ISSN: 2651-4451 • e-ISSN: 2651-446X

Turkish Journal of Physiotherapy and Rehabilitation

2023 34(1)45-54

Dilara Onan, MSc, PT
Aynur Demirel, PhD, PT
Özlem Ülger, PhD, PT

1 *Faculty of Physical Therapy and Rehabilitation, Hacettepe University, Ankara, Turkey*

Correspondence (İletişim):

Dilara ONAN
Faculty of Physical Therapy and Rehabilitation, Hacettepe University, Ankara, Turkey,
E-mail: dilaraonan@gmail.com
ORCID: 0000-0001-9505-6135

Aynur DEMIREL
E-mail: aynurdemirel629@hotmail.com
ORCID: 0000-0002-5773-6292

Ozlem ULGER
E-mail: ozlemulger@yahoo.com
ORCID: 0000-0002-3908-223X

***Received:** 13.10.2021 (Geliş Tarihi)*
***Accepted:** 12.01.2023 (Kabul Tarihi)*

INVESTIGATING THE EFFECTS OF FATIGUE PROTOCOL ON SPATIOTEMPORAL CHARACTERISTICS OF GAIT IN PATIENTS WITH CHRONIC NECK PAIN

ORIGINAL ARTICLE

ABSTRACT

Purpose: Chronic neck pain (CNP) may lead to problems, such as functional limitations, disability, and fatigue. Gait maintains postural orientation; It is important to investigate the effects of fatigue on walking in patients who subjectively define a certain level of fatigue, not for a certain period. This study aimed to investigate the effects of fatigue protocol on gait spatiotemporal characteristics in patients with CNP.

Methods: Fifty-three patients with CNP, and twenty-six healthy controls were included. The groups were matched with Propensity Score Matching in terms of age and fatigue threshold as 26 individuals. Pain intensity and disability were evaluated with the Visual Analog Scale, and Neck Disability Index, respectively. Gait assessment was recorded with OptoGait (1.6.4.0, Microgate, Bolzano, Italy) for one minute while individuals walked at their preferred speed on the treadmill. Individuals keep walking on the treadmill and fatigue levels were asked for Modified Borg Scale. While fatigue reached 4 points, gait assessment was recorded for one minute. A two-way repeated-measures ANOVA was used for interaction time-by-group.

Results: The median pain intensity was 7(4-9), and the disability was moderate in patients. Left step length, stride length, and cadence, showed significant, similar changes within the groups over time($p<0.05$), while there were differences between groups in cadence ($p<0.05$). There was no difference in time-group interaction in terms of gait variables ($p>0.05$).

Conclusion: Fatigue may lead to changes in the gait parameters of patients with CNP, it may cause the development of compensation strategies to maintain the position, mobility, and stabilization of the spine.

Keywords: Neck pain, Fatigue, Gait

KRONİK BOYUN AĞRILI HASTALARDA YORGUNLUK PROTOKOLÜNÜN YÜRÜYÜŞÜN ZAMAN MESAFE KARAKTERİSTİKLERİ ÜZERİNE ETKİLERİNİN ARAŞTIRILMASI

ARAŞTIRMA MAKALESİ

ÖZ

Amaç: Kronik boyun ağrısının (KBA) fonksiyonel limitasyonlar, özür, yorgunluk gibi sorunlara yol açabilmektedir. Yorgunluğun günlük yaşam aktivitelerini etkilemesi, belirli süre için değil, subjektif olarak belirli bir düzeyde yorgunluk tanımlayan hastalarda yorgunluğun postural oryantasyonu sağlayan yürüme üzerine etkilerinin araştırılması önemlidir. Bu çalışmanın amacı, KBA'lı hastalarda yorgunluk protokolünün yürüyüşün zaman mesafe karakteristikleri üzerindeki etkilerini araştırmaktır.

Yöntem: Çalışmaya 53 KBA'lı, 26 sağlıklı kontrol alındı. Gruplar yaş, yorgunluk eşiği bakımından Propensity Score Matching ile 26 birey olacak şekilde eşleştirildi. Ağrı şiddeti, özür sırasıyla Görsel Analog Skala, Boyun Özür Anketi ile değerlendirildi. OptoGait (1.6.4.0, Microgate, Bolzano, İtalya) ile bireyler koşu bandında bireyler tercih ettikleri hızda yürürken yürüyüşleri önce bir dakika süreyle kaydedildi. Yorgunluk düzeyleri Modifiye Borg Skalası ile değerlendirildi. Yorgunlukları 4 puana ulaştığında tekrar 1 dakikalık yürüyüş değerlendirmesi yapıldı, yürüyüş bandı durduruldu. Zaman-grup etkileşimi değerlendirmesinde Tekrarlı Ölçümlerde iki Yönlü ANOVA analizi uygulandı.

Sonuçlar: KBA'lı bireylerde ağrı şiddeti ortancası 7(4-9) idi, özür orta düzeydeydi. Sol adım uzunluğu, çift adım uzunluğu, kadans, ortalama hız gruplar içinde zamanla anlamlı, benzer değişiklikler gösterirken ($p<0,05$). Kadansta gruplar arası farklılık vardı ($p<0,05$). Zaman-grup etkileşiminde yürüyüş değişkenleri açısından fark yoktu ($p>0,05$).

