Araştırma Makalesi

COMPARISON OF THE GAIT CHARACTERISTICS BETWEEN PATIENTS WITH IDIOPATHIC NORMAL PRESSURE HYDROCEPHALUS AND HEALTHY CONTROLS

Ümit YEŞİL[1], Nihal GELECEK[2], Derya KAYA[3], İlke KARA[4], Ahmet Turan IŞIK[5]

Abstract

Aim: We aimed to compare patients' gait characteristics with iNBH before and after the cerebrospinal fluid (CSF) tap test with the control group.

Method: Twenty-three iNBH patients with a mean age of 75.34±5.36 years and 20 healthy controls with a mean age of 72.65±5.63 years participated in the study. The iNPH group underwent gait characteristics assessment immediately before and within the first 24 hours after the CSF tap test. Gait speed, stride length, and cadence were evaluated using the G-walk sensor-based gait analysis system. The same assessments were performed in the control group.

Findings: The percentage change in walking speed, right and left stride length, and cadence parameters of patients with iNPH after the CSF tap test were 6.49, 2.06, 1.02, and 4.16, respectively. In patients with iNPH, there was a statistically significant increase in walking speed ($p<0.05$) after the tap test, while stride length($p>0.05$) and cadence($p>0.05$) did not significantly increase. Walking speed, stride length, and cadence assessment performed before and after the CSF tap test in patients with iNBH were statistically worse than the control group.

Results: The CSF tap test improved gait characteristics in patients with iNPH, but our results showed that iNPH patients with the CSF tap test still had slower gait speed, shorter stride length, and lower cadence than older individuals without iNPH.

Keywords: Aged; Gait analysis; Normal pressure hydrocephalus; Spinal puncture

[1]Corresponding Author: Res. Assist., Dokuz Eylül University, Institute of Health Sciences, Department of Physical Therapy and Rehabilitation, İzmir, Türkiye, fztumityesil@gmail.com ORCID: 0000-0002-6066-1172

[2]Prof. Dr., Dokuz Eylül University, Faculty of Physical Therapy and Rehabilitation, Department of Physical Therapy and Rehabilitation, İzmir, Türkiye, ngelecek71@gmail.com ORCID: 0000-0003-1780-2520

[3]Assoc. Prof. Dr., Dokuz Eylül University, Department of Geriatrics, Aging Brain and Dementia Unit, İzmir, Türkiye, deryakaya29@gmail.com ORCID: 0000-0002-5637-1308

[4]Res. Assist., Dokuz Eylül University, Institute of Health Sciences, Department of Physical Therapy and Rehabilitation,, İzmir, Türkiye ilkekara35@gmail.com ORCID: 0000-0003-4974-533X

[5]Prof. Dr., Dokuz Eylül University, Department of Geriatrics, Aging Brain and Dementia Unit, İzmir, Türkiye, atisik@yahoo.com ORCID: 0000-0001-5867-6503

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İdiyopatik Normal Basınçlı Hidrosefalili Hastalar İle Sağlıklı Kontrollerin Yürüme Özelliklerinin Karşılaşırılması

Öz

Amaç: Amacımız; iNBH'li hastaların beyin omurilik sıvısı (BOS) tap test öncesi ve sonrası yürüyüş özelliklerini belirlemek ve kontrol grubu ile karşılaştırmaktır.

Yöntem: Çalışmaya yaş ortalaması 75.34±5.36 olan 23 iNBH'li hasta ve yaş ortalaması 72.65±5.63 olan 20 sağlıklı kontrol katıldı. iNBH grubuna BOS tap testinin hemen öncesinde ve uygulama sonrası ilk 24 saat içinde yürüyüş özellikleri değerlendirmesi yapıldı. G-walk sensörlü yürüyüş analiz sistemi kullanılarak, yürüyüş hızı, adım uzunluğu ve kadans değerlendirildi. Aynı değerlendirmeler kontrol grubuna da yapıldı.

