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The Polish version of the Boston Carpal Tunnel Questionnaire: Associations between patient-rated outcome measures and nerve conduction studies

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Abstarct*Purpose:* The aim of this study was to investigate the associations between nerve conduction studies and three commonly used patient-reported outcome measures (Disabilities of the Arm, Shoulder and Hand [DASH], Michigan Hand Outcomes Questionnaire [MHQ], and the Polish version of the Boston Carpal Tunnel Questionnaire [BCTQ])
Methods: A total of 218 consecutive patients with carpal tunnel syndrome (CTS) completed the BCTQ, MHQ, and DASH questionnaires followed by nerve conduction studies on their first visit to the clinic.
Results: After a 14-day interval, 189 of these patients completed the BCTQ for the second time. The Polish version of the BCTQ was shown to have excellent internal consistency, test-retest reliability, and validity. The BCTQ's construct validity revealed a strong correlation with MHQ and DASH (both $R>0.7$; $P<0.05$). Generally, compound motor action potential amplitudes correlated slightly with MHQ ($R=0.22$; $P<0.05$) and its subscales, while sensory nerve action potential conduction velocities had a low correlation with the BCTQ's symptom severity scale ($R=-0.16$; $p<0.05$).

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Conclusion: The Polish BCTQ version demonstrated good psychometric properties. It can be used both in clinical and research practice. Objective results of diagnostic procedure influenced patients' lives as measured by subjective questionnaires.
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Introduction

Carpal tunnel syndrome (CTS) is the most common neuropathy of the upper extremities, causing numbness, pain, and tingling in the hands.[1] There are many tools for diagnosing CTS, but none of them is sufficient on its own.[2] Confirmation is based on clinical symptoms, usually accompanied by nerve conduction studies and/or ultrasonography. Nerve conduction studies provide an objective measure of median nerve function but require special technical expertise and equipment.[3] The American Association of Electrodiagnostic Medicine provides the basic information and definitions for the testing needed for CTS diagnosis.[4] In addition, more physicians now use standardized questionnaires to better assess the patient's discomfort as part of a complex assessment.[5] Patients' aspects such as grade of discomfort, social and employment factors, and patients' expectations should be taken into consideration regarding the decision about appropriate treatment.

The subjective severity of patients' symptoms can be evaluated using the Patient-Reported Outcome Measures (PROMs), which are reliable, low-cost, and simple methods for assessing patients with hand disorders, including CTS.[6] Depending of the tool's design, a tool can measure the general health status of patients or more specific disease-related symptoms. So far, many questionnaires that help assess and standardize these types of measurements have been developed. While PROMs present good individual psychometric properties, the researcher is faced with a difficult choice of which form to use when assessing patients.[7]

Another issue with these evaluations is how real damage to the nerves determined by electroneurological methods affects patients' quality of life according to the PROM scale. There are few studies that have tried to investigate the associations between those two parameters. Sonoo et al. reported a comparison between CTS's neurophysiological severity as measured in a study by Bland (2000a) and the Boston Carpal Tunnel Questionnaire (BCTQ)'s symptoms severity scale. The author found a significant linear correlation of r=0.26 between conduction abnormalities and BCTQ's symptomatology based on 29'594 cases.[8,9] Leite et al. described the BCTQ as a valid and responsive instrument, which should be used as a primary outcome measurement in future CTS trials.[10]

The aim of this study was to investigate the association between nerve conductions studies and the most popular questionnaires used in hand surgery for CTS: (1) BCTQ; (2) Michigan Hand Outcome Measure (MHQ); and (3) Disabilities of the Arm, Shoulder, and Hand (DASH).[11] Because the measurement properties of the Polish BCTQ have not yet been provided and used only as a clinimetrically confirmed tool, the authors undertook translation and adaptation of the Polish version of the BCTQ.

