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Original Article

The Effects of a Cerebrospinal Fluid Tap Test on Gait, Balance and Turning in Elderly Patients with Idiopathic Normal Pressure Hydrocephalus

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SUMMARY

Background: Idiopathic normal pressure hydrocephalus (iNPH) is a disease that is clinically characterized by gait disturbance and balance impairment. Our purpose was to evaluate the effects of cerebrospinal fluid tap test procedures on gait, turning and balance parameters in the first 24 hours following the procedure in patients.
Methods: Twenty-eight patients with a median age of 78 years participated in the study. All patients underwent assessment of gait characteristics, turning and balance before and after a tap test. Gait characteristics and turning were measured using the G-walk sensor system. Balance-related issues were assessed using three standardized tests in the Biodex Balance System: postural stability and fall risk tests, and the modified clinical test of sensory integration and balance.
Results: The patients' mean walking speed increased after the tap test ($p < 0.05$), but left stride length, right stride length, and cadence did not show statistically significant improvement ($p > 0.05$). In the balance assessment, significant differences between pre- and post-scores were found on all tests ($p < 0.01$), except for the eyes-closed firm test ($p > 0.05$). Regression analyses revealed that baseline walking speed ($p < 0.05$) was significantly associated with positive tap test response.
Conclusion: The cerebrospinal fluid tap test procedure has positive effects on walking and turning activities, balance, and the risk of falling in older patients with iNPH in the first 24 hours following the procedure. Slow walking speed may predict positive tap test response. For patients unsuitable for shunt surgery, a tap test may be an effective method to reduce the risk of falls and improve factors that may cause falls.

1. Introduction

Idiopathic normal pressure hydrocephalus (iNPH) is a disease that is characterized by normal cerebrospinal fluid (CSF) pressure and cerebral ventricular enlargement, as well as the classic triad of gait disturbance, cognitive impairment and urinary dysfunction.[1] The severity and frequency of the symptoms may vary among patients with iNPH. Among them, impaired gait is usually the first symptom to affect patients.[2–4] As walking speed, stride length, and stride height decrease, stride width and foot rotation angle, which are balance-related characteristics of gait, increase.[5] Gait and balance impairments are clinical problems that often result in movement limitations and significantly increase the risk of falls.[5] In addition, impaired postural stability is one of the main problems for patients, leading to recurrent falls and loss of independence, and difficulties with turning are often the cause of falls in the elderly.[6–8]

Despite the lack of randomized controlled trials indicating its efficacy, the primary treatment for iNPH is shunt surgery, in which CSF is diverted into the peritoneal or atrial cavity; however, for older iNPH patients who refuse or have a contraindication to surgery, serial CSF drainage may be effective.[9,10] With serial CSF removal, iNPH symptoms may improve following the removal of 30–50 ml of CSF via lumbar puncture (LP), called a CSF tap test, lumbar tap test or Miller Fisher Test.[11] Therefore, serial CSF removal is likely to be considered an alternative treatment for certain patients as it can improve gait/balance impairment and degree of disability.

The primary objective of this study was to determine the effects of a CSF tap test on gait, turning and balance parameters in the first 24 hours following the procedure in iNPH patients. The secondary objective was to investigate whether these effects differed by gender and age and to determine which parameters could predict patients who responded to the CSF tap test.

2. Material and methods

2.1. Participants

Patients in the Department of Geriatrics at the University Hospital of the Dokuz Eylul were recruited for this prospective observational study and assessed for eligibility. The inclusion criteria were as follows: 1) aged between 60 and 90 years old, 2) fulfilling the clinical criteria for iNPH as proposed by Relkin and colleagues[12] and 3) able to walk independently (without physical assistance from a per-

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son and/or a device). Patients with severe physical disability or immobility, major primary psychiatric disorders (e.g., schizophrenia, bipolar disorder), unstable major medical conditions (e.g., acute coronary syndrome, respiratory failure), acute cerebrovascular disease and severe visual or hearing impairment were excluded. Patients diagnosed with secondary normal pressure hydrocephalus were also excluded. The study was approved by the local ethics committee (the Non-invasive Research Ethics Committee of the Faculty of Medicine at Dokuz Eylul University, approval no. 7127-GOA) and conformed to the principles of the Declaration of Helsinki. Written informed consent was obtained from each participant.