Bulgular: iNPH'li hastalarda yürüme hızı, sağ ve sol adım uzunluğu ve kadans ölçümlerinde BOS tap testi sonrası değerlerde öncesine göre sırasıyla yüzdesel olarak 6.49, 2.06, 1.02 ve 4.16 arttı. Bununla birlikte yürüme hızındaki artış istatistiksel olarak anlamlı iken ($p<0.05$), adım uzunluğu ve kadanstaki ($p>0.05$) artışlar istatistiksel olarak anlamlı değildi. iNBH'li hastaların yürüyüş özellikleri, kontrol grubunun özellikleri ile karşılaştırıldığında ise hem BOS tap test öncesi hem de sonrasında ölçüm değerlerinin daha düşük olduğu görüldü ($p<0.05$).

Sonuç: iNBH'li hastalarda, BOS tap test uygulanması, hastaların yürüme özelliklerini olumlu yönde iyileştirmekle birlikte, çalışma sonuçlarımız BOS tap test uygulaması yapılan hastaların hala iNBH'li olmayan yaşlı bireylere göre daha yavaş yürüme hızı, daha kısa adım uzunluğu ve daha düşük kadansa sahip olduğunu göstermiştir.

Anahtar Kelimeler: Yaşlı; Normal basınçlı hidrosefali; Yürüme analizi; Spinal ponksiyon

1.INTRODUCTION

Idiopathic Normal Pressure Hydrocephalus (iNPH) is characterized by normal cerebrospinal fluid (CSF) pressure alongside cerebral ventricular enlargement. This condition typically manifests with the classic triad of gait disturbance, cognitive impairment, and urinary dysfunction (Chunyan et al., 2021:210). The incidence rate of iNPH varies between 10 and 22 cases per 100,000 individuals overall, with prevalence rates of 1.30% among individuals aged 65 years and older and 5.9% among those aged 80 years and older (Tseng et al., 2024:16). 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 (Andersson et al., 2019: e0217705; Gallagher et al., 2018: 2244–2250; Song et al., 2019: 389–394). As walking speed, stride length, and stride height decrease, concurrent increases are observed in both stride width and foot rotation angle, indicative of balance-related gait characteristics. Gait and balance impairments are clinical problems that often result in movement limitations and significantly increase the risk of falls (Schniepp et al., 2017:148–157).

Patients with iNPH exhibit higher volumes of white matter in specific brain regions than normal elderly individuals. Additionally, specific cerebrospinal fluid (CSF) markers such as total tau(t-tau), hyperphosphorylated tau (p-tau), and CSF amyloid beta 1-42 (Aβ42) are lower in iNPH patients, while neurofilament light chain (NfL) levels are higher. Gait disturbances in iNPH are found to be correlated with white matter volume in the frontal-parietal lobe, with more lesions in this area and the periventricular white matter leading to more severe gait disturbances (Yang et al., 2023: 1117675). Frontal cortex dysfunction and altered co-activation patterns in iNPH patients can improve post-CSF tap test, enhancing gait characteristics. Serial CSF removal can temporarily alleviate periventricular tension caused by chronic periventricular ischemia, increase ventricular wall compliance, and prevent gradual ventricular enlargement in iNPH (Isik et al., 2019: 2063–2069). However, the complete pathophysiology of iNPH remains incompletely understood, necessitating further research to clarify the disease and its treatment options (Griffa et al., 2021: 1485–1502).

Symptoms of iNPH may improve after the removal of 30-50 ml of CSF via cerebrospinal fluid (CSF) tap test or called lumbar puncture (LP). This improvement is significant for diagnosis and is one of the few prognostic indicators of suitability for shunt implantation (Schniepp et al., 2017:148-157). CSF tap test is one treatment method that creates partial recovery in patients, especially by improving walking speed (Böttcher et al., 2016: 2294–2301). The researchers state that walking speed and stride length are the most sensitive parameters after the CSF tap test (Schniepp et al., 2017:148-157).

Existing studies in this group of patients have compared the gait characteristics of patients before and after the CSF tap test or compared with healthy individuals at follow-up after shunt surgery. Few studies have compared patients with iNPH after the CSF tap test with the healthy control group(Passaretti et al., 2023: 1574–1584). However, studies involving patients undergoing CSF tap test indicate that walking characteristics are predominantly assessed using clinical gait scores and interpreted accordingly. (Lim et al., 2019: 16255)

For this reason, our study aimed to objectively evaluate the walking characteristics of patients undergoing CSF tap tests as an alternative to shunt surgery, an invasive procedure not preferred by iNPH patients. The results obtained serve as a reference for interpreting the effectiveness of the CSF tap test application.

