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RESEARCH

Sensory processing and neuromotor performance in adults with migraine: a comparative study

Migrenli yetişkinlerde duyusal işlemleme ve nöromotor performans: karşılaştırmalı bir çalışma

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Abstract

Purpose: This study was conducted to examine sensory processing and neuromotor performance in adults with migraine.
Materials and Methods: The study was designed to be observational and comparative. Fifty individuals with migraine and fifty healthy individuals, aged between 18-65, participated in the study. The Adult Sensory Profile Questionnaire was utilized to assess sensory processing skills of individuals and the Clinical Observation of Neuromotor Performance was employed for evaluating neuromotor performance of individuals.
Results: Individuals with migraine demonstrated a distinct sensory processing profile, with significant differences in low registration, sensory sensitivity, and sensory avoidance, but not in sensory seeking. Regarding neuromotor performance, significant differences were observed in postural control, somatodyspraxia including supine flexion and finger tapping and visually guided eye movements, specifically during line tracing, convergence-divergence, and quick localization tasks. No significant differences were found in other neuromotor parameters. These findings highlight selective disruptions in sensorimotor functioning among individuals with migraine.
Conclusion: Given the observed sensory processing difficulties and neuromotor performance challenges in individuals with migraine, further research into neuromotor functioning is warranted. Such studies would not only strengthen the current findings but also offer valuable insights for developing effective intervention protocols to address these issues.
Keywords:. migraine, adult, sensory profile, postural control.

Öz

Amaç: Bu çalışma, migrenli yetişkinlerde duyusal işlemleme ve nöromotor performansı incelemek amacıyla gerçekleştirilmiştir.
Gereç ve Yöntem: Çalışma, gözlemsel ve karşılaştırmalı olarak tasarlanmıştır. 18-65 yaş arasında, migrenli 50 birey ve 50 sağlıklı birey çalışmaya katılmıştır. Bireylerin duyusal işlemleme becerilerini değerlendirmek için Yetişkin Duyusal Profil Anketi kullanılmış, nöromotor performansı değerlendirmek için ise Klinik Nöromotor Performans Gözlemi uygulanmıştır.
Bulgular: Migrenli bireyler, düşük kayıt, duyusal hassasiyet ve duyusal kaçınmada belirgin farklılıklar gösteren, ancak duyusal arayışta fark bulunmayan, kendine özgü bir duyusal işlemleme profili sergilemiştir. Nöromotor performans açısından, postural kontrol, somatotipraksi (sırtüstü fleksiyon ve parmak vurma dahil) ve görsel olarak yönlendirilen göz hareketlerinde, özellikle çizgi izleme, konverjans-diverjans ve hızlı lokalizasyon görevlerinde anlamlı farklılıklar gözlenmiştir. Diğer nöromotor parametrelerde anlamlı bir fark bulunmamıştır. Bu bulgular, migrenli bireylerde seçici sensörimotor işlev bozukluklarını vurgulamaktadır.
Sonuç: Migrenli bireylerde gözlenen duyusal işlemleme güçlükleri ve nöromotor performans zorlukları dikkate alındığında, nöromotor işlevsellik üzerine daha fazla araştırma yapılması gerekmektedir. Bu tür çalışmalar, mevcut bulguları güçlendirmenin yanı sıra, bu sorunları ele almak için etkili müdahale protokolleri geliştirmek adına değerli bilgiler sunacaktır
Anahtar kelimeler: migren, yetişkin, duyusal profil, postüral kontrol.

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INTRODUCTION

Migraine is a prevalent neurological disorder and is currently ranked as the second leading cause of years lived with disability worldwide[1]. Individuals who experience sensory processing difficulties may exhibit either heightened or reduced responses to sensory stimuli, such as visual, auditory, or tactile input. These irregularities can lead to challenges in coordinating visually guided eye movements and executing tasks that require fine motor skills[2,3]. Recent studies have suggested dysfunctions in the thalamo-cortical-somatosensory pathways, which may result in abnormal sensory information processing and contribute to the broad range of symptoms observed in individuals with migraine (IwM)[1,4].