Patients and Methods

This study used a cross-sectional design and was performed in two stages. The first stage was BCTQ translation into Polish followed by its adaptation into clinical settings. The second stage of the study was to check the reliability and validity of the Polish BCTQ by testing it on a large group of patients diagnosed with CTS and comparing these results from results obtained from the MHQ, DASH, and NCS. The collected data was subject to thorough statistical analysis. The official license and translation agreement from the Regents of the University of Michigan were obtained (academic license No 3372). The study was approved by the Bioethical Committee of the Jagiellonian University in Krakow (No 1072.6120.32.2017).

Study sample

There were 218 patients included in this study, who had been admitted to the outpatient clinic of the Second Department of the General Surgery and the Department of Neurology of the Jagiellonian University Medical College in Krakow, Poland. Recruitment of 281 consecutive patients was performed from February 2017 to February 2018 (Figure 1). Patients had been diagnosed with CTS, which was confirmed: (1) 64.4% using NCS; (2) 16.7% with ultrasonography; and (3) 18.9% with both tools. Inclusion criteria consisted of several parameters: (1) CTS symptoms and signs; (2) nerve conduction or ultrasonography confirmation (comparing cross-sectional area measurements of the median nerve obtained at the level of the carpal tunnel with those obtained at the level of the pronator quadratus muscle was higher than 2 mm^2);[12] (3) no CTS-related no surgery; (4)>18 years of age: (5) ability to complete the entire questionnaire on their own; (6) Polish as the subject's first language; (7) no changes in symptoms expected in the 14 days between assessments; and (8) no history of mental or neurologic disease. Written informed consent was received from all participants.

Electrodiagnostic criteria for CTS confirmation used in the current study consisted of two parameters: (1) median distal motor nerve latency of>3.6 msec or (2) a median sensory nerve conduction velocity (SNCV) of <50 m/sec across the carpal tunnel. In cases of severe CTS in which the median sensory potentials and the compound muscle action potential (CMAP) from abductor pollicis brevis (APB) muscle were absent, a lumbrical-interosseous distal motor latency