2. 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 for iNPH patients: 1) aged between 60 and 90 years old, 2) fulfilling the clinical criteria for iNPH as proposed by Relkin and colleagues (Relkin et al., 2005:4-16) and 3) able to walk independently (without physical assistance from a person and/or a device). The inclusion criteria for control groups were as follows: 1) aged between 60 and 90 years old, 2) able to walk independently. The exclusion criteria for both groups: 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. 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. 8573-GOA) and conformed to the principles of the Declaration of Helsinki. Written informed consent was obtained from each participant.

2.2. Study Design

The study started in after the ethics committee's approval was obtained. Patients with iNPH and control groups were recruited from the geriatric clinics and assessed for eligibility. 23 iNPH patients and 20 individuals of the control group assessed between January 2024 and March 2024 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 eligible patients who volunteered to participate in the study also underwent gait assessments by the same physiotherapist.

Post-procedure assessments were performed within the first 24 hours following the CSF tap test for iNPH patients.

2.3. Outcome Criteria

Gait Characteristics

The G-Walk sensor system (BTS G-Walk, BTS Bioengineering Company, Italy) was used to assess gait characteristics. The G-Walk system is a wireless and portable inertial system with wearable sensors attached to the L5-S1 of participants using a semi-elastic belt. The system recorded data at a frequency of 100 Hz. Each participant was instructed to walk a 7-meter "test" zone at their comfortable speed. The parameters that were evaluated using the G-Walk were speed (meters/second), cadence (steps/minute), and stride length (meters). The data collected was transmitted via Bluetooth to a computer and processed using the BTS G-Studio software from BTS Bioengineering S.p.A., Italy (Vítečková et al., 2020: e8835).

2.4. Statistical Analysis

All data were analyzed using the SPSS software (IBM Corporation, version 24 for Windows). Descriptive statistics were presented as frequencies and percentages, and variables were displayed as means and standard deviations. Normality was checked using the Shapiro-Wilk test. Since the variables were normally distributed, the Independent Sample t-test was utilized to compare between groups. The paired sample t-test was used to compare the outcomes of the first and second assessments of gait parameters for iNPH patients. Any statistical test resulting in a p-value of less than 0.05 was considered significant.

3. RESULTS

Table 1 shows the demographic and clinical features of iNPH patients and control groups. Three of the 26 screened iNPH patients did not meet the inclusion criteria and were excluded. Twenty-three iNPH patients completed pre- and post-CSF tap tests. A total of 43 individuals (20 control group and 23 iNPH patients) were included in the study. There were no significant differences in the distributions of age, gender and BMI between the two groups.

Demographic Characteristics	iNPH(n=23)	CG(n=20)	p
Age (years)	75.34±5.36	72.65±5.63	0.116

BMI (kg/m^2)	27.23±4.64	26.43±3.87	0.546
Gender(male/female)	11/12	6/14	0.243
Education (11 years and above)	10	8	
Right Dominant	%100	%100	

Table 1. Patient And Control Group Characteristics

Kg:kilogram, m:meter, CG:control group, iNPH: Idiopathic normal pressure hydrocephalus group

Table 2 shows the of change in gait characteristics of patients with iNPH before and after the CSF tap test. 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 ($p>0.05$) in iNPH patients after CSF tap test. The change in gait speed, right and left stride length, and cadence parameters of patients with iNPH after the CSF tap test were 6.49, 2.06, 1.02, and 4.16%, respectively.

Table 2. Change In Gait Characteristics Of Patients With Inph Before And After CSF Tap Test

	iNPH(n=23)			
	Pre CSF tap test	**Post CSF Tap Test**	**p**	**% of change**
Walking speed (m/s)	0.77±0.14	0.82±0.13	**0.045**	6.49
Left stride length (m)	0.97±0.16	0.99±0.15	0.320	2.06
Right stride length(m)	0.98±0.16	0.99±0.14	0.456	1.02
Cadence (steps/min)	97.53±13.15	101.59±15.22	0.109	4.16

m: meter, s: second, min: minute, *CSF: cerebrospinal fluid, iNPH: Idiopathic normal pressure hydrocephalus group,* $p< 0.05$ and *p-value refers to significant statistics*

Table 3. Comparison Of Gait Characteristics Of Patients With Inph And Control Group