Sensory processing plays a crucial role in daily functioning, as it involves interpreting sensory input from movement and the environment to effectively plan and organize behaviour[5,6]. Individuals with sensory processing difficulties may exhibit inadequate responses to sensory stimuli, which can manifest as either heightened or diminished reactions to visual, auditory, or tactile input. These difficulties may affect visually guided eye movements, such as the ability to coordinate eye motions for tracking and focusing on objects[7,8], and may also interfere with both gross and fine motor skills, thereby impacting activities of daily living and academic performance[9,10]. Given the strong interconnection between sensory processing and motor performance, the integration of sensory input is fundamental to postural control, which refers to the ability to maintain balance and stability during various activities[11]. Thus, alterations in sensory processing can influence motor performance, potentially leading to somatodyspraxia, which is characterized by difficulties in planning and executing motor tasks[12,13].

Current research indicates a correlation between migraine and heightened sensitivity to various sensory stimuli, with alterations in brain function potentially contributing to the development of other neurological disorders[14,15]. One study demonstrated that postural instability increases during migraine episodes, possibly due to impaired sensory processing; however, research on this topic remains limited[16].

While the significance of sensory processing and neuromotor performance in IwM is increasingly recognized, studies comparing these parameters between healthy individuals and IwM during the interictal (between-episodes) period are still scarce. A few studies have begun to examine these aspects. For instance, Carvalho et al. reported that IwM experience sensory processing difficulties and balance impairments even during the interictal phase, when compared to healthy controls[11]. Furthermore, it remains unclear whether these deficits are primarily related to postural control or other contributing systems. Luedtke et al. also found that visual processing impairments commonly observed during migraine episodes persisted into the interictal period, supporting the notion that sensory processing dysfunction in migraine is not limited to acute episodes[8]. In line with this, it is hypothesized that IwM exhibit significant impairments in both sensory processing and neuromotor performance compared to healthy individuals. The present study aims to address this gap by conducting a comparative analysis of sensory processing and neuromotor performance between healthy individuals and IwM during the interictal period

MATERIALS AND METHODS

Sample

The research was designed as an observational and comparative study. A total of 100 participants were included, comprising 50 IwM and 50 healthy controls. Inclusion criteria for the IwM group were meeting the diagnostic criteria for migraine according to the International Classification of Headache Disorders, being between 18 and 65 years of age, and currently being in the interictal period. Participants also needed to have the cognitive ability to understand and follow test instructions. Exclusion criteria included the presence of any significant neurological, systemic, or orthopedic condition within the past six months; current pregnancy; and any mental, visual, or auditory impairments that could interfere with test participation. For the control group, participants were required to be between 18 and 65 years of age and have no current or previous history of migraine or other chronic headache disorders.

The minimum required sample size for this study was calculated to be 64 participants per group in order to achieve 80% statistical power at a significance level of 0.05 for a two-tailed test comparing two independent groups, assuming a medium effect size (Cohen's d = 0.50). However, due to recruitment limitations imposed by the COVID-19 pandemic, only 50 IwM and 50 healthy controls were enrolled within the available timeframe. Despite the smaller sample size, the final sample was considered adequate, as the actual effect size calculated for the primary outcome parameter was found to be larger than anticipated (Cohen's d = 0.81). This ensured that the statistical power remained sufficient for the analyses conducted. The sample size calculation was performed using G*Power version 3.1.2.

Procedure

This study was conducted at a specialized private physical therapy and rehabilitation center. Eligible migraine patients meeting the inclusion criteria received comprehensive explanations of the study procedures from our research team before providing informed consent. The study protocol was approved by the Non-Interventional Clinical Research Ethics Committee of Nevşehir Hacı Bektaş Veli University (Decision No: 2020.05.18, dated February 6, 2020) and strictly adhered to Helsinki Declaration guidelines.

All assessments and treatments were performed by a licensed physiotherapist with 10 years of specific experience in neurologic rehabilitation. To ensure data reliability, the physiotherapist administered all tests in a controlled clinical environment following strict standardized procedures, with consistent test sequencing maintained across all participants.

Initially, 144 individuals were assessed for eligibility. However, 44 individuals were excluded for not meeting the inclusion criteria. Specifically, 12 individuals were outside the defined age range of 18 to 65 years. Additionally, four individuals were pregnant, three had auditory impairments, and four were unable to cooperate effectively during the assessments. Furthermore, 24 individuals were excluded due to significant neurological or orthopedic conditions, which were considered major exclusion criteria. Consequently, the final sample consisted of 100 participants, calculated as [144 assessed – 44 excluded] = 100 individuals (Figure 1).

