Original Article

Nine-hole Peg Test and Ten-meter Walk Test for Evaluating Functional Loss in Chinese Charcot-Marie-Tooth Disease

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Abstract

Background: The 9-hole peg test (9-HPT) and 10-meter walk test (10-MWT) are commonly used to test finger motor function and walking ability. The aim of this present study was to investigate the efficacy of these tests for evaluating functional loss in Chinese Charcot-Marie-Tooth (CMT) disease.

Methods: Thirty-four Chinese CMT patients (CMT group) from August 2015 to December 2016 were evaluated with 9-HPT, 10-MWT, CMT disease examination score, overall neuropathy limitation scale (ONLS), functional disability score, and Berg Balance Scale (BBS). Thirty-five age- and gender-matched healthy controls (control group) were also included in the study. Student's nonpaired or paired *t*-test were performed to compare data between two independent or related groups, respectively. The Pearson test was used to examine the correlations between recorded parameters.

Results: The mean 9-HPT completion time in the dominant hand of CMT patients was significantly slower than that in the healthy controls (29.60 ± 11.89 s vs. 19.58 ± 3.45 s; $t = -4.728$, $P < 0.001$). Women with CMT completed the 9-HPT significantly faster than men with CMT (dominant hand: 24.74 ± 7.93 s vs. 33.01 ± 13.14 s, $t = 2.097$, $P = 0.044$). The gait speed of the average self-selected velocity and the average fast-velocity assessed using 10-MWT for CMT patients were significantly slower than those in the control group (1.03 ± 0.18 m/s vs. 1.44 ± 0.17 m/s, $t = 9.333$, $P < 0.001$; 1.31 ± 0.30 m/s vs. 1.91 ± 0.25 m/s, $t = 8.853$, $P < 0.001$, respectively). There was no difference in gait speed between men and women. Both 9-HPT and 10-MWT were significantly correlated with the ONLS, functional disability score, and BBS ($P < 0.05$ for all).

Conclusion: The 9-HPT and 10-MWT might be useful for functional assessment in Chinese patients with CMT.

Key words: Charcot-Marie-Tooth Disease; Charcot-Marie-Tooth Disease Examination Score; Nine-hole Peg Test; Ten-meter Walk Test

Introduction

Charcot-Marie-Tooth (CMT) disease is the most common inherited peripheral nervous system disorder, with a prevalence of up to 1/1214.[1] CMT commonly causes significant muscular deficits and restriction of daily activity, leading to severe disabilities, even at a very young age. Although the progression is relatively slow, CMT always deteriorates progressively, and the ability to balance and exercise might also be affected.[2]

There are many functional assessments used in CMT. The 9-hole peg test (9-HPT) is widely used for assessing dexterity, particularly in patients with CMT, chronic inflammatory demyelinating polyneuropathy, and spinocerebellar ataxia,[3-5] and exhibits excellent inter- and intra-rater intraclass correlation coefficients (ICC), for example, 0.95 (even up to 0.99 in one study) in CMT patients.[6,7] The 10-meter walk test (10-MWT) is also widely used to assess gait speed in individuals with gait limitations, particularly in patients with Parkinson's disease, monoclonal IgM-related neuropathies, stroke, CMT, and other diseases.[8-11] Further, it exhibits excellent reliability (inter-rater ICC, 0.97; intra-rater ICC, 0.96) in CMT patients.[6] Other commonly used scales include

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CMT neuropathy score,[12] CMT Pediatric Scale,[13] overall neuropathy limitation scale (ONLS),[14] functional disability scale (FDS),[15] and Berg Balance Scale (BBS).[16] These scales are well validated and reliable clinical tools, although the Brief Pain Inventory Short Form for diabetic peripheral neuropathy questionnaire, neuropathy symptom score, and neuropathy disability score were previously reported in Chinese patients with peripheral neuropathy.[17,18] Although the 10-MWT[19] and the 6-MWT[20] were previously used in China, 9-HPT and 10-MWT are not widely used in patients with CMT.[21-23] Thus, in the present study, we aimed to examine the efficacy of the 9-HPT and 10-MWT in Chinese patients with CMT.

