

Investigation of the effects of flat cushioning insole on gait parameters in individuals with chronic neck pain

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Purpose: Individuals with chronic neck pain (CNP) walk with a stiffer spine known to cause an increase in dynamic loading on the spine. They also exhibit altered spatiotemporal gait variables, however, it is still unclear whether flat cushioning insole, which reduces dynamic loading on the musculoskeletal system by absorbing the ground reaction force, affects gait parameters in individuals with CNP. The aim of this work was to investigate the effects of flat cushioning insole on neck pain during walking and gait parameters in individuals with CNP. *Methods:* Twenty-one individuals with CNP and 21 asymptomatic controls were included. Assessments of gait parameters and pain were conducted in two sessions, standard shoe only and standard shoe with flat cushioning. In both sessions, all participants performed the 10-meter walk test in two walking conditions: preferred walking, walking at maximum speed. The force sensitive insoles and the video analysis method were used to assess plantar pressure variables and spatiotemporal gait variables, respectively. Pain was assessed using the Visual Analogue Scale. *Results:* Our results indicated that flat cushioning reduced the maximum force and force-time integral in both groups ($p < 0.05$). Flat cushioning increased walking speed and step length in both walking conditions and reduced neck pain during walking at maximum speed in individuals with CNP ($p < 0.05$). In asymptomatic individuals, no difference was found in spatiotemporal gait variables between two sessions ($p > 0.05$). *Conclusions:* These results have suggested that the use of flat cushioning insole may improve neck pain during walking and spatiotemporal gait variables in individuals with CNP.

Key words: chronic neck pain, flat cushioning insole, gait parameters, ground reaction force, dynamic loading, shock absorption

1. Introduction

Neck pain is the second common musculoskeletal disorder after low back pain and affects 70% of the general population at one point through their lifetime. Although it is thought that neck pain has a favourable prognosis, the complaints of one-third of individuals who experience neck pain do not improve and continue to become chronic [8]. Recent studies have shown that individuals with chronic neck pain (CNP) have altered spatiotemporal gait variables. Uthairkhu et al. [21] found that adults with CNP have significantly lower gait speed and step length compared to healthy controls during overground walking with head

rotation and walking at maximum speed. Also, Falla et al. [7] reported that individuals with CNP exhibit lower stride length during treadmill walking at different gait speed (self-selected, 3km/h, 5km/h) with head in neutral, left rotation or right rotation.

The gait cycle begins with the heel strike and contact of the foot with the floor causes the ground reaction force (GRF) between the floor and the plantar surface. The GRF can be measured by force platforms or force sensitive insoles, and these measurements have shown that the amplitude of the GRF varies between 0.5 times and 1.25 times the body weight, depending on factors such as gait parameters, floor, shoe, fatigue, health status [24]. Also, the GRF creates shock waves by dissipating throughout the body [20], [24]. There is

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a high relationship between the amplitude of the GRF and the amplitude of the shock waves in healthy individuals, and factors affecting the amplitude of the GRF also affect the amplitude of the shock waves in the same way [15], [27]. These waves are clearly visible in the calcaneus, knee, hip and forehead regions [10], [15], [25].

The shock waves are absorbed by the natural shock absorbers (bone, cartilage and soft tissue) while they spread from the heels to the head, and therefore the head region, visual system and vestibular system are protected from overload. This damping is primarily the result of the energy absorption by muscle activity, change in joint geometry and deformation in passive tissues, and the changes in these absorbing tissues caused by the shock waves are called dynamic loading [24], [25]. Natural shock absorbers exhibit viscoelastic, time-dependent mechanical behaviour while absorbing the shock waves. This behaviour can lead to inability of the musculoskeletal system to resist sudden and repetitive dynamic loading. For this reason, the factors increasing the amplitude of the shock waves can lead to insufficiency in damping the shock waves dissipating throughout the body [5].