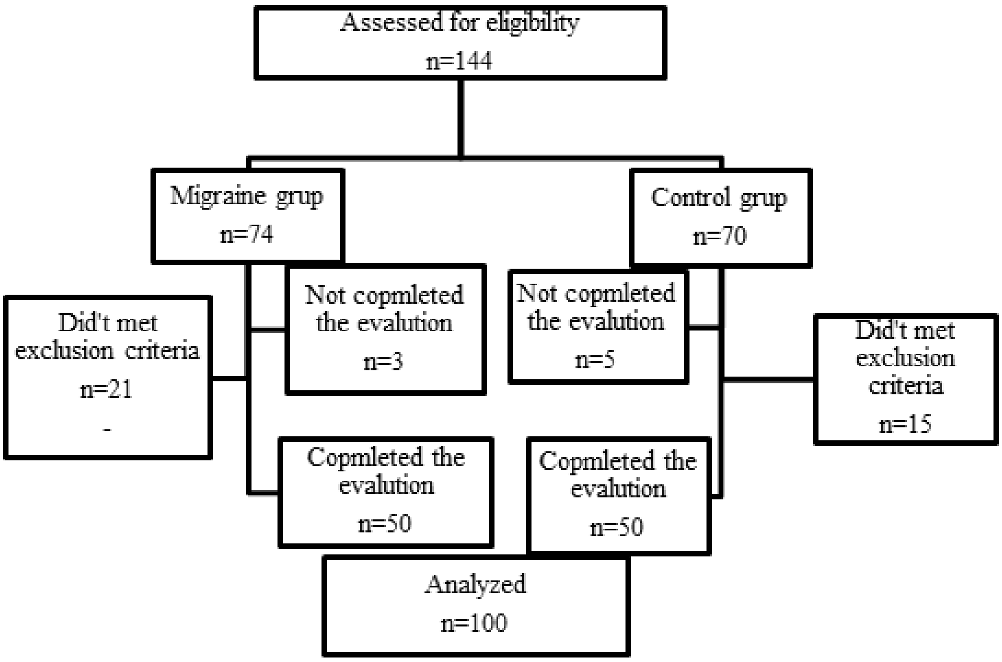

Figure 1. Flow chart of the study.

Measures

Demographic information, including age, gender, weight, educational status, employment status, migraine frequency, and episode duration, was recorded for each participant.

The Adolescent/Adult Sensory Profile questionnaire was utilized to appraise sensory processing skills. This questionnaire consists of 60 items and evaluates six sensory modalities and responses to various sensory stimuli, including taste/smell, movement, visual, touch, auditory development, and activity level. It is suitable for adolescents and adults aged 11 years and above. The questionnaire is based on Dunn's Sensory Processing Theory and is divided into four quadrants: Low Registration, Sensory Seeking, Sensory Sensitivity, and Sensory Avoidance[17]. Validity and reliability analyses have been conducted in Turkish[18].

The Clinical Observation of Neuromotor Performance was employed to assess neuromotor performance. Sub-parameters assessed include posture difficulties, poor bilateral integration and sequencing, somatodyspraxia, visually controlled eye movements, and other clinical observations commonly associated with central nervous system developmental delay or sensory integration dysfunction. Assessment is conducted using + and - signs, where a - sign indicates no difficulties or functional impairments, and a + sign indicates the presence of difficulty or functional insufficiency[19].

Statistical analysis

Graphical methods, including histograms and probability graphs and the Kolmogorov-Smirnov normality test were utilized to determine normal distribution. Descriptive statistics were presented as mean ± standard deviation for normally distributed variables and as median (minimum-maximum) for variables not following normal distribution.

For the comparison of numerical measurements between the two groups, the Student's T test was utilized when parametric test assumptions were met (age, weight, height, low registration, and sensory avoidance), while the Mann-Whitney U test was employed when these assumptions were not met (number of episodes, episode time, duration of diagnosis, sensory seeking, and sensory sensitivity).