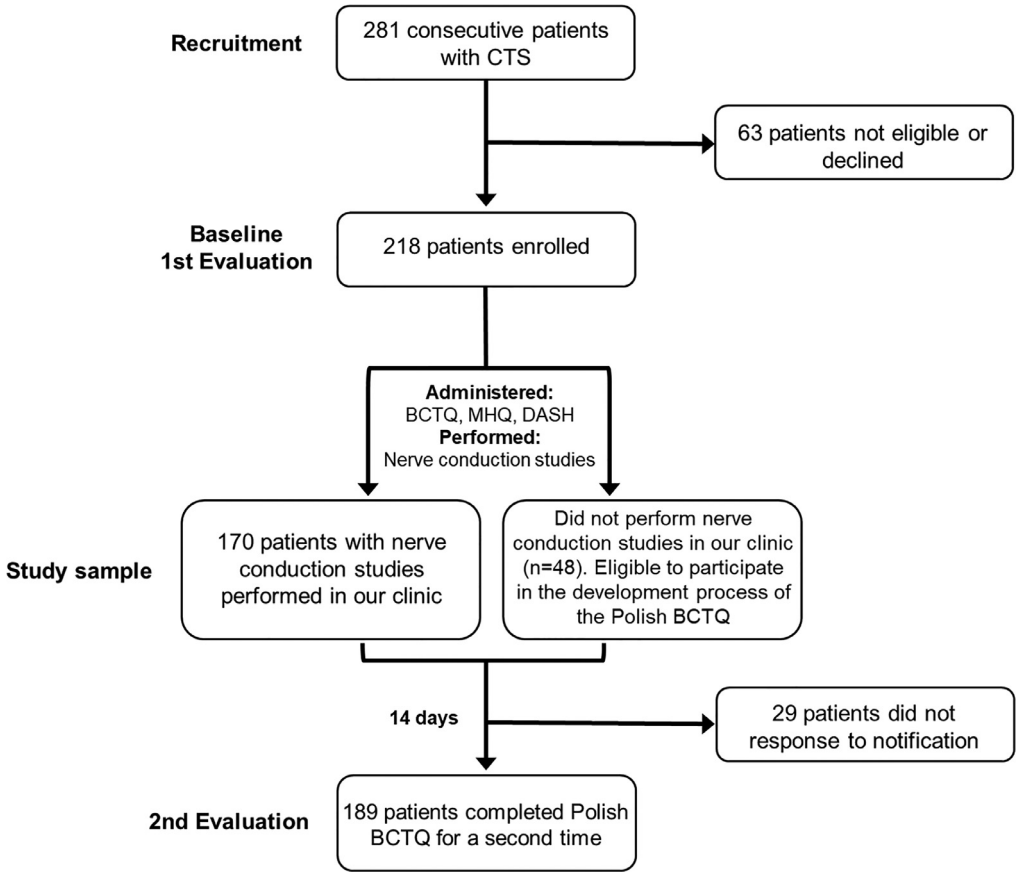

Figure 1 Flow-chart presenting patient recruitment. CTS, carpal tunnel syndrome; BCTQ, Boston Carpal Tunnel Questionnaire; MHQ, Michigan Hand Outcomes Questionnaire; DASH, Disabilities of the Arm, Shoulder, and Hand.

(DML) comparison was performed (the upper limit of a normal test = 0.4 ms).[13]

Instruments and measures

The translation was carried out in accordance with the approved guidelines (American Academy of Orthopedic Surgeons).[14] The final Polish BCTQ version is located in the supplementary files.

The BCTQ (Levine et al. 1993) consists of an 11-item subscale for symptom severity (SSS) and an 8-item subscale for functional impairment (FSS).[15] The total results were the means of both scores. Any unanswered questions were not included in the final score, and the average of the existing answers items could be substituted for the missing answer(s). In bilateral cases, patients were asked to evaluate only the most symptomatic hand. When patients could not unambiguously determine which hand had the worse function (from which they suffered more), they were asked to fill out the form as for dominant hand.

To compare the adapted questionnaire with the validated tools, the Polish version of MHQ and DASH were used. The MHQ is a hand-specific tool that assesses patients' hand/wrist function by applying every disability/disorder.[16-18] Its usefulness has been confirmed in patients with CTS.[19] The left and right hand are evaluated separately with 37 main questions covering six scales. Higher scores are associated with better hand states except for pain, which is related to more intense pain. In the current study, the final outcome was calculated only for hands with CTS. If both hands were affected, the score was analyzed for the hand that patients used to fill out the BCTQ score. Missing values were handled based on the scoring mechanism.

The second questionnaire, which assesses the entire upper limb with every musculoskeletal disorder, is DASH, to which CTS patients have been highly responsive.[7,20] Higher scores indicate greater disability. According to the scoring algorithm of the disability/symptom module, if more than three items are missing, then the DASH cannot be scored. Additional sport/music or work modules need to be entirely completed to be valid for analysis.

Electrophysiological examinations were performed with a Viking Quest electromyograph (Nicolet Biomedical Incorporated, Madison, USA) using surface stimulating and recording electrodes.[21] Supramaximal, constant-current bipolar stimulation was undertaken using a bar electrode (percutaneous). A sensory nerve conduction study was performed on the median nerve using a stimulation rate of 2 Hz. The antidromic method was used to stimulate the median nerve at the wrist with a recording electrode usually placed on the index or middle finger achieving a distance of 13 cm from the wrist. Sensory nerve

action potentials (SNAPs) were recorded using two ring electrodes.

Motor nerve conduction studies were performed by placing an electrode above the abductor pollicis brevis muscle using a single stimulus protocol and a distance of 5 cm. A stimulation rate of 1 Hz was used to obtain the F-wave. At all sites, the stimulus duration was 0.2msec. CMAPs were recorded using two surface cup electrodes (8 mm in diameter) applied 3cm apart. For consistency, the nerve conduction studies were all performed by the same neurologist. Hand skin temperature (32–34°C) was monitored throughout the study. Stimulations were conducted over the median nerve at the wrist, elbow, and axilla. The CMAP was recorded from the APB muscle.