Degenerative changes, pain and increased stiffness cause an increase in dynamic loading by decreasing the shock absorption capacity of the spine [2], [12], [23]. Falla et al. [7] showed that individuals with CNP exhibit less trunk rotation movement during walking, which refers to an increase in stiffness of the spine. We have assumed that altered spatiotemporal gait variables in individuals with CNP could be a consequence of a protection strategy against increased dynamic loading on the spine caused by increased stiffness and pain. Numerous studies have shown that the walking pattern is an important factor affecting the amplitude of the shock waves, and as the walking speed, step length or cadence increase, the amplitude of the shock waves also increases [21], [16].

Although it was known that individuals with CNP have altered spatiotemporal gait variables and walk with a stiffer spine [7], [21], to the best of our knowledge, there is no study investigating the effects of a decrease in the amplitude of the shock waves dissipating throughout the body on neck pain severity during walking and spatiotemporal gait variables. The use of flat cushioning insole has been suggested to decrease the amplitude of the shock waves during gait [11], [4]. Our first aim was to determine the validity and intra-rater reliability of the video analysis method used in this study to assess spatiotemporal gait variables. Also, our second aim was to investigate the effects of flat cushioning insole on neck pain severity

during walking and spatiotemporal gait variables in individuals with CNP, compared to asymptomatic controls. We hypothesized that the use of flat cushioning insole improves neck pain during walking and spatiotemporal gait variables in individuals with CNP.

2. Materials and methods

2.1. Participants

Twenty-one individuals with CNP (15 female, 6 male) and 21 age-matched asymptomatic controls (15 female, 6 male) participated in this study. Inclusion criteria for individuals with CNP were: (1) age between 18 and 55, (2) neck pain persisting longer than 3 months, (3) Neck Disability Index-Turkish version score more than 10/100. Inclusion criteria for control group were: (1) age between 18 and 55, (2) having not experienced neck pain longer than 3 months, (3) currently having no neck pain. Exclusion criteria for both groups were: (1) a history of trauma or surgery in the spine or head regions, (2) neurological deficits resulted from neck disorders, (3) a lack of anatomical integrity of the foot, (4) a history of surgery or trauma in the foot region, (5) other musculoskeletal or neurological problems which may affect gait performance.

Ethical approval taken for this study was obtained from Dokuz Eylul University Institutional Non-invasive Research Ethics Board (No.: 2016/28-28 – Date: 03.11.2016). Informed consent was read and signed by all participants before their participation. This study was conducted in the motion analysis laboratory of the Dokuz Eylul University between January and March 2017.

2.2. Test procedure

Gait parameters (spatiotemporal gait variables, plantar pressure variables) and neck pain were assessed in two sessions, standard shoe only and standard shoe with flat cushioning. In both sessions, 10-meter walk test was performed in two walking conditions: preferred walking (PW) and walking at maximum speed (MAXW). In PW condition, participants were instructed to walk at a speed that feels comfortable from the start line to the finish line. In MAXW condition, participants were instructed to walk from the start line to the finish line at a speed as fast as they

can. Before testing, at least three trials were performed to allow participants to be familiar with the procedure. The orders of sessions and walking conditions were randomized and one-minute rest was given after each test. Each walking test was repeated three times. All participants were provided standard shoes and flat cushioning insoles fitting their shoe-size. Flat EVA insoles which have a 1cm thickness and 20 shore A were used as shock absorbers. In order to exclude any therapeutic and corrective effects other than shock absorption, flat insole without any arch and heel supports was preferred. The shoes with additional depth for insoles which have a 3.5 cm heel for females and 2.5 cm heel for males (Aertex-EW80W for females, Aertex-LT500M for males) were used. Plantar pressure variables were assessed using the force sensitive insoles (Pedar-X, Novel GmbH, Munich-Germany) and spatiotemporal gait variables were assessed using the video analysis method with the use of a slow-motion camera (120 fps). Neck pain severity was assessed using the Visual Analogue Scale at the beginning of both sessions and immediately following the end of the each walking condition in individuals with CNP.