Methods

Ethical approval

The study was conducted in accordance with the *Declaration of Helsinki* and was approved by the local ethics committee of the First Affiliated Hospital of Zhengzhou University (No. 51 - 2014). Informed written consent was obtained from all adult patients or the guardians of the children patients.

Study population

From August 2015 to December 2016, 34 patients with CMT from the neuromuscular clinic, Department of Neurology at the First Affiliated Hospital of Zhengzhou University participated in the study. Inclusion criteria were as follows:[24] (1) length-dependent peripheral neuropathy; (2) signs of peripheral nerve injuries; (3) abnormal nerve conduction function of peripheral nerves; (4) genetically confirmed CMT diagnosis; (5) age ≥7 years; and (6) able to cooperate with the inspection and evaluation. Exclusion criteria were: (1) CMT accompanied by other diseases, including diabetes, cancer, alcoholism, and heavy metal poisoning; (2) unable to cooperate with the inspection and evaluation; and (3) age <7 years. A total of 35 age- and gender-matched healthy controls were also recruited, none of whom had received operations on joints, had diseases such as peripheral neuropathy, or had central nervous system diseases.

Clinical assessment and neurological data

Medical records were reviewed to determine demographic, clinical, and laboratory characteristics. Variables included gender, age, height, weight, occupation, dominant hand, genotype, complications, the type of foot surgery, and the use of a foot orthosis. All control subjects were assessed using 9-HPT and 10-MWT, and all patients underwent a standardized protocol that included the following evaluations:

Nine-hole peg test

Subjects were asked to pick up the pegs from a container one at a time, place the pegs into the holes in any order until all the holes were filled, and then remove the pegs one at a time and return them to the container. The test was performed as quickly as possible. The time started as soon as the subject touched the first peg and stopped when the last peg hit the container. Both the dominant and nondominant hands were tested twice, and the average time of each hand was calculated (the pegs and container were produced by Devine Medical, Norwalk, CA, USA).[25]

Ten-meter walk test

Subjects were instructed to walk at a normal comfortable speed and a maximum speed for 10 m without assistance, and time was recorded for the intermediate 6 m for excluding acceleration and deceleration. The performance time started and stopped with the toes of the leading foot crossing the 2-m mark and the 8-m mark, respectively. For data analysis, an average self-selected velocity (ASSV) and average fast-velocity (AFV) of three trials were calculated.[26]

Charcot-Marie-Tooth disease examination score

Charcot-Marie-Tooth disease examination score (CMTES), the clinical component of the CMT neuropathy score, did not include neurophysiological assessment,[27] and thus avoided differences related to use of different methods for examining nerve conduction velocity. CMTES was considered the only specific scale for CMT patients, and each CMTES assessment was scored on a 0–4-point scale, reflecting the progressive severity of impairment.

Overall neuropathy limitation scale

ONLS was used to evaluate the motor function of the limb, and was scored from 0 (no limitations) to 5 or 7 (no purposeful movement for the upper and lower limb section).[28]

Functional disability scale

FDS was used to evaluate lower extremity motor function,[29] which was divided into nine levels corresponding to scores of 0–8, with the higher the score, the more serious the motor dysfunction.

Berg balance scale

The BBS was used to evaluate balance ability, and included 14 different balance tasks, including standing, reaching, bending, and transferring abilities. This scale had an overall score ranging from 0 (severely impaired patient) to 56 points (excellent).[30]

Statistical analysis

Numerical data were expressed as constituent ratio (%), whereas normally distributed data were expressed as the mean ± standard deviations (SD). Differences between groups at baseline for age, height, and weight were assessed using the independent Student's *t*-test. Categorical data were compared using Chi-square test. Differences between two independent or related groups were analyzed using the independent or paired Student's *t*-test. Pearson's correlation analysis was performed to assess correlations between the recorded parameters. The significance level was set at $\alpha = 0.05$. All statistical analyses were performed with statistical software (SPSS version 17.0 for Windows; SPSS Inc., Chicago, IL, USA).