2.2. Study design

A total of 28 patients who were diagnosed with iNPH at a geriatric clinic between March 2022 and January 2023 were included in this prospective observational study. All the patients with iNPH underwent a CSF tap test, during which 30–50 ml of CSF was removed. The same geriatrician performed all the procedures. All the patients who were eligible and volunteered to participate in the study also underwent gait and balance assessments by the same physiotherapist before and after the CSF tap test. Post-procedure assessments were performed within the first 24 hours following the procedure. The study started in March 2022 after the ethics committee's approval was obtained.

2.3. Outcome criteria

2.3.1. Gait characteristics

The G-Walk sensor system (BTS G-Walk, BTS Bioengineering Company, Italy) was used to assess gait characteristics. The BTS G-Walk (G-Sensor 2) is a portable, wireless, inertial system with wearable sensors. All data were collected at a frequency of 100 Hz. The device was attached with a semi-elastic belt to the L_5-S_1 examined participants. Each participant was instructed to walk the 7-meter "test" zone at a walking speed comfortable to them. The parameters that were evaluated using the G-Walk were speed (meters/second), cadence (steps/minute), and stride length (meters).[13] For the turn test, the participant was asked to walk at a comfortable walking speed for 7 meters and return to the start line by turning 1 meter wide. Analysis duration(s), speed (meters/second), cadence (steps/minute), stride length (meters), and gait cycle duration(s) were throughout turning. The acquired data were transmitted via Bluetooth to a computer and processed using BTS G-Studio software (BTS Bioengineering S.p.A., Italy).[13]

2.3.2. Balance

The Biodex Balance System (Biodex Medical Systems, NY, USA) was used to assess balance-related variables. This system has a fixed and movable platform and a touchscreen on which the participant can visually track his/her movements. The researchers adjusted the platform and the screen according to the participant's position and height. Three different test protocols were included: postural stability (PS), fall risk (FR), and modified clinical test of sensory integration and balance (mCTSIB).[14,15]

The PS test examines a patient's ability to maintain his/her centre of balance. The device measures the participant's anterior-posterior (AP) and medial-lateral (ML) oscillations and provides the AP index, ML index, and total stability index scores.[15] The FR test measures the patient's postural sway velocity to predict risk. There is a circular platform that moves freely and simultaneously about the AP and ML axes and provides an overall stability index score.[16] The mCTSIB provides a generalized assessment of how well the patient can integrate various senses with respect to balance and compensate when one or more of those senses are compromised. The mCTSIB was performed in four different conditions: eyes open-firm surface (EO-firm), eyes closed-firm surface (EC-firm), eyes open-foam surface (EO-foam), and eyes closed-foam surface (EC-foam). The device computes an overall sway index as the standard deviation of the recorded position away from the centre.[15]

2.3.3. Definition of minimum clinically important change (MCIC) criteria and identification of responders and non-responders to the tap test

Although the minimum clinically important change (MCIC) criteria may vary among individuals with different pathologies, no previous study has reported an MCIC for gait speed after a tap test or shunt surgery in individuals with iNPH. Therefore, we utilized the MCIC value of 0.06 m/s in Parkinson's disease patients with similar characteristics to iNPH in previous studies to categorize patients as responders or non-responders.[17,18]

2.4. Statistical analysis

All data were analyzed using SPSS software (IBM Corporation, version 24 for Windows). Descriptive statistics were summarized as frequencies and percentages, and variables were presented as means and standard deviations. Normality was checked with the Shapiro-Wilk test. Because the variables were not normally distributed, the Wilcoxon signed-rank test was used to compare the outcomes of the first and second assessments of all parameters evaluated for the primary purpose. For the second purpose, the patients were divided into two groups, male and female, and the cut-off point was determined in age groups (65–80 and 81–90 years), responder and non-responder; the Mann-Whitney U test was used for comparison between groups. Any statistical test with a p-value less than 0.05 was considered significant. A logistic regression model was used to predict markers that may predict response to the tap test.