Categorical variables were described using frequency and percentage (n, %). The Pearson chi-square test (gender, sub parameters of postural difficulties, total flexion in supine position, line do not follow, and convergence and divergence) and Fisher's exact test (repeated finger tapping, quick localization, protective extension and support reactions) were applied for the analysis of categorical variables. The significance level for all analyses was set at $p < 0.05$. Effect sizes were calculated using Phi or Cramer's V coefficient, contingent upon the size of the table, to examine the dependency between categorical variables. Cohen's d coefficient was implemented to assess the difference between groups in terms of numerical measurement[20].

RESULTS

The individuals in both the migraine and control groups exhibited similar demographic and clinical characteristics, indicating a homogeneous distribution between groups (Table 1). There were no statistically significant differences in age ($p = 0.946$), weight ($p = 0.864$), height ($p = 0.980$), or sex distribution ($p = 1.000$).

The mean scores from the Adolescent/Adult Sensory Profile are presented in Table 2. Compared to the control group, individuals in the migraine group demonstrated significantly higher levels of sensory sensitivity ($p < 0.001$) and sensory avoidance ($p < 0.001$). However, no significant difference was found in sensory seeking behaviour ($p = 0.913$).

The significant findings from the Clinical Observation of Neuromotor Performance are summarized in Table 3. Regarding postural control parameters, no difference was observed in the "extension in prone position" subtest. However, the migraine group showed significantly greater impairments in proximal stability in the crawling position ($p < 0.001$), extensor muscle tone ($p < 0.001$), balance ($p < 0.001$), neck flexion in the supine position ($p < 0.001$), and postural correction ($p < 0.001$).

In terms of bilateral integration and sequencing skills, no significant group differences were found for mixed handedness, midline crossing, right-left discrimination, planned movement sequences, or bilateral motor coordination subtests.

With respect to somatodyspraxia, significant group differences were observed in total body flexion in the supine position ($p = 0.001$) and repeated finger tapping ($p = 0.022$). No significant differences were noted in hand manipulation or diadochokinesis.

Table 1. Demographic and clinical characteristics of the migraine and control group.

	Migraine group (n=50)	Control group (n=50)	p
	X ±SD	X ±SD	
Age (years)	38.5±10.12	38.36±10.51	0.946
Weight (kg)	71.22±13.81	71.70±14.15	0.864
Height (cm)	164.94±8.19	164.9±7.87	0.980
Gender	n %	n %	
Female	41 (82)	41 (82)	1.000
Male	9 (18)	9 (18)	
	median (min-max)		
Number of episodes (day/ month)	5 (1-30)	-	-
Episode time (hours)	13.50 (3-72)	-	-
Duration of diagnosis (years)	8.50 (1-40)	-	-

X: Mean, S: Standart Deviation.

Table 2. Sensory profiles average scores of IwM and healthy individuals.

Age range	Quarters (X ±SD	Migraine group (n=50)	Control group (n=50)	Effect size	p
18-64 years	Low registration	32.80±6.15	27.50±6.82	0.82	<0.001
	Sensory seeking	42.14±7.51	43.74±8.04	0.21	0.913
	Sensory sensivity	50.86±7.82	38.48±6.85	1.68	<0.001
	Sensory avoidance	47.0±8.79	35.46±5.99	1.53	<0.001

X: Mean, S: Standart Deviation

Tablo 3. Comparison of neuromotor functions between groups.

		Migraine group (n=50)	Control group (n=50)	Effect size	p
Postural difficulties		n %	n %		
Proximal stability in crawling position	-	34 (68)	50 (100)	0.44	<0.001
	+	16 (32)	0 (0)		
Extensor muscle tone	-	9 (18)	34 (68)	0.51	<0.001
	+	41 (82)	16 (32)		
Balance	-	15 (30)	42 (84)	0.55	<0.001
	+	35 (70)	8 (16)		
Neck flexion in supine position (on back position)	-	13 (26)	31 (62)	0.36	<0.001
	+	37 (74)	19 (38)		
Postural correction	-	23 (46)	41 (82)	0.38	<0.001
	+	27 (54)	9 (18)		
Somatodyspraxia					
Total flexion in supine position	-	12 (24)	31 (62)	0.38	0.001
	+	38 (76)	19 (38)		
Repeated finger tapping	-	45(90)	0(0)	0.23	0.022
	+	5(10)	50(100)		
Visually controlled eye movements					
Line do not follow	-	9 (18)	45 (90)	0.72	0.001
	+	41 (82)	5 (10)		
Covergence and divergence	-	16 (32)	46 (92)	0.62	0.001
	+	34 (68)	4 (8)		
Quick localization	-	44 (88)	50 (100)	0.25	0.012
	+	6 (12)	0 (0)		
Other clinical observations					
Protective extension and support reactions	-	46(92)	50(100)	0.20	0.041
	+	4(8)	0(0)		

The "-"sign indicates that there is no difficulty or functional impairment. The "+" sign indicates difficulty or functional insufficiency.