Results

Clinical and neurological data

The dominant hand was the right hand for all the study participants. There were no differences in gender,

age ($t = 0.839$, $P = 0.405$), height ($t = 0.497$, $P = 0.621$), or body weight ($t = 1.783$, $P = 0.079$) between the CMT group and the control group. The mean age at onset of symptoms of CMT patients was 18.44 ± 14.09 years (range 1–61 years), and the mean disease duration was 12.65 ± 8.14 years (range 1–30 years). Nerve conduction results showed injury to both the motor nerve and the sensory nerve in all patients, and the genotype included CMT disease type 1A (CMT1A, 58.8%), CMT disease type 2A (20.6%), and CMT disease type 1X (20.6%).

Clinical manifestations

The muscle strength of both hands was symmetrical in all subjects, as was the muscle strength for both feet. CMT patients showed diminished or absent tendon reflexes (100.0%), pes cavus (85.3%), drop foot (85.3%), and claw hand (32.4%), as well as bilateral atrophy of the first dorsal interosseous muscle (85.3%), bilateral thenar muscle atrophy (58.8%), hypothenar muscle atrophy (bilateral 47.1%, unilateral 2.9%), gastrocnemius atrophy (bilateral 47.1%, unilateral 2.9%), and anterior tibial muscle atrophy (bilateral 52.9%, unilateral 5.9%). Abnormalities of gait with toe walking were observed in 25 CMT patients (73.5%), and heel walking impairment in 32 CMT patients (94.2%). Six patients (17.6%) underwent orthopedic surgery, and five patients (14.7%) used ankle-foot orthosis in daily life. Abnormal pin sensitivity was observed in ten patients, and abnormal vibration observed in 22 patients. Other symptoms included hand tremor in two patients, abnormal vision with delayed P100 latency of two eyes in one patient, hearing loss with abnormal brainstem auditory evoked potential in one patient, and lower limb fracture in one patient. No cognitive changes were observed in any patients.

Clinical assessment data

Nine-hole peg test

All CMT patients and healthy controls completed the test, although the completion time was significantly longer in CMT patients [Table 1]. The dominant hand completed 9-HPT faster than the nondominant hand (CMT group: $t = -2.060$, $P = 0.047$; control group: $t = -5.464$, $P < 0.001$). The 9-HPT completion time was significantly shorter in women with CMT than that in men with CMT, while slight sex differences in completion time were also observed in the control group in the dominant hand [Table 2].

10-meter walk test

Walking speeds were measured by 10-MWT. Two CMT patients did not finish the test, one patient walked slowly at 0.38 m/s while the remaining participants completed the test. CMT patients walked more slowly than control subjects [Table 1]. There was a positive correlation of AFV with ASSV for CMT patients and control subjects (CMT group: $r = 0.900$, $P < 0.001$; control group: $r = 0.618$, $P < 0.001$). There were no gender differences in gait speed [Table 2].

Correlation results

There was a positive correlation of 9-HPT completion time with ONLS and FDS, and a negative correlated with BBS just for CMT patients. There was also a negative correlation of ASSV/AFV with ONLS and FDS, and a positive correlation with BBS. There was no correlation of CMTES with 9-HPT completion time of the dominant hand, ASSV, or AFV, whereas there was a significant correlation of CMTES with 9-HPT completion time of the nondominant hand [Table 3].

The was a positive correlation of the course of disease with CMTES ($r = 0.491$, $P = 0.003$), but no correlation with 9-HPT completion time (dominant hand: $r = 0.009$, $P = 0.960$; nondominant hand: $r = -0.023$, $P = 0.897$), ASSV ($r = -0.061$, $P = 0.746$), AFV ($r = -0.156$, $P = 0.402$), ONLS ($r = 0.175$, $P = 0.323$), FDS ($r = -0.028$, $P = 0.875$), and BBS ($r = -0.182$, $P = 0.302$). In addition, except for a positive correlation of ASSV with height ($r = 0.487$, $P = 0.005$), there were no correlations between 9-HPT completion time, 10-MWT, or independent variables [Table 4].