Procedure

At the first clinic visit, the eligible patients were informed of the study concepts and asked if they agreed to participate in the study. Written informed consent was obtained, and basic demographic information such as sex, age, body mass index (BMI), affected hand, dominant hand, symptom duration (in months), and place of residence. The patient was examined physically and completed the BCTQ, MHQ, and DASH questionnaires. At the end, NCS were repeated in our own diagnostic laboratory even if the information was already available elsewhere. In cases in which the patient declined, they were disqualified from electrophysiological analysis but not from the BCTQ adaptation process (48 patients). All the patients were asked to complete the BCTQ 14 days later. They could accomplish this in three ways: (1) at the second visit in the clinic; (2) send the completed form by post, which had been delivered to them after their first appointment; or (3) send the completed form by e-mail, which was delivered to them after their first appointment. Points 2 and 3 occurred after previous telephone notification.

To preserve the highest research quality, only patients with a fully completed BCTQ at the first visit were included in the final analysis. If there were missing data at the second BCTQ assessment, this patient was excluded from the test-retest analysis (Figure 1).

Statistical analysis

Continuous data are presented as the mean with standard deviation or median with interquartile range depending on normal distribution. Discrete data are presented using frequency and percentages. Normal distribution was verified using the Shapiro–Wilk test.

There are clearly specified quality criteria for measurement properties of health status questionnaires.[22] The first one is reliability, which is defined as the degree to which the measurement is free from measurement error. It was assessed using three properties: (1) internal consistency (Cronbach's alpha coefficient); (2) reproducibility ($ICC_{2.1}$, a two-way random effects absolute agreement model and the Bland–Altman analysis); and (3) measurement error (the standard error of measurement [SEM] and the minimum detectable change [MDC95]).[23,24] Test-retest reliability was assessed by administering the form to the same patients twice at 2-week intervals. The plot for the BCTQ scores' SSS and FSS were paired together with a scatterplot between the first and second assessments, which demonstrated how close the scores on repeated measures were to each other.

The construct validity informs us about the degree to which the scores of a PROM instrument are consistent with the hypothesis based on the assumption that the PROM instrument can measure what it is designed to measure.[22,23] The Spearman correlation coefficient was applied to find the association between the BCTQ and the Polish MHQ and DASH. There are no existing predefined hypotheses for investigating construct validity, so we decided to test one hypothesis for each additional instrument using the correlation coefficient R value. The following hypotheses were defined: (1) $R \leq -0.5$showed at least a moderate correlation between the BCTQ scales and the MHQ total score and (2) $R \geq 0.5$ demonstrated at least moderate correlation between the BCTQ scales and the DASH functional score. In this analysis, MHQ outcomes were only considered in the affected hands.

Ceiling and floor effects describe the number of participants who achieved the lowest or highest possible score. This value need to be <15% of the respondents.[25] A P-value of <0.05 was considered to be statistically significant. The statistical analyses were performed using STATISTICA v13.3 (StatSoft Inc., Tulsa, OK, USA).

Results

Overall, 218 patients were included in this study, of whom 173 (79.4%) were women and 45 (20.6%) were men. All the subjects were Polish, and the mean age was 56.8 ± 13.7 years. Both hands were affected by CTS in 99 (45.4%) patients followed by the right hand in 89 (40.8%) patients and the left hand in 30 (13.8%) patients. The overall patient demographic data are presented in Table 1.

The translation and adaption process revealed that there were no linguistic issues and no activities were renamed. Pretesting on a group of 10 patients presented no difficulties, and there were no difficulties during testing using the final version of the questionnaire. Missing items were not observed in the first assessment of BCTQ; however, 20 (9.2%) of the patients showed missing data in the second assessment of the BCTQ, and 9 (4.1%) patients did not attend the clinic or post the second BCTQ. Overall, 189 patients completed the BCTQ twice, which showed a high response rate of 86.7%. No floor or ceiling effects were observed.