Regarding visually controlled eye movement tasks, significant differences were found in line following ($p = 0.001$), convergence-divergence ($p = 0.001$), and quick localization ($p = 0.012$) between the groups. Lastly, among the additional clinical observation parameters, a significant difference was found in protective extension and balance reactions ($p = 0.041$), whereas no significant group differences were noted in combined movement patterns, finger-to-nose coordination, or slow movement performance (Table 3).

DISCUSSION

The current study, which conducted a comparative analysis of sensory processing and sensory-based neuromotor performance between IwM and healthy controls, reveals important differences between the two groups. The findings highlight significant variations in both sensory processing and neuromotor performance, emphasizing the multifactorial nature of migraine and its potential impact on various aspects of daily life.

A key finding of this study is that adults with migraine demonstrated significantly higher levels of sensory sensitivity, sensory avoidance, and low registration compared to the control group, suggesting a distinct sensory profile in IwM. These results are consistent with prior research indicating heightened sensory sensitivity in IwM[21-23]. However, a novel contribution of this study is the observation that sensory avoidance and low registration were also elevated in the migraine group. This indicates that IwM not only tend to be more sensitive to sensory input but also may fail to register certain stimuli or actively avoid them. These findings contribute to a deeper understanding of migraine as a condition involving not only pain perception but also a more global alteration in the processing of environmental stimuli[22,24].

High sensory sensitivity scores reflect a slow habituation to sensory stimuli, whereas high sensory avoidance scores suggest a rapid habituation response and an active effort to avoid overstimulation[25,26]. Painful or distressing reactions may emerge due to heightened sensitivity and a corresponding defensive response to sensory stimuli[27]. For example, IwM often avoid bright and noisy environments, preferring to withdraw from overstimulating situations[28-30]. Additionally, during migraine episodes, individuals may experience cognitive difficulties and have trouble multitasking[31]. Although the underlying cause of cognitive dysfunction observed between migraine episodes remains unclear, it is hypothesized to be associated with disruptions in sensory processing[32].

Sensory sensitivity, which arises from a low neurological threshold, may lead to increased distractibility and memory difficulties in IwM. This can hinder their ability to focus on tasks, particularly in environments with multiple competing sensory inputs[28,30].

In terms of neuromotor performance, notable differences were observed between groups. IwM demonstrated poorer postural control, greater difficulty with somatodyspraxia (i.e., motor planning and body awareness), and impairments in visually guided eye movements. Our findings indicate that postural control is significantly compromised in IwM compared to healthy controls. This is consistent with existing literature suggesting that disrupted sensory processing may contribute to postural instability, potentially linked to cerebellar dysfunction[33]. Additionally, previous studies have noted that motor clumsiness in IwM may persist beyond active migraine episodes and continue during the interictal period[4,34]. Supporting this, research in pediatric migraine populations has also reported motor coordination challenges among affected children[10]. While our findings clearly point to neuromotor differences between groups, further investigation is needed to better understand the underlying mechanisms, particularly the potential interplay between migraine, motor coordination, and higher-order cognitive processes.

Moreover, IwM showed greater difficulty in tasks requiring visually controlled eye movements such as line tracing and convergence-divergence compared to controls. This suggests that migraine may affect visual processing systems and that individuals may struggle with tasks involving ocular motor coordination. These findings align with earlier studies reporting abnormalities in the visual processing pathways of individuals with migraine[34-37].

In the present study, neuromotor performance was assessed using a clinical observation-based test. However, future research should focus on more detailed evaluations of specific subcomponents within this assessment. A more nuanced analysis of individual neuromotor skills would enhance the current understanding and provide a more comprehensive perspective. Additionally, it is important to consider that data collection coincided with the onset of the COVID-19 pandemic in our country, which may have influenced participants' performance or test conditions. These potential confounding factors should be acknowledged in interpreting the results and carefully controlled for in future studies. Accounting for such temporal effects is essential to ensure accurate conclusions and methodological rigor in subsequent research.