Tartışma: Yorgunluk, KBA'lı hastaların yürüme parametrelerinde değişikliklere yol açabilir. Omurganın pozisyonunu, mobilitesini, stabilizasyonunu korumak için yürüyüşte kompansasyon stratejilerinin geliştirilmesine neden olabilir.

Anahtar Kelimeler: Boyun ağrısı, Yorgunluk, Yürüyüş

INTRODUCTION

Neck pain (NP), which continues for longer than three months, is defined as chronic neck pain (CNP), and studies have shown that CNP may lead to problems, such as functional limitations, fear of movement, disability, and neck muscle fatigue or general fatigue (1,2).

When the location of the neck region is considered, the importance may be understood of the functions of sensorial receptors, such as muscle spindles and golgi tendon organ, proprioceptors, and nociceptors in the neck muscles. These functions include the perception of motion, determination of the location of a motion in space, perception of pain stimuli, transmission to the cortex, processing and responding processes (3). Muscle fatigue changes the discharge of receptors, such as muscle spindles and golgi tendon organ, and postural orientation deteriorated by the alteration of proprioception (4,5). The fatigue of the neck muscles of individuals with neck pain begins in a shorter time in isometric voluntary neck movements compared to healthy controls (6). On the other hand, individuals with neck pain experience general fatigue during activities in their daily lives (2). Fishbain et al. reported a relationship between self-reported fatigue and pain, so they stated that general fatigue should be addressed in patients experiencing pain (7). While carrying a bag, climbing stairs, or walking moderate and long distances, patients with pain may develop several problems, such as fatigue starting in the upper extremity and spreading to the lumbar region, cardiac loading, and strain. Thus, sprains may occur (8,9).

Gait is an important phenomenon in providing and maintaining postural orientation (6). Gait parameters may be affected in case of pain and disability (1,10). Various studies have shown that, although limited, step length, gait speed, and cadence decrease, and postural sway increase in the anteroposterior direction in patients with CNP compared to healthy control (HC) (1,11,12). These findings suggest that CNP may be associated with gait disturbance.

After insufficient rest, the pain and stiffness associated with fatigue may cause muscle fatigue, thereby generating a vicious circle (13). Although EMG studies on fatigue, strength, and endurance of neck muscles showed the relationship between muscle fatigue and NP (6), information about how the patients manage general fatigue is lacking. Fatigue affects daily living activities and it is important to investigate the effects of fatigue on walking in patients identified with a subjective certain level of fatigue rather than for a certain period.

Fatigue affects daily living activities, and it is important to investigate the effects of fatigue on walking in patients identified with a subjective certain level of fatigue rather than for a certain period. There is a lacking area in fatigue and walking studies in patients with CNP in the literature. Therefore, the effects of general fatigue on gait parameters should be investigated in patients with NP. The present study aims to investigate the effects of general fatigue protocol on gait spatiotemporal characteristics in patients with CNP.

METHODS

Research Approval and Participants

This cross-sectional study was conducted in the author’s institution after the approval for this research was granted by the ethics committee of the authors’ affiliated institutions. All participants were given informed consent. All procedures were conducted according to the Declaration of Helsinki. The research was carried out at Hacettepe University Faculty of Physical Therapy and Rehabilitation, between January 2018 and January 2019, and is a cross-sectional study.

The study included 26 individuals in HC and 53 patients with CNP who had unilateral non-specific pain in the neck and shoulder area and were diagnosed with CNP by a physiatrist and referred to physiotherapy. The inclusion criteria were the presence of pain for at least three months, a resting pain score of≥2 according to the Visual Analog Scale (VAS) (14,15), the Neck Disability Index (NDI) score of≥5(mild and above) (16), and whose dominant leg is the right side.

Exclusion criteria were defined as the presence of any neurologic or systemic disease, intervertebral disc displacement, radiating pain neck from the upper extremity, radiculopathy, myelopathy, insufficiency malignancy, tendinitis or bursitis in any upper/lower extremity, scoliosis, acute inflammation, non-union of a fracture, pregnancy, a history of upper/lower extremity surgery.

Demographics and Self-Ratings

The demographic data of all patients (gender, age, and body mass index) were recorded. The pain intensity during the activity of all patients with CNP was evaluated with VAS, by the participant marking a vertical line on a 10cm horizontal line to represent the intensity of the pain where 0=no pain,10=intolerable pain (14). Functional disability was evaluated with the 10 items NDI, which consists of 10 items asked for functional tasks such as the activities of daily life, driving, reading, lifting, working, and recreation. Each item is scored between 0 and 5, providing a total score ranging from 0=no disability to 50=complete disability (16,17).

Gait and Fatigue Assessments

In the assessment of the spatiotemporal (distance, timing) characteristics of gait, a treadmill, and a valid, reliable OptoGait photocell-based system were used (Version 1.6.4.0, Microgate, Bolzano, Italy). The spatial variables included stride length and step length; the temporal variables included gait cycle, speed, cadence, step time, pre-swing, swing, stance phases, single and total support, and load response (1). Each bar is 1 meter long, and each bar, which is placed 3 mm above the ground and 1 cm apart, has 96 LEDs. The device is designed so that when an individual passes between 2-rod bars positioned parallel on the floor, their feet block the transmission and reception. The timing, size, and distance are detected, and spatial-temporal parameters are calculated automatically. OptoGait is connected to a personal computer using the OptoGait software program via an interface unit. The data were output at a frequency of 1000 Hz and stored on a computer (18). Optogait is an acceptable system for the assessment of gait in the general population (18).