3. Results

Six of the 34 screened patients did not meet the inclusion criteria and were excluded. A total of 28 individuals (16 males and 12 females) were included in the study. Twenty-eight patients completed pre- and post-CSF tap tests. Table 1 shows the clinical and demographic characteristics of the participants.

Table 2 shows the change in the gait characteristics before and after the CSF tap test. In our findings, significant improvements were seen in the walking speed ($p < 0.05$), but left stride length, right strike length, and cadence did not show statistically significant improvement ($p > 0.05$).

Table 3 shows the change in the forward gait, turning, and return gait parameters before and after the CSF tap test. Significant improvements were seen in the turning stride length ($p < 0.05$), but

Table 1
Patient characteristics.

Demographic characteristics (n = 28)	Responders (n = 13)	Non-responders (n = 15)	p
Age (years)	79.10 ± 5.80	77.61 ± 8.04	0.627
Education (11 years and above)	41%	46%	
BMI (kg/m^2)	26.67 ± 4.58	25.25 ± 3.79	0.426
Right dominant	100%	100%	

Kg: kilogram, m: meter.

other parameters did not show statistically significant improvement. Table 4 shows the change in the balance parameters before and after the CSF tap test. In the subtests, significant differences were found between the before and after scores on all tests ($p < 0.01$) except for the EC-firm test ($p > 0.05$).

The mean differences in the gait and balance parameters before and after the CSF tap test were calculated in terms of gender and age. There were no significant differences between groups in terms of gender ($p > 0.05$), except for in the EC-foam test ($p < 0.05$) (Table 5). In terms of age, group comparisons showed that there were no significant differences in any parameter ($p > 0.05$) (Table 6).

Table 7 presents sub-analyses of the gait and balance variables before and after the tap tests for both the groups of tap test responders and non-responders. The tap test responders showed significant improvements in all gait and balance parameters ($p < 0.05$), except for eyes close-firm and eyes open-foam ($p > 0.05$).

The significant differences between responders and non-responders led us to perform a secondary analysis to identify independent predictors of tap test response in our sample. Therefore, we performed a logistic regression analysis. Age, gender, body-mass index, walking speed, stride length, cadence, fall risk index, postural stability index, and sway indexes (SI) for all conditions in the mCTSIB test (EO-firm, EC-firm, EO-foam, EC-foam indexes) were included in the regression model as independent variables. Univariate logistic regression analyses revealed that baseline walking speed ($p < 0.05$) was significantly associated with post-tap test response, but other parameters did not show statistically significant (Table 8).

4. Discussion

This study showed that the CSF tap test had positive effects, in a very short time, on gait speed and turning activity in the total stability index, FR, and mCTSIB but no effect on cadence and stride length. In addition, these changes did not differ by age or gender. Positive

Table 2
Comparisons of gait characteristics between pre- and post-CSF tap test.

	Pre-CSF tap test	Post-CSF tap test	p
Walking speed (m/s)	0.77 ± 0.21	0.85 ± 0.17	**0.046***
Left stride length (m)	0.96 ± 0.22	1.01 ± 0.17	0.067
Right stride length (m)	0.96 ± 0.22	1.01 ± 0.16	0.082
Cadence (steps/min)	98.58 ± 14.77	102.9 ± 78.7	0.218

CSF: cerebrospinal fluid, m: meter, min: minute, s: second.
* p < 0.05 and p-value refers to significant statistics.

Table 4
Comparisons of balance parameters between pre- and post-CSF tap test.