The mean values with SD for SSS and FSS are presented in Table 2. Cronbach's alpha revealed high values for each scale (SSS:0.91; FSS: 0.92). The ICC showed the desired values (SSS:0.85; FSS:0.87), which indicate good retest reliability. The MDC95 was in approximately 1 point for both scales. The remaining parameters in addition to the MHQ, DASH, and NCS results are presented in Table 3.

The Bland–Altman plots along with scatter plot graph are presented in Figure 2. The limits of agreement (LoA) for the SSS varied from −0.97 (95% CI: −1.09–(−)0.85) to 0.9 (95% CI: 0.78–1.01), and for the FSS, the total score varied from −0.94 (95% CI: −1.07–(−)0.82) to 0.97

Table 1 Patient demographic data (total n=218).

Characteristic		Value (n; mean; median)	(%; SD; Q1-Q3)
Gender			
	Male	45	20,6%
	Female	173	79,4%
Nationality			
	Polish		100%
Age (years)		56.8	13.7
BMI (kg/m^2)		28.4	5.0
Affected hand			
	Right	89	40,8%
	Left	30	13,8%
	Bilateral	99	45,4%
Dominant hand			
	Right	192	88,1%
	Left	18	8,3%
	Ambidextrous	8	3,7%
Symptom duration (months)		12	(6-29)
Place of residence			
	Village	76	34,9%
	City	142	65,1%

Table 2 Internal consistency and test-retest reliability of the Polish version of the BCTQ.

BCTQ	#1 Assessment (n=218) Mean Score	SD	#2 Assessment (n=189) Mean Score	SD	Cronbach's Alpha	ICC	SEM	MDC95
Symptom Severity Scale	3.3	0.8	2.9	0.9	0.906	0.845	0.32	0.90
Functional Status Scale	3.2	0.9	2.9	1	0.924	0.868	0.34	0.93

BCTQ,Boston Carpal Tunnel Questionnaire; ICC,Intraclass Correlation Coefficient; MDC95, Minimal detectable change 95%; SEM, standard error of measurement; SD, standard deviation.
$SEM = SD \times \sqrt{1 - ICC}$.
$MDC95 = 1.96 \times SEM \times \sqrt{2}$).

(95% CI: 0.85-1.09) for the 14-day time interval, suggesting an acceptable agreement between the two measurements.

The BCTQ correlation with questionnaires is presented in Table 4. The Polish version of the BCTQ confirmed the stated hypotheses regarding the R value. Forms BCTQ, MHQ, and DASH associations with NCS are presented in Table 5. Only the MHQ total score and the MHQ domains correlated with CMAP amplitudes (R=0.16-0.23; $p<0.05$). BCTQ's SSS correlated with the SNAP conduction velocity (R=−0.16; $p<0.05$).

Discussion

The present study demonstrated associations between various PROMs and NCS in patients with CTS. Mondelii et al. suggested using the BCTQ and NCS in conjunction with each other as a complementary method that makes the comparison between different studies possible.[26] The use of PROMs completed the assessment of the patients, which would be difficult to fully capture without these tools. The questions in such forms provide answers that are directed to assess certain patient problems. PROM enables us to systematize and standardize the subjective features that physicians most desire to evaluate in patients, which usually are immeasurable, as mathematical numbers. This can create some numerical pattern that can be very variable in CTS, but the changes can be used to evaluate treatment impact.

In the current study, NCS in CTS patients significantly correlated with the motor potentials found in electrophysiological studies only with respect to the MHQ. Correlation between NCS and PROM showed that objective results of diagnostic procedure influenced patients' lives as measured by subjective questionnaires. The electrodiagnostics mainly measured the state of myelination of large motor and sensory axons. Interestingly, although the MHQ form is

Table 3 Average values with standard deviation of measured parameters.