The treadmill was selected to generate controlled fatigue (19). First, the subject became accustomed to walking on the treadmill at a comfortable walking speed. Then, each subject determined their preferred walking speed. The preferred walking speed of individuals remained constant throughout the protocol. Spatiotemporal parameters were recorded at this preferred walking speed by the OptoGait photocell-based system for one minute. After this recording, the participants continued to walk until they were fatigued. Fatigue levels of participants were asked every minute and the participants scored their perception of fatigue. When the fatigue level reached the level of four points (somewhat severe) according to Modified Borg Scale (MBS)(20), the gait parameters were recorded again by the OptoGait photocell-based system for one minute, the fatigue threshold was recorded and the test was completed. The four (4) is a little intense level on the Modified Borg Scale. Therefore, to prevent cardiovascular adaptations and create general body fatigue that patients experience in their daily living, we determined the fatigue threshold to 4 as “a little intense” (20).

The MBS assesses the intensity of exercise or resting dyspnea and the intensity of fatigue on a scale of 0-10(0=none, 10=maximum intensity) (20).

Statistical analysis

Data obtained in the study were analyzed statistically using IBM SPSS software version 20.0 (Statistical Package for the Social Sciences, IBM Corp., Armonk, NY, U.S.A.). Group characteristics were calculated as mean and standard deviation values. The conformity of the data to normal distribution was assessed using the Shapiro-Wilks tests. A value of $p<0.05$ was accepted as statistically significant. The Propensity Score Matching was performed with R 4.1.2 Studio ggplot2 ve BlandAltmanLeh program.

To study the effects of the FP, the outcome measures were compared time-by-group interaction effects, one the between-groups factor (group) and one the within-groups factor (time) by a two-way repeated-measures ANOVA. In the examination of whether there was a difference between the cadence before and after the FP, the ANOVA analysis was performed. According to cadence the observed power of the study was 0.932. The sample size was sufficient.

RESULTS

Participants

There were 53 individuals with CNP and 26 individuals with HC. There was no difference between groups concerning gender, BMI, preferred speed (Table 1) and spatio-temporal characteristics of

Table 1. Characteristics of Participants

	Before Propensity Score Matching			After Propensity Score Matching		
	CNP (n=53) Median (% 25-75)	**HC (n=26) Median (% 25-75)**	**P Value**	**CNP (n=26) Median (% 25-75)**	**HC (n=26) Median (% 25-75)**	**P Value**
Age (Years)	46 (39-52.5)	32 (28-45.25)	0.007*	40 (25-44)	32 (28-45)	0.898
BMI (kg/m^2)	25.70 (23.4-29.3)	26.35 (22.7-28.2)	0.854	25.3 (21.5-28.4)	26.4 (22.7-28.2)	0.470
Gender (F/M) (n)	38/15	13/13	0.083	16/10	13/13	0.402
Fatigue Threshold (min)	7.29 (4.47-9.83)	12.67 (9.2-16.57)	0.000**	9.75 (8-15.24)	12.67 (9.2-16.26)	0.188
Preferred Walking Speed (Km/h)	4.1 (3.35-4.9)	4.9 (3.87-5.22)	0.051			0.743
Pain Intensity (cm)	7 (4-9)	-		6 (4-8)		
Disability	18 (11-23)	-		14 (7-19)		

min: Minute, cm: centimeter, Km/h: Kilometer/hour, * p<0.05, ** p<0.000, CNP: Chronic Neck Pain, HC: Healthy Controls, BMI: Body Mass Index, cm: Centimeter, ***p:*** Statistical Significance**,** F:Female, M:Male

Table 2. The Baseline Results of Spatiotemporal Characteristics of Gait

Spatiotemporal Characteristics of Gait	CNP (N=26) Mean±SD	HC (N=26) Mean±SD	P Value
Right Step Length$_{T0}$	66±12.2	65.2±10.9	0.136
Left Step Length$_{T0}$	65.8±11.5	64±10.3	0.310
Stride Length$_{T0}$	131.8±23.9	129±21	0.219
Right Stance Phase$_{T0}$	60.7±4.7	61.3±5.1	0.392
Left Stance Phase$_{T0}$	60.7±4.5	61.3±4.9	0.424
Right Swing Phase$_{T0}$	41.5±5.7	40.2±5.2	0.762
Left Swing Phase$_{T0}$	41.5±5.7	40.2±5.1	0.424
Right Single Support$_{T0}$	40.2±4.9	39.5±4.3	0.941
Left Single Support$_{T0}$	40.9±4.7	39±4.4	0.719
Total Double Support$_{T0}$	19.2±8	21.4±8.6	0.313
Right Load Response$_{T0}$	8.8±4.3	10.4±4.4	0.149
Left Load Response$_{T0}$	9.3±4.4	10.5±4.4	0.452
Right Preswing Phase$_{T0}$	10.5±4.1	10.8±4.3	0.508
Left Preswing Phase$_{T0}$	9.7±4.3	11.1±4.5	0.247
Right Step Time$_{T0}$	0.527±0.166	0.503±0.062	0.989
Left Step Time$_{T0}$	0.503±0.145	0.501±0.069	0.955
Gait Cycle$_{T0}$	1.06±0.29	1.02±0.11	0.806
Cadance$_{T0}$	132.8±23.6	120.1±18.4	0.296
Right Speed$_{T0}$	1.3±0.24	1.27±0.3	0.364
Left Speed$_{T0}$	1.41±0.34	1.30±0.32	0.426
Avarage Speed$_{T0}$	1.35±0.24	1.29±0.31	0.351