Discussion

In the present study, we found that the most frequent symptoms of CMT were located in the lower limbs. Except for diminished or absent tendon reflexes, the three most frequent symptoms were heel walking impairment, pes cavus/drop foot first interosseous muscle atrophy, and toe walking impairment. As previously reported, the rate of heel walking impairment was 94.2%, slightly higher than the rate of a severe group of CMT1A patients (93%).[15] By contrast, the rate of toe walking impairment was 73.5%, which was markedly higher than the rate in CMT1A patients (2% in mild group, 41% in severe group). Further, reduced thumb mobility and intrinsic finger function in CMT patients limited prehension, resulting in abnormal posture during the 9-HPT test. For example, the peg was grabbed by the thumb and the proximal portion of the index finger and was placed on the board with the first interosseous muscle down and a valgus elbow. Further, CMT patients found it easier to place the peg on the board than grab the peg.

The 9-HPT is a standardized, ratio scale tool with established norms, and is available and portable for use in a variety of settings, including the clinic, laboratory, and home. 9-HPT is used to examine dexterity and hand/eye coordination as

Table 1: Scores for the 9-HPT and 10-MWT in CMT disease patients and healthy controls

Parameters	CMT ($n = 34$)	Control ($n = 35$)	t	P
9-HPT				
Dominant hand (s)	29.60 ± 11.89	19.58 ± 3.45	–4.728	<0.001
Non-dominant hand (s)	32.12 ± 12.97	21.37 ± 3.36	–4.682	<0.001
10-MWT				
ASSV (m/s)	1.03 ± 0.18	1.44 ± 0.17	9.333	<0.001
AFV (m/s)	1.31 ± 0.30	1.91 ± 0.25	8.853	<0.001

Data are presented as mean ± SD. 9-HPT: Nine-hole peg test; 10-MWT: Ten-meter walk test; CMT: Charcot-Marie-Tooth; ASSV: Average self-selected velocity; AFV: Average fast-velocity; SD: Standard deviation.

Table 2: Scores for the 9-HPT and 10-MWT between women and men

Parameters	CMT		*t*	*P*	Control		*t*	*P*
	Men (*n* = 20)	Women (*n* = 14)			Men (*n* = 20)	Women (*n* = 15)		
9-HPT								
Dominant hand (s)	33.01 ± 13.14	24.74 ± 7.93	2.097	0.044	20.72 ± 3.57	18.06 ± 2.69	2.411	0.022
Non-dominant hand (s)	35.87 ± 13.60	26.76 ± 10.20	2.118	0.042	22.26 ± 3.54	20.20 ± 2.77	1.860	0.072
10-MWT								
ASSV (m/s)	1.03 ± 0.21	1.02 ± 0.15	0.082	0.935	1.44 ± 0.21	1.43 ± 0.11	0.104	0.918
AFV (m/s)	1.30 ± 0.34	1.33 ± 0.24	–0.257	0.799	1.94 ± 0.26	1.87 ± 0.25	0.724	0.474

Data are presented as mean ± SD. 9-HPT: Nine-hole peg test; 10-MWT: Ten-meter walk test; CMT: Charcot-Marie-Tooth; ASSV: Average self-selected velocity; AFV: Average fast-velocity; SD: Standard deviation.

Table 3: Correlation of 9-HPT and 10-MWT scores with CMTES, ONLS, FDS, and BBS

Parameter	CMTES		ONLS		FDS		BBS	
	r	*P*	*r*	*P*	*r*	*P*	*r*	*P*
9-HPT (D)	0.335	0.053	0.652	<0.001	0.487	0.004	−0.463	0.006
9-HPT (ND)	0.552	0.001	0.780	<0.001	0.663	<0.001	−0.527	0.001
ASSV	−0.174	0.349	−0.529	0.002	−0.481	0.006	0.612	<0.001
AFV	−0.275	0.135	−0.611	<0.001	−0.574	0.001	0.697	<0.001

9-HPT: Nine-hole peg test; 10-MWT: Ten-meter walk test; CMTES: Charcot-Marie-Tooth examination score; ONLS: Overall neuropathy limitation scale; FDS: Functional disability score; BBS: Berg Balance Scale; D: Dominant hand; ND: Nondominant hand; ASSV: Average self-selected velocity; AFV: Average fast-velocity.