2.3. Neck Disability Index

Neck Disability Index consisting of 10 items related to pain and activities of daily living is the most valid questionnaire to assess disability caused by neck pain. The maximum score which a patient may get from this questionnaire is 100, and the minimum is 0. Higher scores mean to have more disability [1].

2.4. Video Analysis Method

The video analysis method was used to assess spatiotemporal gait variables involving gait speed, step length and cadence. A pilot study was conducted to determine the validity and reliability of the video analysis method. Ten asymptomatic individuals (5 male, 5 female) were included into the pilot study. The slow-motion camera (Galaxy Note 5, Samsung, Seoul – South Korea) which can capture 120 frames per second and the timing photocell gates (Brower TC Timing System, USA) were used. The timing photocell gates have been used in studies as the gold standard assessment of gait speed, and they were used in the pilot study to determine the validity of the video analysis method [14]. Also, all assessments were repeated by the same rater after three days from initial assessment

to determine the intra-rater reliability of the video analysis method. Two walking conditions consisting of preferred walking and walking at maximum speed were performed in the pilot study. The order of walking conditions was randomized, and one-minute rest was given after each test. Each walking test was repeated three times. Spatiotemporal gait variables were assessed using data recorded at middle 10 meters of the 14-meter walkway to give participants distance for acceleration and deceleration. Two photocell gates were placed at start and finish lines of the 10 meters to calculate gait speed. Before test, at least three trials were performed to allow participants to be familiar with the procedure. The time taken to walk 10 meters measured by both the timing photocell gates and the slow motion camera was converted to meters/second (m/s) to calculate gait speed. In order to calculate cadence and step length, the completed steps between start and finish lines of the 10 meters were counted. Cadence was calculated by proportioning the total duration of these steps to one minute. The distance of 10 meters was divided into the number of steps to calculate step length. During the analysis of the recordings, the video speed was reduced to 1/8, allowing for more detailed viewing. To determine the intra-rater reliability of the video analysis method, the intraclass correlation coefficient (ICC) was calculated by analysing the data measured by the same rater in three days apart. The correlation between the time taken to walk the 10 meters measured by the timing photocell gates and by the video analysis method was calculated to determine the validity of the video analysis method.

2.5. Plantar pressure parameters

In-shoe pedobarographic system (Pedar-X, Novel GmbH, Munich-Germany) was used to measure the maximum force (MF) and force-time integral (FTI) during the stance phase of the gait. The system consists of flexible insoles which have 99 force sensors and 1.9 mm thickness. These insoles measure plantar pressure data using a sample rate of 60 Hz. This system was found to be reliable and valid to measure interface force and pressure data between the plantar surface and shoe [9].

2.6. Visual Analog Scale

The severity of neck pain was assessed by the Visual Analogue Scale (VAS). Participants were asked to

mark the severity of their pain on the 100 mm line. The distance from the beginning of the line to the point that the patient has marked indicates the severity of pain. Zero value means no pain, and as the distance from the beginning of the line increases, the severity of pain increases [17].

2.7. Statistical analysis

The sample size was not calculated before the study but was determined based on the similar studies investigating the gait parameters in individuals with CNP [7], [21]. Shapiro–Wilk test was used to determine if data has a normal distribution. Parametric statistical tests were applied because the assumption of normality was met for all data. Paired sample *t*-test was used to determine the effects of flat cushioning insole on gait parameters consisting of plantar pressure variables and spatiotemporal gait variables for two groups and on neck pain for the only individuals with CNP. Independent samples *t*-test was used to compare two groups for spatiotemporal gait variables.

3. Results

The pilot study indicated that the intra-reliability of the video analysis method was found to be good in PW-cadence (ICC = 0.880), and found to be excellent for all other variables (gait speed and step length in PW, and gait speed, step length and cadence in MAXW) (ICC > 0.9) (Table 1). The gait speed data measured by the two devices showed an excellent correlation in both conditions ($\rho > 0.90$ for all) (Table 2). The results of the pilot study have suggested that the video analysis method is valid and reliable to be used by clinicians and researchers to measure spatiotemporal gait variables of the gait as a cheap and practical method that does not require a equipped laboratory.