CNP: Chronic Neck Pain, HC: Healthy Controls SD:Standart Deviation, T_0: Before Fatigue Protocol, p: Significant level.

gait (Table 2). However, there was a difference between the groups in terms of age and fatigue threshold (p=0.007, p=0.000, respectively). Patients with CNP got tired at 5.38 minutes earlier than individuals with HC. It was thought that these two variables might affect the gait parameters, and the groups had to be matched so that there would be no difference. After the propensity score matching analysis, there was no difference between the groups in terms of age and fatigue threshold, when the results of the analysis were examined for 26 individuals in each group. The dominant extremity of all individuals was right. Therefore, there was no difference between the groups. The demographic characteristics were given in Table 1. There were no differences between the groups in terms of right and left lower extremity gait results in baseline (Table 2).

The Results of Two-Way Repeated-Measures ANOVA for Spatiotemporal Characteristics of Gait

After the FP, the right step length, right and left stance phase, right and left swing phase, right and left single support, total double support, right and left load response, right and left pre-swing phase, right and left step time, gait cycle, right and left speed, average speed showed no significant effect for the time in CNP and HC groups (p>0.05). However, left step length, stride length and cadence showed a significant effect on time (p<0.05). In patients with CNP and HC, there were statistically significant increases in left step length, and stride length; decreases in the cadence according after FP (p<0.05) (Table 3).

The right and left step length, stride length, right and left stance phase, right and left swing phase, right and left single support, total double support, right and left load response, right and left pre-swing phase, right and left step time, gait cycle, cadence, right and left speed, average speed showed similar changes over the time in CNP and HC groups. There were no significant time-by-group interaction effects of these spatiotemporal characteristics (p>0.05) (Table 3).

The results showed significant effects for the group in the cadence (p=0.044). However, there was no significant difference between the groups in terms of spatiotemporal characteristics (p>0.05), except for cadence (Table 2). Among the groups after FP, the cadence was higher in CNP compared to HC (p=0.044).

Table 3. The Propensity Score Matching Results of Spatiotemporal Characteristics of Gait and Results of Two-Way Repeated Measures ANOVA According to Fatigue Protocol

Spatiotemporal Characteristics of Gait	Before Propensity Score Matching		After Propensity Score Matching		The Results of ANOVA After Propensity Score Matching		
	CNP (N=53) Mean±SD	HC (N=26) Mean±SD	CNP (N=26) Mean±SD	HC (N=26) Mean±SD	Time (F, P-Value, n^2)	Group (F, P-Value, n^2)	Time x Group (F, P-Value, n^2)
Right Step Length$_{T0}$	60.86±12.24	65.19±10.92	66±12.2	65.2±10.9	2.109, 0.153, 0.041	0.232, 0.632, 0.005	1.065, 0.307, 0.021
Right Step Length$_{T1}$	62.57±12.23	65.48±11.48	67.8±12.3	65.5±11.5			
Left Step Length$_{T0}$	61.14±12.29	64.04±10.27	65.8±11.5	64±10.3	7.536, **<0.05,** 0.133	0.370, 0.546, 0.007	0.028, 0.867 0.001
Left Step Length$_{T1}$	63.22±12.71	65.88±10.79	67.9±13.2	65.9±10.8			
Stride Length$_{T0}$	121.94±24.52	129±21.01	131.8±23.9	129±21	5.878, **<0.05,** 0.107	0.301, 0.586, 0.006	0.257, 0.614, 0.005
Stride Length$_{T1}$	125.51±24.5	131.34±22.1	135.4±24.3	131.3±22.1			
Right Stance Phase$_{T0}$	60.38±4.24	61.33±5.11	60.7±4.7	61.3±5.1	0.671, 0.417, 0.014	0.399, 0.531, 0.008	0.028, 0.867, 0.001
Right Stance Phase$_{T1}$	59.52±3.96	60.96±4.34	60.1±4.4	61±4.3			

CNP: Chronic Neck Pain, HC: Healthy Controls SD:Standart Deviation, T_0: Before Fatigue Protocol, T_1: After Fatigue Protocol, **F:**F ratio , ***p:*** Statistical Significance**, n^2:** Partial Eta Squared

Table 3. (Continuous) The Propensity Score Matching Results of Spatiotemporal Characteristics of Gait and Results of Two-Way Repeated Measures ANOVA According to Fatigue Protocol