Table 4: Correlation of 9-HPT and 10-MWT scores with independent variables

Parameter	Age at examination		Course		Height	
	r	*P*	*r*	*P*	*r*	*P*
9-HPT (D)	0.046	0.795	0.009	0.960	−0.024	0.893
9-HPT (ND)	−0.001	0.995	−0.023	0.897	−0.005	0.979
ASSV	0.029	0.874	0.032	0.864	0.487	0.005
AFV	−0.207	0.264	−0.159	0.392	0.256	0.165

9-HPT: Nine-hole peg test; 10-MWT: Ten-meter walk test; D: Dominant hand; ND: Nondominant hand; ASSV: Average self-selected velocity; AFV: Average fast-velocity.

a measure of hand function, and its reliability and validity have been demonstrated in adults with CMT.[6,31] Our CMT patients were markedly slower to completed the 9-HPT compared with mild CMT1A patients (dominant hand: 15 ± 5.1 s; nondominant hand: 16 ± 4.6 s),[32] but much faster than spinocerebellar ataxia patients (dominant hand: 47.2 ± 35.7 s; nondominant hand: 52.2 ± 41.8 s).[33] Nevertheless, despite this variance in 9-HPT completion time in these subgroups of CMT patients, the findings confirm that the completion time of the dominant hand was shorter than that for the nondominant hand.

There is some evidence that 9-HPT completion time is shorter in women than that in men,[34] as observed in this study. The absolute values for walking speed were reported to be lower in women than men at all ages,[35] whereas men also had faster walking speeds than women.[8,36] However, in the present study, there were no differences in gait speed between men and women assessed using 10-MWT. Gait speed was reported to be reduced in older and taller individuals[26] while 10-MWT was significantly correlated with gender, and slightly correlated with age, in CMT1A patients.[11] By contrast, we found that only ASSV was positively correlated with height.

Pagliano *et al*.[37] reported a positive correlation of the 9-HPT completion time in children with CMT with the ONLS score ($r = 0.586$, $P = 0.005$) and the CMTES score ($r = 0.617$, $P = 0.003$). Similarly, we found a positive correlation of 9-HPT completion time of the nondominant hand with ONLS, FDS, and CMTES, and a positive correlation of 9-HPT completion time of the dominant hand with ONLS and FDS, in CMT patients. Birouk *et al*.[29] also reported that dysfunction in CMT1A patients can increase the course of the disease. By contrast, we only found a positive correlation of CMTES with disease course, with no correlation of 9-HPT completion time, ASSV, AFV, ONLS, FDS, or BBS with the disease course. These contrasting findings might relate to the small sample size in this study.

There are some limitations to the scales used in the present study. Several studies have shown that 9-HPT and 10-MWT could be used to determine changes in the clinical function of patients,[5,38] as well as to assess disease severity in cross-sectional studies.[7,8] However, the study can only be carried out in cross-sectional study at this stage, and dynamic follow-up will be conducted to assess the sensitivity of different assessment methods in the future work. In addition, it could be difficult to evaluate the disease severity and function in patients with hereditary sensory and autonomic neuropathy using 9-HPT and 10-MWT. Kwong *et al*.[39] reported that the leg selected as the weight-bearing leg in item 13 (standing unsupported one foot in front) and item 14 (standing on one leg) of the BBS can influence the item scores, and thus the total score. These findings were verified in stroke patients, with a lower BBS when the paresis leg was

selected. Although CMTES is considered the only specific scale for CMT patients, it has a similar limitation.

In summary, the findings suggest that CMT patients perform worse on 9-HPT and 10-MWT. These findings with 9-HPT were consistent with other studies, apart for the similar ASSV and AVF between men and women. Nevertheless, the data suggest that 9-HPT and 10-MWT can be used in Chinese patients with CMT.

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Conflicts of interest

There are no conflicts of interest.

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