	CG(n=20)	**iNPH(n=23) Pre CSF tap test**	**p**	**iNPH(n=23) Post CSF Tap Test**	**p**
Walking speed (m/s)	1.10±0.23	0.77±0.14	**0.0001**	0.82±0.13	**0.0001**
Left stride length (m)	1.18±0.16	0.97±0.16	**0.0001**	0.99±0.15	**0.001**
Right stride length(m)	1.18±0.16	0.98±0.16	**0.0001**	0.99±0.14	**0.0001**
Cadence (steps/min)	112.55±12,85	97.53±13.15	**0.001**	101.59±15.22	**0.019**

m: meter, s: second, min: minute, CSF: cerebrospinal fluid, CG: control group, iNPH: Idiopathic normal pressure hydrocephalus group, $p< 0.05$ and *p-value refers to significant statistics*

Secondly, all the gait characteristics differed significantly between patients with iNPH and healthy controls (Table 3). Patients with iNPH have a statistically significant lower walking speed, stride length and cadence compared to subjects without iNPH ($p<0.05$).

4. DISCUSSION

Based on the findings of our study, we observed a significant improvement in the walking speed of iNPH patients after the CSF tap test. However, there was no statically change in their stride length and cadence. Specifically, the CSF tap test resulted in a 6.49% increase in walking speed, a 2.06% increase in right stride length, a 1.02% increase in left stride length, and a 4.16% increase in cadence parameters of iNPH patients. Patients with iNPH have a lower walking speed, stride length, and cadence compared to the control group. Although the gait characteristics of patients with NPH improved after the CSF tap test, they were still statistically lower than those of the control group.

Bovonsunthonchai et al. (2024:2053) reported that the stride length, cadence, and walking speed of patients with iNPH improved by 6.86%, 5.82%, and 10.53%, respectively, after the CSF tap test. These results are consistent with previous studies (Chunyan et al., 2021:210; Lim et al., 2019:16255; Oztop Cakmak et al., 2023:232-237; Stolze et al., 2000:1678-1686.) and our results. Bovonsunthonchai et al. noted that the absence of a control group was a limitation of the study. Our study found no statistically significant difference even if the gait characteristics of patients with iNPH approached the control group. The results of the findings are also supported by a meta-analysis, including 17 studies (Passaretti et al., 2023: 1574–1584).

Dias et al. (2023:1126298) conducted a study to evaluate the gait characteristics of patients with iNPH and healthy individuals in a home environment. They used a gait analysis system with wearable sensors and found a 60% difference in gait characteristics between the two groups. They investigated whether gait characteristics improved after iNPH patients underwent shunt surgery and normalized to healthy controls. After surgery, gait characteristics improved, and cadence approached that of the healthy control group. In our study, gait characteristics of iNPH patients improved after the CSF tap test, but statistical differences with healthy controls remained unchanged. This may be explained by the shunt surgery being more effective than the CSF tap test.

Passaretti et al. have reported an important finding that has reinforced the idea that shunt surgery has a more profound effect on iNPH pathophysiology due to prolonged CSF drainage. The study found that there was a significant improvement in patients who underwent shunt surgery, compared to those who underwent the CSF tap test. However, despite improvement, the gait of iNPH patients never completely normalized compared to healthy controls at different time points. This observation supports the idea that

the alteration of CSF dynamics specific to iNPH also leads to irreversible damage, which could potentially favor a neurodegenerative process (Bräutigam et al., 2019:10-13; Grasso et al., 2019: 458–463; Passaretti et al., 2023: 1574–1584).

Our study was conducted to determine the changes in walking parameters within the first 24 hours after the CSF tap test in iNPH patients and to compare them with the walking characteristics of healthy geriatric individuals. The inability to obtain follow-up measurements for subsequent periods was the most significant limitation of our study. On the other hand, the objective evaluation of the effects of the CSF tap test on gait characteristics as an alternative to shunt surgery and the fact that it is one of the few studies comparing with a healthy control group are the strengths of the study.

5. CONCLUSION

Patients with iNPH have slower walking speeds, shorter stride lengths, and lower cadence than age-matched peers without iNPH. The gait characteristics of patients with iNPH improved after undergoing a CSF tap test within first 24 hours, however, they did not reach the level of the without iNPH geriatrics.

Sources of Support

None

Conflict of Interest

The Authors declare that there is no conflict of interest

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