	Before Propensity Score Matching		After Propensity Score Matching		The Results of ANOVA After Propensity Score Matching		
Spatiotemporal Characteristics of Gait	**CNP (N=53) Mean±SD**	**HC (N=26) Mean±SD**	**CNP (N=26) Mean±SD**	**HC (N=26) Mean±SD**	**Time (F, P-Value, n²)**	**Group (F, P-Value, n²)**	**Time x Group (F, P-Value, n²)**
Left Stance Phase$_{T0}$	60.48±4.2	61.34±4.9	60.7±4.5	61.3±4.9	1.426, 0.238, 0.028	0.101, 0.752, 0.002	0.163, 0.688, 0.003
Left Stance Phase$_{T1}$	60.24±3.90	60.36±4.56	60.2±4.6	60.4±4.6			
Right Swing Phase$_{T0}$	40.66±7.55	40.15±5.2	41.5±5.7	40.2±5.2	0.022, 0.883, 0.000	1.549, 0.219, 0.031	0.583, 0.449, 0.012
Right Swing Phase$_{T1}$	42.22±4.75	39.57±4.61	41.6±4.9	39.6±4.6			
Left Swing Phase$_{T0}$	41.23±5.09	40.24±5.08	41.5±5.7	40.2±5.1	0.306, 0.582, 0.006	1.592, 0.213, 0.031	0.598, 0.443, 0.0112
Left Swing Phase$_{T1}$	40.86±5.5	40.12±4.5	42.2±5	40.1±4.5			
Right Single Support$_{T0}$	39.62±7.26	39.5±4.25	40.2±4.9	39.5±4.3	0.000, 0.993, 0.000	0.125, 0.725, 0.003	0.429, 0.516, 0.0009
Right Single Support$_{T1}$	39.57±5.01	39.58±4.56	40.5±4.1	39.6±4.6			
Left Single Support$_{T0}$	39.52±6.94	38.97±4.36	40.9±4.7	39±4.4	0.022, 0.882, 0.000	0.835, 0.365, 0.017	3.781 0.058 0.072
Left Single Support$_{T1}$	40.51±7.15	39.84±4.33	39.9±3.6	39.8±4.3			
Total Double Support$_{T0}$	19.43±7.55	21.38±8.64	19.2±8	21.4±8.6	0.416, 0.512, 0.008	1.073, 0.305, 0.021	0.006, 0.938, 0.00
Total Double Support$_{T1}$	18.58±6.56	20.88±8.44	18.6±7.7	20.9±8.4			
Right Load Response$_{T0}$	8.89±4.21	10.40±4.38	8.8±4.3	10.4±4.4	0.000, 0.994, 0.000	1.954, 0.168, 0.038	0.027, 0.870, 0.001
Right Load Response$_{T1}$	9.02±3.71	10.3±4.3	8.9±4.3	10.3±4.3			
Left Load Response$_{T0}$	9.55±5.42	10.49±4.38	9.3±4.4	10.5±4.4	0.318, 0.575, 0.006	1.389, 0.244, 0.028	0.016, 0.898, 0.000
Left Load Response$_{T1}$	8.77±3.35	10.3±4.22	9±3.8	10.3±4.2			

CNP: Chronic Neck Pain, HC: Healthy Controls SD:Standart Deviation, T_0: Before Fatigue Protocol, T_1: After Fatigue Protocol, **F:**F ratio , ***p:*** Statistical Significance**, n²:** Partial Eta Squared

Table 3. (Continuous) The Propensity Score Matching Results of Spatiotemporal Characteristics of Gait and Results of Two-Way Repeated Measures ANOVA According to Fatigue Protocol

	Before Propensity Score Matching		After Propensity Score Matching		The Results of ANOVA After Propensity Score Matching		
Spatiotemporal Characteristics of Gait	**CNP (N=53) Mean±SD**	**HC (N=26) Mean±SD**	**CNP (N=26) Mean±SD**	**HC (N=26) Mean±SD**	**Time (F, P-Value, n²)**	**Group (F, P-Value, n²)**	**Time x Group (F, P-Value, n²)**
Right Preswing Phase$_{T0}$	10.12±4.12	10.79±4.35	10.5±4.1	10.8±4.3	1.491, 0.228, 0.030	0.545, 0.464, 0.011	1.276, 0.264, 0.025
Right Preswing Phase$_{T1}$	9.64±3.53	10.74±4.48	9.4±4	10.7±4.5			
Left Preswing Phase$_{T0}$	9.95±4.02	11.14±4.52	9.7±4.3	11.1±4.5	0.268, 0.607, 0.005	0.779, 0.382, 0.016	0.642, 0.427, 0.013
Left Preswing Phase$_{T1}$	9.43±3.91	10.4±4.31	9.9±4.2	10.4±4.3			
Right Step Time$_{T0}$	0.503±0.137	0.503±0.062	0.527±0.166	0.503±0.062	0.024, 0.876, 0.000	0.099, 0.754, 0.002	1.999, 0.164, 0.039
Right Step Time$_{T1}$	0.51±0.1	0.51±0.06	0.512±0.138	0.516±0.062			
Left Step Time$_{T0}$	0.499±0.126	0.501±0.069	0.503±0.145	0.501±0.069	3.545, 0.066, 0.067	0.014, 0.907, 0.000	0.409, 0.526, 0.008
Left Step Time$_{T1}$	0.50±0.11	0.52±0.06	0.515±0.133	0.524±0.067			
Gait Cycle$_{T0}$	1.034±0.238	1.022±0.119	1.06±0.29	1.02±0.11	0.547, 0.463, 0.011	0.104, 0.748, 0.002	1.422, 0.239, 0.028
Gait Cycle$_{T1}$	1.04±0.24	1.05±0.12	1.053±0.304	1.052±0.121			
Cadance$_{T0}$	125.58±22.73	120.1±18.35	132.8±23.6	120.1±18.4	12.374, **0.001**, 0.202	4.25, **0.044**, 0.08	1.414, 0.240, 0.028
Cadance$_{T1}$	121.11±20.57	114.26±14.19	121±18.7	114.3±14.2			
Right Speed$_{T0}$	1.20±0.31	1.27±0.30	1.3±0.24	1.27±0.3	0.379, 0.541, 0.008	0.239, 0.627, 0.005	0.094, 0.761, 0.002
Right Speed$_{T1}$	1.20±0.29	1.25±0.29	1.30±0.26	1.25±0.30			
Left Speed$_{T0}$	1.23±0.36	1.30±0.32	1.41±0.34	1.30±0.32	3.508, 0.067, 0.067	1.271, 0.265, 0.025	0.392, 0.534, 0.008
Left Speed$_{T1}$	1.21±0.28	1.25±0.31	1.32±0.27	1.25±0.31			
Avarage Speed$_{T0}$	1.21±0.30	1.28±0.30	1.35±0.24	1.29±0.31	3.878, 0.055, 0.073	0.662, 0.420, 0.013	0.142, 0.708, 0.003
Avarage Speed$_{T1}$	1.20±0.27	1.25±0.30	1.31±0.26	1.25±0.31			