Variable		Total (#1 Assessment)
BCTQ	Symptom Severity Scale	3.3 ± 0.8
	Functional Status Scale	3.2 ± 0.9
MHQ	Total score	3.2 ± 0.9
	I. Overall hand function	2.9 ± 1.0
	II. Activities of daily living	48.6 ± 20.4
	III. Work performance	43.7 ± 21.2
	IV. Pain	51.5 ± 28.2
	V. Aesthetic	50.2 ± 24.6
	VI. Satisfaction	55.5 ± 28.1
DASH	Functional Score	66.8 ± 25.9
	Sport	34.9 ± 23.8
	Work	47.3 ± 23.5
CMAP wrist	Latency [ms]	59.5 ± 30.1
	Amplitude [μV]	49.0 ± 25.5
SNAP	CV [m/s]	5.1 ± 1.7
	Amplitude [μV]	7.4 ± 3.4

BCTQ, Boston Carpal Tunnel Questionnaire; MHQ, Michigan hand outcome questionnaire; DASH, The Disabilities of the Arm, Shoulder and Hand; SNAP, Sensory nerve action potentials; CMAP, compound motor action potentials; CV, conduction velocity.

Table 4 Correlation of BCTQ with MHQ and DASH for hands diagnosed with Carpal Tunnel Syndrome (CTS).

Variable		Symptom Severity Scale		Functional Status Scale	
		R	p	R	p
MHQ affected hand	Total score	−0.72	0.000	−0.76	0.000
	I. Overall hand function	−0.70	0.000	−0.69	0.000
	II. Activities of daily living	−0.64	0.000	−0.76	0.000
	III. Work performance	−0.55	0.000	−0.60	0.000
	IV. Pain	0.63	0.000	0.58	0.000
	V. Aesthetic	−0.38	0.000	−0.47	0.000
	VI. Satisfaction	−0.66	0.000	−0.66	0.000
DASH	Functional Score	0.71	0.000	0.81	0.000
	Sport	0.50	0.006	0.49	0.006
	Work	0.63	0.000	0.72	0.000

PRUNE, Patient-Rated Ulnar Nerve Evaluation; MHQ, Michigan hand outcome questionnaire; DASH, The Disabilities of the Arm, Shoulder and Hand; * inverse correlation because in MHQ better score indicates better result.

not disease-specific, it produced a higher association with NCS than did the BCTQ. The reason for this could be that CTS is very often bilateral (45.4% in the current study), and the MHQ questionnaire addresses each hand separately. The BCTQ SSS subscale correlated only with SNAP conduction velocity. The above results do not assume an advantage of one tool over another one. Each questionnaire measures subjective perceptions of symptoms in different situations. An NCS is a functional tool in CTS diagnosis and can be used for monitoring patients after carpal tunnel release surgery.[27]. In other studies, there were no or weak associations between preoperative median and ulnar conduction measures with BCTQ.[26,28,29]

In accordance to the article written by Mondelli et al., NCS changes in different ways as does the BCTQ. NCS evaluates peripheral nerve damage. Nerve function restoration depends on the degree to which the nerve was damaged. In more advanced cases, the complete nerve function restoration is impossible. The BCTQ assesses patients' subjective feeling and impact of CTS on their life. In mild cases, there is a possibility that patients feel strong pain, which is the result of impairment or damage of the most sensitive, thin nerves. The BCTQ score could then be higher and would indicate a more severe type of CTS. However, in more serious cases, in which the median nerve is almost completely damaged, the subjective feeling of pain is rather small. Thus, the final BCTQ score could be lower and would indicate a softer stage of CTS.[26] In summary, a correlation between NCS and BCTQ show that the PROM results could be explained by NCS because nerve damage is detected by both