In conclusion, this study enhances our understanding of migraine as a complex neurological condition with widespread effects on sensory processing and neuromotor performance. By addressing not only primary symptoms but also the broader sensory and neuromotor disruptions such as postural instability, visual processing deficits, and sensory modulation difficulties clinicians can develop more effective and personalized interventions. Given that sensory processing difficulties in IwM can indirectly compromise balance, coordination, and visual function, further research is needed to validate these results and explore their clinical applications. Future studies should investigate neuromotor performance in greater detail to refine intervention strategies, ultimately guiding the development of targeted therapies that enhance functional outcomes and overall well-being for IwM.

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REFERENCES

1. Ashina M, Terwindt GM, Al-Karagholi MA, de Boer I, Lee MJ, Hay DL et al. Migraine: disease characterisation, biomarkers, and precision medicine. Lancet. 2021;397:1496-504.
2. Headache Classification Committee of the International Headache Society (IHS). The international classification of headache disorders, 3rd edition. Cephalalgia. 2018;38:1-211.
3. Brennan KC, Pietrobon D. A systems neuroscience approach to migraine Neuron. 2018;97:1004-21.
4. Dai W, Qiu E, Lin X, Liu R, Zhou G, Feng Y et al. Abnormal thalamo-cortical interactions in overlapping communities of migraine: an edge functional connectivity study. Ann Neurol. 2023;94:1168-81.
5. Ayres AJ. Sensory Integration and Learning Disorders. Los Angeles, Western Psychological Services. 1972.
6. Chien CW, Rodger S, Copley J, Branjerdporn G, Taggart C. Sensory processing and its relationship with children's daily life participation. Phys Occup Ther Pediatr. 2016;36:73-87.
7. O'Hare L, Hibbard PB. Visual processing in migraine. Cephalalgia. 2016;36:1057-76.
8. Luedtke K, Schulte LH, May A. Visual processing in migraineurs depends on the migraine cycle. Ann Neurol. 2019;85:280-3.
9. d'Onofrio F, Barbanti P, Petretta V, Casucci G, Mazzeo A, Bussone G. Migraine and movement disorders. Neurol Sci. 2012;33:S55-9.
10. Esposito M, Verrotti A, Gimigliano F, Ruberto M, Agostinelli S, Scuccimarra G et al. Motor coordination impairment and migraine in children: a new comorbidity? Eur J Pediatr. 2012;171:1599-604.
11. Carvalho GF, Luedtke K, Pinheiro CF, Jeronymo JC, Bevilaqua-Grossi D. Migraine and balance impairment: influence of subdiagnosis, otoneurological function, falls, and psychosocial factors. Headache. 2022;62:548-57.
12. Balıkçı A, Kırteke F, Dirgen GÇ, Özkan A, Öztürk Y, Gökçay G. Dikkat eksikliği ve hiperaktivite bozukluğu tanılı bir vakada Ayres duyu bütünleme temelli ergoterapi müdahalesinin etkileri. Fenerbahçe Ünivsersitesi Sağlık Bilimleri Dergisi. 2021;1:152-67.
13. Thompson A, Murphy D, Dell'Acqua F, Ecker C, McAlonan G, Howells H et al. Impaired communication between the motor and somatosensory homunculus is associated with poor manual dexterity in autism spectrum disorder. Biol Psychiatry. 2017;81:211-9.
14. Messina R, Rocca MA, Colombo B, Teggi R, Falini A, Comi G et al. Dysregulation of multisensory processing stands out from an early stage of migraine: a study in pediatric patients. J Neurol. 2020;267:760-9.
15. Boran HE, Bolay H, Gantenbein AR, Sandor PS, Jancke L, Meyer M. Sensory processing and sensorimotor integration in migraine. In: Neurophysiology of the Migraine Brain. Cham, Springer, 2021;113-31.
16. Carvalho GF, Luedtke K, Pinheiro CF, Jeronymo JC, Bevilaqua-Grossi D. Migraine with aura is related to delayed motor control reaction and imbalance following external perturbations. Front Neurol. 2021;12:755990.
17. Brown C, Tollefson N, Dunn W, Cromwell R, Filion D. The adult sensory profile: measuring patterns of sensory processing. Am J Occup Ther. 2001;55:75-82.