Table 1. Reliability of the video analysis method

	ICC	%95 Confidence Interval
PW – speed [m/s]	0.906	0.643–0.976
PW – step length [cm]	0.912	0.624–0.978
PW – cadence [step/min]	0.880	0.519–0.970
MAXW – speed [m/s]	0.991	0.957–0.991
MAXW – step length [cm]	0.988	0.929–0.997
MAXW – cadence [step/min]	0.962	0.846–0.991

ICC – Intraclass Correlation Coefficient, PW – Preferred walking, MAXW – Walking at maximum speed.

No statistical difference was found between groups regarding the demographic characteristics ($p > 0.05$) (Table 3).

Table 2. Correlation between gait speed data measured by timing photocell gates and video analysis method

	ρ'	ρ''
PW – speed [m/s]	0.991	0.997
MAXW – speed [m/s]	0.974	1

ρ' – Spearman correlation coefficient, ρ'' – Spearman correlation coefficient calculated following 72 hours, PW – Preferred walking, MAXW – Walking at maximum speed.

Table 3. Demographic characteristics of groups

	Neck pain (<i>n</i> = 21) Mean (SD)	Controls (<i>n</i> = 21) Mean (SD)	<i>p</i>
Age [years]	35.67 (12.64)	35.33 (12.51)	0.932
Weight [kg]	69.05 (13.30)	65.11 (12.15)	0.3
Height [cm]	168.81 (7.60)	166.43 (7.08)	0.323
BMI [kg/m ²]	24.32 (4.11)	23.47 (3.9)	0.497
Sex (female) [%]	71.43	71.43	–
NDI [%]	23.33 (5.77)	–	–

Independent Samples *t*-test, BMI – Body Mass Index, NDI – Neck Disability Index.

3.1. Comparison of two sessions for both groups

Our findings indicated that the use of flat cushioning insole results in a decrease in the MF and FTI in both groups ($p < 0.05$) (Table 5). In individuals with CNP, the neck pain severity during MAXW was reduced with flat cushioning insole ($p < 0.001$), however, there was no difference in neck pain severity during PW between both sessions ($p > 0.05$) (Table 4). In individuals with CNP, it was shown that the use

Table 4. Pain severity of neck pain group in both sessions

	Neck pain (<i>n</i> = 21) Mean (SD)		
	shoe	flat cushioning	<i>p</i>
BS [mm]	22.9 (1.46)	21.2 (1.45)	0.221
PW [mm]	23.1 (1.62)	19.6 (1.41)	0.066
MAXW [mm]	34.5 (1.84)	23.8 (1.94)	<0.001*

Paired sample *t*-test, * – $p < 0.05$, BS – Beginning of session, PW – Preferred walking, MAXW – Walking at maximum speed.

