval (CI) data for the control *Group* in the WB and EB *Conditions*.

	<i>T2D</i>	<i>Control</i>	
	Baseline	WB	EB
JTHFT:			
1. Page Turning (s)	7.13	(5.95 – 11.89)	(5.33 – 7.80)
2. Stacking Checkers (s)	6.71	(4.60 – 8.80)	(4.16 – 7.23)
3. Small Objects (s)	11.29	(6.80 – 25.93)	(6.64 – 18.26)
4. Light Objects (s)	4.89	(4.00 – 5.23)	(4.16 – 7.23)
5. Heavy Objects (s)	5.00	(3.56 – 5.57)	(3.72 – 5.04)
6. Spoon Feeding (s)	11.85	(9.24 – 11.53) *	(9.04 – 12.87)
7. Handwriting (s)	23.98	(10.89 – 21.71) *	(9.87 – 22.27) *
FDT (s)	29.95	(29.96 – 54.02) *	(26.07 – 38.12)
Max Grip (N)	226.1	(193.7 – 416.3)	(206.4 – 423.7)
Max Pinch (N)	47.9	(30.2 – 59.5)	(27.6 – 53.0)
RMSE (N)	1.05	(0.35 – 0.94) *	(0.27 – 0.75) *
CV (–)	0.097	(0.033 – 0.079) *	(0.029 – 0.062) *
ApEn (–)	0.18	(0.20 – 0.41) *	(0.19 – 0.45) *
DFA (–)	1.17	(0.90 – 1.15) *	(0.94 – 1.14) *

* Indicates T2D values at baseline are outside the computed 95% CI. ApEn, approximate entropy; CV, coefficient of variation; DFA, detrended fluctuation analysis; EB, elbow block; FDT, functional dexterity test; JTHFT, Jebsen-Taylor hand function test; RMSE, root mean squared error

Table 3.

Number of kinesthesia errors produced by the T2D and control *Groups* in each of the tested *Conditions*.

(a) Kinesthesia: Tip Digit 1 to Tip Digit 2				
	<i>Baseline</i>	<i>WB</i>	<i>EB</i>	<i>Total Errors</i>
Control	1	4	4	9
T2D	0	7	4	11
(b) Kinesthesia: Tip Digit 1 to Tip Digit 5				
	<i>Baseline</i>	<i>WB</i>	<i>EB</i>	<i>Total Errors</i>
Control	0	2	3	5
T2D	0	5	2	7