CNP: Chronic Neck Pain, HC: Healthy Controls SD:Standart Deviation, T_0: Before Fatigue Protocol, T_1: After Fatigue Protocol, **F:**F ratio , ***p:*** Statistical Significance**, n²:** Partial Eta Squared

DISCUSSION

This study investigated the effects of the fatigue protocol on gait spatiotemporal characteristics in patients with CNP. Also, to our knowledge, it is the first study to investigate the fatigue protocol effects on spatiotemporal characteristics in patients with CNP. In this study, according to ANOVA results, there were statistically significant increases in left step length, and stride length; decreases in the cadence according after FP in both groups. The cadence was higher in CNP compared to HC after the FP between groups. However, there were no statistically significant differences in spatiotemporal parameters except for cadence. We showed that spatiotemporal characteristics change with fatigue in patients with CNP and HC groups. And we found that patients with CNP got tired earlier than individuals with HC. We think that the reason for patients with CNP and HC groups to do this is to compensate and to stabilize against fatigue during walking.

Patients with CNP have reported that repetitive activities that require a stable posture to be maintained, such as driving or typing, carrying bags, and climbing stairs, caused fatigue in the muscles of the cervical, and lumbar region (13, 21). However, the previous studies lack clarity regarding certain details about fatigue, which directly affect walking, such as the fatigue threshold and the period of occurrence of fatigue. Therefore, it was deemed necessary in the current study to investigate how walking is affected in patients with CNP by creating fatigue independent of activities. Pain and functional ability may be predictive factors in fatigue (22). It has been reported that chronic pain, such as low back pain, fibromyalgia, rheumatoid arthritis, and headache, is associated with fatigue (7). Although there is a lack of studies concerning the effects of fatigue during walking in CNP, we found that patients with CNP got tired 5.38 minutes earlier than the HC group. We think that the reason for this may be pain intensity and disability. Fatigue may occur with personal or environmental factors, with activity or without activity (22). However, in our study that we compared with HC, the pain intensity was above moderate, and the disability was moderate level, suggesting that pain and disability may cause earlier fatigue in patients with CNP. In an evidence-based review, Fishbain et al. reveal the reason for the development of fatigue with pain based on three pieces of evidence. First, fatigue increases with increasing pain, and fatigue decreases with decreasing pain. Secondly, the increase in the duration of pain increases the likelihood of fatigue. Thirdly, as the intensity of pain increases, fatigue also increases (7). Although studies on fatigue and disability in chronic pain are limited, fatigue has been associated with increased pain and impairment of functional abilities in neurological studies. The pain and fatigue also cause increased chronic disability and this cycle may continue in complex ways by increasing each other (23).

In recent studies in the literature, it has been stated that there are differences in spatiotemporal characteristics of walking in patients with CNP compared to the HC group (1,24,25). Although these studies have been a subject of interest in the literature recently, they have been conducted in different walking protocols in patients with CNP and have shown that patients with CNP have less speed, cadence, step length, and stride lengths compared to individuals in the HC group. Uthaikhup et al. found that the decrease in speed was associated with disability (1), while Kırmızı et al. found the step length and preferred speed parameters associated with disability (26). Kırmızı et al. stated that altered gait parameters might be to compensate for the reduced shock absorption capacity (26). However, unlike these study protocols, our study investigated the effects of fatigue on the spatiotemporal parameters of gait in the CNP and HC group. After fatigue protocol, we found differences in cadence, stride length, and left step length in CNP and HC groups. However, among the groups, the cadence was higher in CNP than in HC. It has been reported that patients in the CNP group have a shorter stride length to the support base and thus provide stability by reducing anteroposterior displacement (27). It is stated that shorter steps are more stable and safe, and the asymmetry in step lengths can be accepted as a measure of walking ability (28,29). Therefore, the underlying problem of step length asymmetry may be indicative of compensatory mechanisms. It has been observed that individuals take longer steps on the right and left with fatigue. However, left stride length is significant in individuals. The fact that dominant feet are correct in all individuals, and the left stride length increases with fatigue in all individuals and is higher in CNP compared to HC may indicate that individuals with CNP are more prone to deterioration of stabilization ability. Since the right foot is dominant, it may be compensating for fatigue, but the left foot may not be able to compensate.