Table 5. Gait parameters of both groups in PW and MAXW conditions

	Neck pain (n = 21) Mean SD						Controls (n = 21) Mean SD						p^3		p^4	
	shoe		flat cushioning		p^1		shoe		flat cushioning		p^2					
	PW	MAXW	PW	MAXW	PW	MAXW	PW	MAXW	PW	MAXW	PW	MAXW	PW	MAXW	PW	MAXW
MF [N/BW]	11.55 (1.72)	13.16 (2.13)	10.91 (1.8)	12.37 (1.96)	0.040*	0.041*	13.07 (2.02)	14.18 (1.11)	12.10 (1.30)	13.38 (1.52)	0.004*	0.004*	–	–	–	–
FTI [N/BW*s]	5.35 (0.79)	4.53 (0.8)	5.05 (0.86)	4.21 (0.68)	0.028*	0.01*	5.29 (0.73)	4.37 (0.54)	5.05 (0.64)	4.09 (0.54)	0.012*	0.008*	–	–	–	–
Speed [m/s]	1.30 (0.18)	1.89 (0.23)	1.35 (0.19)	1.96 (0.26)	0.013*	0.004*	1.45 (0.2)	2.11 (0.23)	1.47 (0.17)	2.12 (0.26)	0.248	0.711	0.012*	0.003*	0.034*	0.051
Step length [cm]	69.17 (8.84)	81.67 (9.7)	71.34 (8.54)	83.57 (9.92)	<0.001*	<0.001*	73.28 (5.84)	86.33 (6.66)	74.02 (5.73)	86.74 (7.67)	0.102	0.368	0.084	0.078	0.239	0.253
Cadence [steps/min]	112.52 (96.82)	139.13 (12.2)	111.33 (10.31)	139.80 (12.65)	0.549	0.580	118.26 (8.91)	147.96 (11.83)	118.35 (7.48)	146.84 (12.97)	0.918	0.305	0.024*	0.022*	0.016*	0.083

p^1 – Paired sample *t*-test for neck pain group, p^2 – Paired sample *t*-test for control group, p^3 – Independent samples *t*-test for comparison both groups in shoe only session, p^4 – Independent samples *t*-test for comparison both groups in flat cushioning session; * – $p < 0.05$, PW – Preferred walking, MAXW – Walking at maximum speed, MF – Maximum force, FTI – Force time integral.

of flat cushioning insole increases gait speed and step length in both walking conditions ($p < 0.05$). In asymptomatic individuals, no difference was found in spatiotemporal gait variables between two sessions ($p > 0.05$) (Table 5).

3.2. Comparison of two groups

In the shoe only session, individuals with CNP showed lower gait speed and cadence in both walking conditions, compared to asymptomatic controls ($p < 0.05$). When comparing two groups in the flat cushioning session, individuals with CNP exhibited lower gait speed and cadence in PW condition ($p < 0.05$), but no statistical difference was found between groups in MAXW condition ($p > 0.05$) (Table 5).

4. Discussion

Our results showed that the use of flat cushioning insole reduces the MF and FTI amplitudes in both groups. Also, the use of flat cushioning insole reduced neck pain severity during MAXW and increased gait speed and step length in PW and MAXW conditions in individuals with CNP. However, the use of flat cushioning insole had no effect on spatiotemporal gait variables in asymptomatic individuals.

In the study, we used the flat cushioning insole in an attempt to decrease dynamic loading on the spine.

We measured the GRF using the force sensitive insoles to determine whether there is a decrease in dynamic loading caused by the shock waves. Studies have suggested that there is a high correlation between the amplitude of the GRF and the amplitude of the shock waves dissipating throughout the body during walking and a decrease in the amplitude of the GRF means to a decrease in the amplitude of the shock waves [10], [15]. It was recommended that the use of flat insole with Shore A 20 provides a reduction in the amplitude of the GRF and the amplitude of the shock waves propagating through the lower extremity [11], [4]. Further, Folman et al. [6] showed that use of viscoelastic heel insoles reduced the amplitude of the GRF and the amplitude of the shock waves recorded from the forehead. This have shown that the use of shock absorbing insole reduces dynamic loading on the spine during walking. The aforementioned studies are consistent with our results suggesting that the use of flat cushioning insole with Shore A 20 reduces the MF and FTI amplitudes.