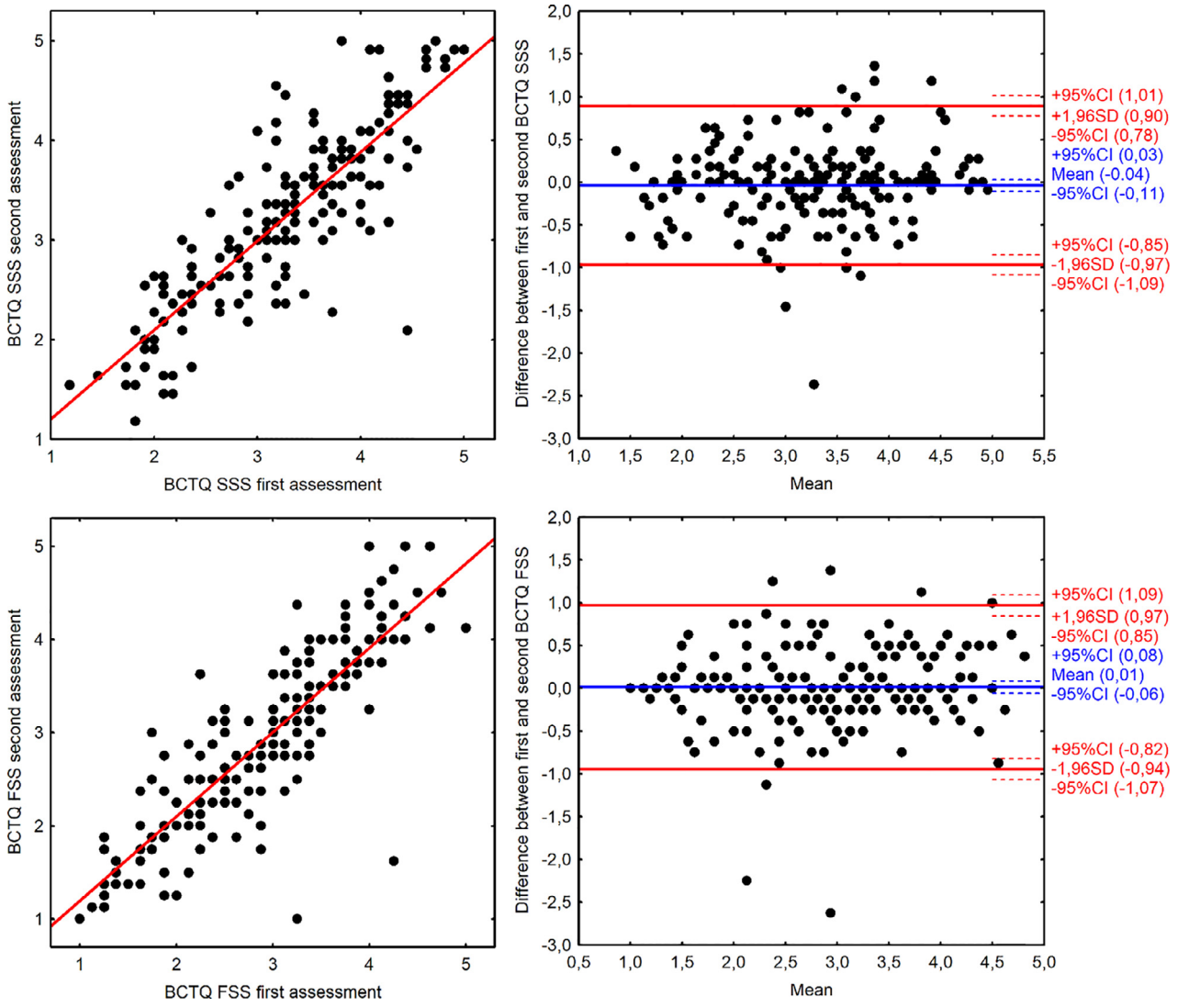

Figure 2 The Bland–Altman plot for the results during a 14-day time interval for completion of the Boston Carpal Tunnel Questionnaire (BCTQ) separately for Symptom Severity Scale (SSS) and Functional Status Scale (FSS).

of these measurements, and by using both these methods, which are subjective and objective, we can build an accurate overall picture of the patient.