In this study, the findings show that walking parameters showed similar significant responses after fatigue in individuals with CNP and HC. However, when we look at the between groups, the difference in cadence, which is higher in CNP than in HC, is striking. In adaptation to fatigue, individuals in the CNP and the HC group decreased cadence, both within and between groups. Among the groups, cadence results in individuals CNP were higher than in HC, after the FP. However, studies in the literature indicated that cadence is less in CNP compared to HC. (12, 30). In our results, individuals with CNP were getting tired almost 5 minutes earlier. In addition to pain and disability, individuals' with CNP have higher walking cadences than HC, which may lead to earlier fatigue. Both groups decrease the number of steps per minute while getting tired, but because their cadence is higher, individuals with CNP may get tired first. Although our results indicated that both groups showed similar changes in adapting to fatigue; The cadence parameter may cause the inability of individuals with CNP to adapt to fatigue during walking.

When there is an abnormality in one of the bones, joints, muscle structures, normal walking is impaired (25). With the pain, the time spent in the standing phase decreases, and the time spent in the swing phase increases (31). In our results, after the fatigue protocol, there were no significant differences in stance, pre-swing and swing phases, load responses, and single and total support both within and between groups. Although the number of studies investigating the spatiotemporal characteristics of walking in patients with CNP is limited in the literature, patients with CLBP have been found higher swing duration compared to the HC group (32,33). Ground reaction forces act on the body in the stance phase, and shortening the stance phase provides a reduction in ground reaction forces and relieves pain (34). In individuals with LBP, wide-angle movements of the spine are avoided to minimize the forces that may cause pain. Apart from being a protective strategy, it is stated that pain may affect walking parameters negatively (32). The fact that the lumbar region is closer to the lower extremity but the neck is far from the lower extremity may be a normal consequence of these results being insignificant. Uthaikhup et al. state that the gait did not vary between the CNP and the HC group when observed (1). From the results of our study supporting the results of Uthaikhup et al. and Kırmızı et al., we think that when the observation is performed, the dynamics of walking change with fatigue, although the gait does not vary between patients with CNP and HC (1,26).

A series of limitations were observed in this study. The most important limitation of this study is that although perceived fatigue is examined, the fatigue threshold wasn't measured by the amount of lactic acid in the blood. Also, the findings obtained in this study raise the questions of how investigations and evaluations should be performed on how proprioception sensation, body sway, ground reaction forces, and compensatory body movements may be affected by fatigue and gait parameters in individuals with CNP. We evaluated only the kinematics of gait. There is a need for further studies to examine fatigue both systematically and through what is perceived by the patients.

In conclusion, fatigue may lead to changes in the gait parameters of patients with CNP, and in general, it may cause the development of compensation strategies to maintain the position of the spine, and maintain mobility and stabilization. In this case, the result of changes in gait parameters in individuals with CNP, fatigue is seen to be one of the factors causing these changes. The most important results of this study show that patients with CNP are tired earlier than HC. When all individuals, get tired while walking, they increase the left step length, and stride length parameter, however, decrease the cadence. The higher cadence in CNP compared to HC suggests that it may cause early fatigue in CNP. When patients come to clinics, it would be useful to evaluate the parameter of fatigue together with gait.

Source of Support: None

Conflict of Interest: The authors report no declarations of interest.

Author Contribution; DO, AD, OU: Conceptualization, Methodology, Investigation, Writing-Original draft preparation, Visualization, Project administration. DO, AD, OU: Conceptualization, Methodology, Formal Analysis, Writing-Original draft preparation, Visualization. DO, AD, OU: Conceptualization, Methodology, Writing- Reviewing and Editing, Project administration, Supervision. DO, AD, OU: Resources, Writing- Reviewing and Editing, and Supervision. DO, AD, OU: Investigation, Writing- Reviewing and Editing, Resources.

Explanations: This study has been never presented or published in a scientific platform.