	Balance		
	Pre-CSF tap test	Post-CSF tap test	p
Total stability index	2.01 ± 1.54	0.98 ± 0.78	**0.001****
Anterior-posterior SI	1.32 ± 0.46	0.66 ± 0.46	**0.002***
Medial-lateral SI	1.21 ± 1.18	0.64 ± 0.64	**0.005***
Fall risk index	2.48 ± 1.75	1.31 ± 0.42	**0.001****
CTSIB			
Eyes open-firm	1.01 ± 0.38	0.82 ± 0.38	**0.003***
Eyes close-firm	1.67 ± 0.41	1.48 ± 0.68	0.116
Eyes open-foam	2.16 ± 1.04	1.68 ± 0.71	**0.022***
Eyes close-foam	3.59 ± 1.12	2.96 ± 1.21	**0.014***

CSF: cerebrospinal fluid, RI: Risk Index, SI: Stability Index.
* p < .05; ** p < .01 and p-value refers to significant statistics.

Table 3
Comparisons of gait characteristics during forward gait, turning and return gait between pre- and post-CSF tap test.

	Forward gait			Turning			Return gait		
	Pre-CSF tap test	Post-CSF tap test	p	Pre-CSF tap test	Post-CSF tap test	p	Pre-CSF tap test	Post-CSF tap test	p
Analysis duration (s)	10.64 ± 4.01	12.5 ± 9.17	0.758	7.42 ± 3.28	6.37 ± 2.12	0.527	11.73 ± 5.19	11.03 ± 6.79	0.959
Walking speed (m/s)	0.84 ± 0.21	0.81 ± 0.24	0.619	0.52 ± 0.22	0.55 ± 0.25	0.499	0.73 ± 0.23	0.77 ± 0.24	0.332
Stride length (m)	1.02 ± 0.22	1.02 ± 0.23	0.722	0.91 ± 0.18	0.99 ± 0.21	**0.011***	0.91 ± 0.25	0.98 ± 0.21	0.181
Cadence (steps/min)	99.96 ± 12.33	96.21 ± 20.61	0.356	72.02 ± 31.37	70.95 ± 36.07	0.913	97.79 ± 15.35	94.13 ± 23.21	0.397
Gait cycle duration (s)	1.22 ± 0.14	1.30 ± 0.35	0.308	2.61 ± 2.92	2.75 ± 2.5	0.777	1.25 ± 0.23	1.37 ± 0.6	0.232

CSF: cerebrospinal fluid, m: meter, min: minute, s: second.
* p < 0.05 and p-value refers to significant statistics.

Table 5
Comparisons of average differences of gait and balance parameters before and after CSF tap test in terms of gender.

	Pre and post-CSF tap test AD		p
	Man (n = 16)	Women (n = 12)	
Walking speed (m/s)	0.11 ± 0.14	0.11 ± 0.08	0.381
Left stride length (m)	0.09 ± 0.08	0.22 ± 0.33	0.340
Right stride length (m)	0.09 ± 0.09	0.22 ± 0.33	0.304
Cadence (steps/min)	8.72 ± 9.80	9.73 ± 6.97	0.412
Total stability index	0.95 ± 1.13	1.31 ± 1.57	0.347
Anterior-posterior SI	0.67 ± 0.97	1.02 ± 1.16	0.113
Medial-lateral SI	0.77 ± 0.78	0.88 ± 0.98	0.597
Fall risk	1.56 ± 2.19	0.65 ± 0.52	0.394
Eyes open-firm	0.29 ± 0.22	0.22 ± 0.20	0.336
Eyes close-firm	0.57 ± 0.30	0.64 ± 0.48	0.975
Eyes open-foam	0.96 ± 0.86	0.69 ± 0.61	0.642
Eyes close-foam	1.32 ± 0.59	0.75 ± 0.76	**0.044***

AD: average difference, CSF: cerebrospinal fluid, m: meter, min: minute, RI: Risk Index, s: second, SI: Stability Index.
* p < .05 and p-value refers to significant statistics.

Table 6
Comparisons of average differences of gait and balance parameters before and after CSF tap test in terms of age.