18. Üçgül MŞ, Karahan S, Öksüz Ç. Reliability and validity study of Turkish version of Adolescent/Adult Sensory Profile. Br J Occup Ther. 2017;80:510-6.
19. Lane SJ. Sensory modulation. In: Sensory Integration: Theory And Practice (Eds AC Bundy, SJ Lane, EA Murray) 2nd Ed. Philadelphia, F.A. Davis. 2002.
20. Cohen J. Statistical Power Analysis for the Behavioral Sciences. 2nd ed. New York, Routledge. 2013.
21. Genizi J, Halevy A, Schertz M, Zelnik N, Srugo I. Sensory processing difficulties correlate with disease severity and quality of life among children with migraine. Front Neurol. 2019;10:448.
22. Goadsby PJ, Holland PR, Martins-Oliveira M, Hoffmann J, Schankin C, Akerman S. Pathophysiology of migraine: a disorder of sensory processing. Physiol Rev. 2017;97:553-622.
23. Meylakh N, Henderson LA. Exploring alterations in sensory pathways in migraine. J Headache Pain. 2022; 23:5.
24. Aydın MŞ. Adolesan/yetişkin duyu profili anketi Türkçe uyarlamasının geçerlilik güvenilirlik çalışması [master's thesis]. Ankara: Hacettepe University. 2015.
25. Dunn W, Brown C. Factor analysis on the Sensory Profile from a national sample of children without disabilities. Am J Occup Ther. 1997;51:490-5.
26. Metz AE, Boling D, DeVore A, Hollenbeck AR. Dunn's model of sensory processing: an investigation of the axes of the four-quadrant model in healthy adults. Brain Sci. 2019;9:35.
27. Neverdahl JP, Uglem M, Matre D, Omland PM, Tronvik E, Sand T. Pain thresholds and suprathreshold pain after sleep restriction in migraine–a blinded crossover study. Cephalalgia. 2022;42:466-80.
28. Lévêque Y, Masson R, Fornoni L, Donnet A, Brissart H, Cortese S et al. Self-perceived attention difficulties are associated with sensory hypersensitivity in migraine. Rev Neurol (Paris). 2020;176:829-38.
29. Lisicki M, D'Ostilio K, Coppola G, Scholtes F, Maertens de Noordhout A, Parisi V et al. Headache-related alterations of visual processing in migraine patients. J Pain. 2020;.21:593-602.
30. Vilà-Balló A, Marti-Marca A, Torres-Ferrús M, Gallardo VJ, Alpuente A, Pozo-Rosich P. Neurophysiological correlates of abnormal auditory processing in episodic migraine during the interictal period. Cephalalgia. 2021;41:45-57.
31. Gil-Gouveia R, Martins IP. Clinical description of attack-related cognitive symptoms in migraine: a systematic review. Cephalalgia. 2018;38:1335-50.
32. Martins IP. Cognitive performance in chronic migraine. Arq Neuropsiquiatr. 2020;78:131-2.
33. Dijkstra BW, Bekkers EM, Gilat M, de Rond V, Hardwick RM, Nieuwboer A. Functional neuroimaging of human postural control: a systematic review with meta-analysis. Neurosci Biobehav Rev. 2020;115:351-62.
34. Jürgens TP, Schulte LH, May A. Migraine trait symptoms in migraine with and without aura. Neurology. 2014;82:1416-24.
35. Hanson LL, Ahmed Z, Katz BJ, Warner JE, Crum AV, Zhang Y et al. Patients with migraine have substantial reductions in measures of visual quality of life. Headache. 2018;58:1007-13.
36. Cui W, Zhang J, Xu F, Wang L, Wang X, Liu F et al. MRI evaluation of the relationship between abnormalities in vision-related brain networks and quality of life in patients with migraine without aura. Neuropsychiatr Dis Treat. 2021;17:3569-79.
37. Shepherd AJ, Joly-Mascheroni RM. Visual motion processing in migraine: enhanced motion after-effects are related to display contrast, visual symptoms, visual triggers and attack frequency. Cephalalgia. 2017;37:315-26.