Acknowledgement: None

REFERENCES

1. Uthaikhup S, Sunkarat S, Khamsaen K, Meeyan K, Treleaven J. The effects of head movement and walking speed on gait parameters in patients with chronic neck pain. Man Ther. 2014; 19(2):137-41.
2. Fishbain DA, Cutler RB, Cole B, Lewis J, Smets E, Rosomoff HL, et al. Are Patients with Chronic Low Back Pain or Chronic Neck Pain Fatigued? Pain Med. 2004; 5(2):187-195.
3. Bolton PS. The somatosensory system of the neck and its effects on the central nervous system. J Manipulative Physiol Ther. 1998; 21(8):553-563.
4. Hill JM. Increase in the discharge of muscle spindles during diaphragm fatigue. Brain Res. 2001; 918(1):166-170.
5. Paillard T. Effects of general and local fatigue on postural control: A review. Neurosci Biobehav Rev. 2012; 36(1):162-176.
6. Lamoth CJ, Meijer OG, Wuisman PI, van Dieën JH, Levin MF, Beek PJ. Pelvis-Thorax Coordination in the Transverse Plane During Walking in Persons With Nonspecific Low Back Pain. Spine. 2002; 27(4):E92-E99.
7. Fishbain DA, Cole B, Cutler RB, Lewis J, Rosomoff HL, Fosomoff RS. Is Pain Fatiguing? A Structured Evidence-Based Review. Pain Med. 2003; 4(1):51-62.
8. McGill SM, Marshall L, Andersen J. Low back loads while walking and carrying: comparing the load carried in one hand or in both hands. Ergonomics. 2013; 56(2):293-302.
9. Ramadan MZ, Khalaf TM, Ragab AM, AbdElgawad AA. Influence of Shopping Bags Carrying on Human Responses While Walking.J Healthc Eng. 2018; 27:5340592-.
10. Al-Obaidi SM, Al-Zoabi B, Al-Shuwaie N, Al-Zaabie N, Nelson RM. The influence of pain and pain-related fear and disability beliefs on walking velocity in chronic low back pain. Int J Rehabil Res. 2003; 26(2):101-108.
11. Wannaprom N, Treleaven J, Jull G, Uthaikhup S. Neck muscle vibration produces diverse responses in balance and gait speed between individuals with and without neck pain. Musculoskelet Sci Pract. 2018; 35:25-29.
12. Poole E, Treleaven J, Jull G. The influence of neck pain on balance and gait parameters in community-dwelling elders. Man Ther. 2008; 13(4):317-324.
13. Kimura M, Sato H, Ochi M, Hosoya S, Sadoyama T. Electromyogram and perceived fatigue changes in the trapezius muscle during typewriting and recovery. Eur J Appl Physiol. 2007; 100(1):89-96.
14. Price DD, McGrath PA, Rafii A, Buckingham B. The validation of visual analogue scales as ratio scale measures for chronic and experimental pain. Pain. 1983; 17(1):45-56.
15. Kovacs FM, Abraira V, Royuela A, Corcoll J, Alegre L, et al. Spanish Back Pain Research Network. Minimum detectable and minimal clinically important changes for pain in patients with nonspecific neck pain. BMC Musculoskelet Disord. 2008; 10(9):43.
16. Vernon H, Mior S. The Neck Disability Index: a study of reliability and validity. J Manipulative Physiol Ther. 1999; 14(7):409-15.
17. Aslan E, Karaduman A, Yakut Y, Aras B, Simsek IE, Yagli, N. (2008). The cultural adaptation, reliability and validity of neck disability index in patients with neck pain: a Turkish version study. Spine, 2008; 33(11):E362-E365.
18. Lee MM, Song CH, Lee KJ, Jung SW, Shin DC, Shin SH. Concurrent Validity and Test-retest Reliability of the OPTOGait Photoelectric Cell System for the Assessment of Spatio-temporal Parameters of the Gait of Young Adults. J Phys Ther Sci. 2014; 26(1):81-5.
19. Bisiaux M, Moretto P. The effects of fatigue on plantar pressure distribution in walking. Gait Posture. 2008; 28(4):693-8.
20. Borg GA. Psychophysical bases of perceived exertion. Med Sci Sports Exerc. 1982; 14(5):377-81.
21. Hostens I, Ramon H. Assessment of muscle fatigue in low level monotonous task performance during car driving. J Electromyogr Kinesiol. 2005; 15(3):266-74.
22. Daneshmandi H, Choobineh AR, Ghaem H, Alhamd M, Fakherpour A. The effect of musculoskeletal problems on fatigue and productivity of office personnel: a cross-sectional study. J Prev Med Hyg. 2017; 58(3):E252-E258.
23. Yorkston KM, Johnson K, Boesflug E, Skala J, Amtmann D. Communicating about the experience of pain and fatigue in disability. Qual Life Res. 2010; 19(2):243-51.
24. Falla D, Gizzi L, Parsa H, Dieterich A, Petzke F. People With Chronic Neck Pain Walk With a Stiffer Spine. J Orthop Sports Phys Ther. 2017; 47(4):268-77.
25. Kirmizi M, Simsek IE, Elvan A, Akcali O, Angin S. Investigation of the effects of flat cushioning insole on gait parameters in individuals with chronic neck pain. Acta Bioeng Biomech. 2019; 21(2):135-141.
26. Kirmizi M, Simsek IE, Elvan A, Akcali O, Angin S. Gait speed and gait asymmetry in individuals with chronic idiopathic neck pain. Musculoskelet Sci Pract. 2019; 41:23-27.
27. Bhatt T, Wening JD, Pai YC. Influence of gait speed on stability: recovery from anterior slips and compensatory stepping. Gait Posture. 2005; 21(2):146-56.
28. Espy DD, Yang F, Bhatt T, Pai YC. Independent influence of gait speed and step length on stability and fall risk. Gait & Posture, 2010; 32(3):378-382.
29. Allen JL, Kautz SA, Neptune RR. Step length asymmetry is representative of compensatory mechanisms used in post-stroke hemiparetic walking. Gait & Posture, 2011; 33(4):538-543.
30. Lee D, Sung PS. Comparison of kinematic similarity index during gait between adults with and without nonspecific chronic neck pain. Gait & Posture, 2022; 91:99-104
31. Stanos S, Mogilevsky M, Rader L, McLean J, Baum A. Chapter 73 - Physical Medicine Approaches To Pain Management. In: Smith HS, editor. Current Therapy in Pain. Philadelphia: W.B. Saunders; 2009; 527-40.
32. Bonab M, Colak TK, Toktas ZO, Konya D. Assessment of Spatiotemporal Gait Parameters in Patients with Lumbar Disc Herniation and Patients with Chronic Mechanical Low Back Pain. Turk Neurosurg. 2020; 30(2):277-284.
33. Demirel A, Onan D, Oz M, Ozel Aslıyuce Y, Ulger O. Moderate disability has negative effect on spatiotemporal parameters in patients with chronic low back pain. Gait Posture. 2020; 79:251-255.
34. Elbaz A, Mirovsky Y, Mor A, Enosh S, Debbi E, Segal G, Barzilay Y, Debi R. A novel biomechanical device improves gait pattern in patient with chronic nonspecific low back pain. Spine. 2009; 34(15):E507-12.