	Pre and post-CSF tap test AD		p
	65–80 years (n = 14)	81–91 years (n = 14)	
Walking speed (m/s)	0.08 ± 0.06	0.14 ± 0.15	0.791
Left stride length (m)	0.11 ± 0.07	0.19 ± 0.32	0.939
Right stride length (m)	0.10 ± 0.08	0.20 ± 0.32	0.705
Cadence (steps/min)	5.51 ± 4.83	12.84 ± 9.86	0.089
Total stability index	1.16 ± 1.54	1.04 ± 1.11	0.728
Anterior-posterior SI	0.93 ± 1.13	0.70 ± 0.98	0.354
Medial-lateral SI	0.88 ± 1.02	0.76 ± 0.71	0.926
Fall risk	0.98 ± 1.02	1.38 ± 2.28	0.839
Eyes open-firm	0.20 ± 0.21	0.32 ± 0.20	0.147
Eyes close-firm	0.58 ± 0.26	0.62 ± 0.48	0.951
Eyes open-foam	1.02 ± 0.68	0.68 ± 0.82	0.157
Eyes close-foam	0.99 ± 0.71	1.15 ± 0.74	0.538

AD: average difference, CSF: cerebrospinal fluid, m: meter, min: minute, RI: Risk Index, s: second.
p-value refers to significant statistics.

Table 7
Sub-analyses of the gait and balance variables between before and after CSF tap tests for responders and non-responders.

	Responders (n = 13)			Non-responders (n = 15)		
	Pre-CSF tap test	Post-CSF tap	p	Pre-CSF tap	Post-CSF tap	p
Walking speed (m/s)	0.65 ± 0.12	0.84 ± 0.13	**0.05***	0.86 ± 0.2	0.85 ± 0.19	0.755
Left stride length (m)	0.87 ± 0.15	1.01 ± 0.13	**0.007****	1.03 ± 0.23	1.02 ± 0.2	0.824
Right stride length (m)	0.87 ± 0.16	1.01 ± 0.13	**0.007****	1.04 ± 0.23	1.02 ± 0.19	0.884
Cadence (steps/min)	92.22 ± 13.07	105.65 ± 18.78	**0.05***	102.66 ± 14.4	100.46 ± 12.57	0.196
Total stability index	1.82 ± 0.75	0.74 ± 0.15	**0.05***	1.83 ± 1.80	0.92 ± 0.58	0.049
Anterior-posterior SI	1.18 ± 0.57	0.54 ± 0.17	**0.05***	1.76 ± 1.72	0.64 ± 0.37	**0.031***
Medial-lateral SI	1.08 ± 0.70	0.38 ± 0.10	**0.05***	0.96 ± 1.07	0.81 ± 0.67	0.722
Fall risk	3 ± 2.51	1.12 ± 0.17	**0.05***	1.96 ± 0.90	1.24 ± 0.45	**0.008****
Eyes open-firm	1.02 ± 0.20	0.74 ± 0.21	**0.028***	0.97 ± 0.41	0.90 ± 0.48	0.109
Eyes close-firm	1.57 ± 0.50	1.63 ± 0.81	0.799	1.55 ± 0.37	1.26 ± 0.37	0.075
Eyes open-foam	1.79 ± 0.83	1.40 ± 0.67	0.114	2.11 ± 1.13	1.82 ± 0.77	0.126
Eyes close-foam	3.24 ± 1	2.38 ± 0.52	**0.047***	3.41 ± 1.01	2.84 ± 1.09	0.071

CSF: cerebrospinal fluid, m: meter, min: minute, RI: Risk Index, s: second.
* p < .05; ** p < .01 and p-value refers to significant statistics.

Table 8
Univariate logistic regression analyses identifying factors associated with tap test response.