Sonoo et al. also took into consideration that there was no gold standard for determining the presence of CTS. Clinical examination and NCS can only assess the probability of this disease, and both measurements can give false positive and false negative results. However, among all of the possible diagnostic procedures for CTS detection, studies have suggested that NCS has sufficiently high specificity and sensitivity and is a good candidate for this purpose.

The BCTQ is widely used for assessment of patients with CTS and has been translated into many different languages.[30–36] This study provides BCTQ's translation and adaptation into Polish and will expand the range of disease-specific PROM used in hand surgery and rehabilitation for monitoring patients' conditions. The measurement properties of the original version of the BCTQ consisted of Cronbach alphas of 0.89 and 0.91 for SSS and FSS respectively, and reproducibility as Pearson's correlation coefficient of $r = 0.91$ and 0.93 for SSS and FSS, respectively. The results of the present work demonstrated similar optimal measurement property values. Responsiveness was not assessed in the current study because this work only assessed patients before surgical interventions. According to Leite et al., a systematic review of the FSS effect sizes varied from 0.48 at 6 weeks to 1.44 at 27 weeks post-operatively, and for the SSS, it varied from 1.13 at 13.5 weeks to 2.33 at 27 weeks post-surgery.[10] In the current study, the LoA values were almost identical to MDC values, representing random measurement error. A larger LoA score versus MDC score might have been caused by a distinct change in a patient's feeling about his/her hand.

In the current study, the authors used the original version, which is still the most commonly used one. Future studies should focus on the utility of the presented models for monitoring CTS patients.

The strengths of this analysis include the prospective nature of the study and the aim to compare the most commonly used outcome instruments with objective measures

Table 5 Correlation of BCTQ, MHQ, and DASH with NCS for hands with diagnosed CTS based on 170 patients.

Variable		CMAP wrist		SNAP	
		Latency [ms]	Amplitude [μV]	CV [m/s]	Amplitude [μV]
		R	R	R	R
BCTQ	Symptom Severity Scale	0.10	0.01	**−0.16***	−0.14
	Functional Status Scale	0.11	−0.09	−0.07	−0.12
MHQ symptomatic hand	Total score	−0.11	**0.22***	0.04	0.07
	I. Overall hand function	−0.09	**0.23***	0.08	0.07
	II. Activities of daily living	−0.10	**0.21***	0.08	0.10
	III. Work performance	−0.06	**0.17***	−0.06	0.03
	IV. Pain	0.12	**−0.17***	−0.11	−0.15
	V. Aesthetic	−0.11	**0.16***	0.01	−0.08
	VI. Satisfaction	−0.10	**0.22***	0.03	0.07
DASH	Functional Score	0.09	−0.11	−0.03	−0.09
	Work	0.03	−0.08	−0.01	−0.01

BCTQ, Boston Carpal Tunnel Questionnaire; MHQ, Michigan hand outcome questionnaire; DASH, The Disabilities of the Arm, Shoulder and Hand; SNAP, Sensory nerve action potentials; CMAP, compound motor action potentials; CV, conduction velocity
inverse correlation because in MHQ better score indicates better result.
* $p < 0.05$.

in CTS patients. Study limitations were indicted by our sample, which was a convenience sample; hence selection bias could not be excluded. Patients who responded to the survey might not have accurately represented the population affected by CTS.

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The remaining authors have no financial relationships relevant to this article to disclose.

Conflict of Interest

The other authors have no conflicts of interest to disclose

Ethical Approval

The research was approved by the Bioethical Committee of the Jagiellonian University, Krakow, Poland (No. 1072.6120.213.2017). The methods and protocols were carried out in accordance with the approved guidelines.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.bjps.2018.12.032.

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