There are several studies investigating the effects of the use of shock absorbing insole on the spinal pain. Jefferson et al. [13] showed that use of the flat cushioning insole for four consecutive 12-hour shifts significantly improves the spinal and lower extremity pain in workers with back and lower extremity pain. Shabat et al. [19] compared the effect of placebo and shock absorbing insole on low back pain among sixty workers whose job involves long-distance walking in five-week crossover trials. The results of the study showed that the use of shock absorbing insole signifi-

cantly reduces the severity of low back pain compared to placebo. To the best of our knowledge, there is no study investigating the effects of the use of shock absorbing insole on neck pain, and this may be explained by the fact the neck is not subjected to dynamic loading as much as the lower back during walking [20]. However, our results showed that the use of flat cushioning insole reduces the severity of neck pain during MAXW. Falla et al. [7] found that individuals with CNP exhibit less trunk rotation movement during walking, which refers to an increase in stiffness of trunk. The spinal pain and increased spinal stiffness decrease the shock absorption capacity and cause an increase in dynamic loading on the spine [2], [12], [23]. Therefore, the neck pain and increased trunk stiffness may cause an increase in dynamic loading on the spine in individuals with CNP. The reduction in neck pain, which was found in our study, may be caused by the use of flat cushioning insole compensates for increased dynamic loading by absorbing the GRF.

Recent studies have suggested that individuals with CNP have altered spatiotemporal gait variables. Uthakhup et al. [21] reported that adults with CNP have lower gait speed and step length, compared to no-pain controls during overground walking with head rotation and walking at maximum speed. Further, Falla et al. [7] reported that individuals with CNP exhibit lower stride length during treadmill walking at different gait speed (self-selected, 3km/h, 5km/h) with head in neutral, left rotation or right rotation. As the gait speed, step length or cadence increase, the amplitude of the GRF and the amplitude of the shock wave dissipating throughout the musculoskeletal system increase [24], [16]. Individuals with CNP may exhibit altered spatiotemporal gait variables to compensate for reduced shock absorption capacity. Our results indicated that the use of flat cushioning insole improves gait speed and step length in both walking conditions, therefore we have suggested that the use of flat cushioning insole improves spatiotemporal gait variables by decreasing dynamic loading on the spine.

Individuals with CNP exhibited lower gait speed and cadence, compared to asymptomatic controls in both walking conditions for shoe only session. For flat cushioning session, individuals with CNP still exhibited lower gait speed and cadence during PW, however, there was no difference in spatiotemporal gait variables during MAXW between groups. These results indicated that the use of flat cushioning insole reduces the differences between groups in spatiotemporal gait variables during MAXW, the most probably because the use of flat cushioning insole has signifi-

cantly decreased neck pain severity during MAXW. Also, as higher amplitude of the shock wave affects the spine in MAXW condition compared to PW condition due to higher gait speed [24], [16], effects of flat cushioning insole could be more evident in MAXW condition.

Earlier studies have suggested that the use of shock absorbing insole, which is softer, more elastic and thicker, may affect balance ability negatively by decreasing the plantar sensory input [3]. This hypothesis has not been supported by the studies investigating the effects of shock absorbing insole on balance [22]. The results of our study did not indicate any adverse effects of flat cushioning insole on spatiotemporal gait variables in both groups, which may also indicate that the gait performance of adults was not adversely affected by insole which has a 1 cm thickness and 20 shore A.

4.1. Limitations

There are several limitations in our study. First, the effects of flat cushioning insole on neck pain and spatiotemporal gait variables were measured only during 10-meter walk test, this distance may be insufficient to show the effects during long distance walking. The second limitation is that pain severity was assessed using the Visual Analogue Scale that represents only one dimension of pain (intensity). Thirdly, participants were not blinded to the testing conditions (standard shoe with and without flat cushioning insole), and this may cause potential sources of bias. Further, the spatiotemporal gait variables that were measured in this study are limited. There is a need for future research which investigates the effect of cushioning insole on pain and gait parameters during longer distance walking by using gait analysis equipment providing more detailed data.

5. Conclusions

The results of this study showed that the use of flat cushioning insole improves neck pain during walking and spatiotemporal gait variables in individuals with CNP. These results have suggested that individuals with CNP exhibit altered spatiotemporal gait variables in an attempt to decrease dynamic loading on the spine during walking. Therefore, the use of flat cushioning insole may have beneficial effects on gait parameters in individuals with CNP who are found to

have negative alterations in their spatiotemporal gait variables.

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