Variables in the model	B	Standart error	p	OR	95% CI
Age (years)	-0.006	0.059	0.924	0.994	0.886–1.116
Gender	-0.575	0.782	0.462	0.563	0.122–2.603
Body mass index (kg/m^2)	0.004	0.089	0.962	1.004	0.843–1.196
Walking speed (m/s)	-11.160	4.6	**0.015***	0.001	0.001–0.118
Left stride length (m)	-5.298	2.8	0.058	0.001	0.001–1.209
Right stride length (m)	-5.356	2.730	0.05	0.005	0.001–0.994
Cadence	-0.061	0.033	0.065	0.941	0.881–1.004
Fall risk	0.409	0.346	0.238	1.505	0.764–2.966
Postural stability	0.043	0.284	0.880	1.044	0.599–1.819
Eyes open-firm	-0.996	1.113	0.931	0.908	0.103–8.041
Eyes close-firm	0.355	0.884	0.674	1.427	0.273–7.466
Eyes open-foam	-0.349	0.375	0.351	0.705	0.338–1.470
Eyes close-foam	-0.060	0.333	0.856	0.941	0.490–1.807

Kg: kilogramm, m: meter, OR: odds ratio.
* p < 0.05 and p-value refers to significant statistics.

CSF tap test response is associated with slower walking speed. However, age, gender, body mass index, baseline gait characteristics, and balance parameters alone are insufficient for predicting patients who may respond to the CSF tap test.

In addition to age-related changes in patients with iNPH, the presence of cognitive disorders, negative changes in gait characteristics, and balance abnormalities are considered the most important findings associated with the disease and predisposing factors that increase the risk of falling.[19] Although randomized controlled trials are lacking, the main treatment for the disease is shunt surgery; alternative treatment options should be considered given the fact that some older adults might not always be fit for surgery, and others might not be willing to undergo surgery due to comorbidities, frailty, medications, and life expectancy.[10,19,20] Isik et al. suggested that serial CSF removal can temporarily reduce the periventricular tension force caused by chronic periventricular ischemia (which is one of the potential mechanisms in the pathophysiology of iNPH), increase the compliance of the brain's ventricular wall, and prevent the gradual enlargement of the ventricles.[10]

The major problems in patients with iNPH are balance disorders and falls. Studies have shown that patients with iNPH are more likely to fall than the elderly population, and it has been stated that changes in dynamic balance parameters may be responsible for this situation.[18–20] Balance disorders in iNPH are accepted as an essential component of the disease phenotype, and studies have indicated that objective evaluation of static and dynamic balance would be valuable for preventing falls and fall-related health problems in this group.[21] However, Nikaido et al. stated that gait and static balance tests would not be sufficient to distinguish fall patients with mild gait disturbance from patients with iNPH who did not fall; on the contrary, tests related to dynamic balance were more distinctive in terms of fall risk.[22,23] In this study, both static and dynamic balance, as well as walking and turning activities, were evaluated using objective methods, and the acute effect of the CSF tap test on patients was discussed in detail.

Abram et al. evaluated the PS of patients with iNPH via sensory integration tests using computerized dynamic posturography and determined that there were significant improvements in somatosensory and visual dominant tests after the CSF tap test. No changes were observed in the vestibular dominant tests.[24] On the other hand, Lundin et al. evaluated patients with iNPH who underwent shunt surgery with computerized dynamic posturography (CDP) and observed poor improvement in sensory integration tests after surgery. In this research, the static and dynamic balance of patients with iNPH were evaluated with the Biodex Balance System (BBS) after the CSF tap test, and positive improvements were observed in a short time, except for in the EC-firm test. These findings suggest that the CSF tap test procedure positively affects the visual and somatosensory dominant balance functions of patients with iNPH.[25]

Heß et al. emphasized that demyelination, brain atrophy, neurotransmitter signalling abnormalities, and decreased cerebral blood flow accompanied by accumulation of toxic metabolites in patients with iNPH may cause motor symptoms, central dysfunction, and defective integration of inputs from the visual, vestibular, and somatosensory systems.[26] They also found positive improvements in the PS of patients with iNPH who underwent shunt surgery. In this study, we found similar positive changes in the PS (total stability index, AP stability index, ML stability index) and FR (FR index) score after the CSF tap test, suggesting that the procedure can reduce the risk of falling even after very short periods.

Dynamic balance disorder is considered a high-risk factor for falls in patients with iNPH and causes patients to develop several compensatory gait mechanisms. The most important of these are increases in stride width and decreases in walking speed with the enlargement of the support surface.[23] Ishikawa et al. evaluated walking speed after the CSF was removed and stated that the selectivity of the test was not different between the 1st and 4th days.[27] This result was taken as a reference in constructing our study, and the second measurements were made on the 1st day after the CSF tap test. Similar to previous studies in the literature,[4,10,27] in our study, an increase in the walking speed of patients was observed in a short time after the CSF tap test. In a study that involved both shunt surgery and the CSF tap test, Song et al. stated that walking speed and stride length increased, but cadence did not change. Contrary to expectations, our study showed no change in both stride length and cadence after the CSF tap test. The second evaluation was performed immediately after the procedure; although a rapid change in some gait-related parameters was observed, some changes may require time.

The activity that older people have the most difficulty with is turning while walking. In patients with iNPH, these turning activities are also impaired and pose a risk of falling. Bovonsunthonchai et al. stated that in patients with iNPH, the number of steps and the turning time increased. However, there were positive improvements in these parameters after the CSF fluid was removed.[8] In our study, an improvement was observed in the stride length parameter during turning, even in a short time after the CSF tap test. However, there was no change in the speed, cadence, and analysis duration parameters during turning. Whereas the rapid change in the balance parameters after the CSF tap test was effective in the patients taking steps more comfortably and increasing their step length during turning, it was not effective in the change of turning speed and cadence.

In the secondary outcomes, we investigated whether the gender and age of the patients made a difference in the effects related to the CSF tap test. There was no difference between the results for changes due to either gender or age. Furthermore, our regression analysis revealed that a positive response to the CSF tap test was not correlated with age or gender. The CSF tap test caused positive changes, similar to the gains of patients with iNPH at younger ages, especially in patients over 80 years of age. These results show that patients who are unsuitable for surgery or who refuse surgery can benefit from the CSF tap test in balance, walking, and turning activities immediately after the procedure, even if they are older.

Referring to a previous study, Bovonsunthonchai et al.[17] defined responders as patients whose walking speed increased by 0.06 and reported that 37% of patients responded to the tap test. They claimed that these different response levels in tap test responders may be necessary to predict the success of shunt surgery. We applied this 0.06 m/s increase criterion in our study and found that 47% of the patients were responders. Griffa et al.[28] found that their study associated slow walking speed with responsiveness to the CSF tap test. Our results are similar. This effect may be because patients with slow walking speeds are more affected depending on the duration and severity of the disease. Since patients with iNPH are typically elderly, their walking speed may reach certain limits, so those with significantly reduced walking speed may respond more to tap testing. However, it is unclear why the balance parameters in these patients did not predict the tap test result, although they improved after the tap test. This may be due to irreversible brain damage associated with ventriculomegaly of balance control.[28]

The most important limitations of our study are the small number of cases and the insufficient number of patients for follow-up measures planned for acute effects. However, in this study, we objectively evaluated the acute effects of the CSF tap test application on balance, gait, turning, and risk of falling in patients with iNPH who cannot undergo shunt surgery with computer-assisted data. In addition, our research is one of the few studies attempting to identify the parameters that can predict response to the tap test.

5. Conclusion

In elderly patients with iNPH, the CSF tap test procedure causes positive changes in walking and turning activities, balance, and risk of falling in a very short time. Slow walking speed is associated with predicting responsiveness to the CSF tap test. In patients who are unfit for shunt surgery, the CSF tap test may be an effective method of reducing the risk of falls or improving factors that may cause falls. However, further studies are needed to obtain more conclusive results.

Declaration of conflict of interest

The authors declare that there is no conflict of interest.

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