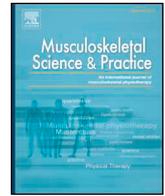




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Original article

Gait speed and gait asymmetry in individuals with chronic idiopathic neck pain

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ABSTRACT

Background: Recent studies have shown that individuals with chronic idiopathic neck pain (CINP) exhibit altered spatiotemporal gait parameters. Problems arising from the neck joints and related soft tissues, and most mechanical neck pain appear asymmetric. However, whether individuals with CINP have an asymmetric gait has not been clarified.

Objectives: The aim was to investigate if there was a significant difference in gait speed (GS) and gait asymmetry (GA) between individuals with CINP and healthy controls.

Design: Case-Control Study.

Method: Twenty individuals with CINP and 20 healthy controls were included. All participants performed the 10-m walking test in three walking conditions: preferred walking (PW), preferred walking with head rotation and walking at maximum speed (MAXW). The timing gate system and pressure sensitive insoles were used to calculate GS and GA, respectively. GA was calculated using the difference between right and left swing durations.

Results/findings: Individuals with CINP had slower GS in all walking conditions compared to controls ($p < 0.05$). In PW and MAXW conditions, gait was found to be asymmetric in individuals with CINP compared to controls ($p < 0.05$). There was no difference in GA between the walking conditions in either group ($p > 0.05$).

Conclusions: Individuals with CINP had a slower and more asymmetrical gait. GA should be evaluated as a part of the routine gait analysis since it has potential to cause asymmetric loading on joints which could cause other musculoskeletal problems in the long-term. Also, future research is needed to clarify the reasons why gait is more asymmetric in individuals with CINP.

1. Introduction

Neck pain is the second most common musculoskeletal problem after back pain and affects 70% of the general population (Goode et al., 2010). In the relevant literature, chronic idiopathic neck pain (CINP) is considered as one of the major musculoskeletal problems which may lead to varying functional impairments including altered gait (Hoy et al., 2010; Poole et al., 2008; Uthakup et al., 2014). Overall, gait speed is considered an important indicator of functional status and physical well-being, and it is frequently addressed by researchers and clinicians in health research and clinical practice (Graham et al., 2008; Middleton et al., 2015). It was reported that older individuals with CINP had lower gait speed and cadence during walking with head rotation and longer gait cycle durations in both with and without head

rotation conditions (Poole et al., 2008). Lower gait speed and step length were also found in walking with head rotation and walking at maximum speed in adults with CINP (Uthakup et al., 2014).

Gait involves the cyclic movements of the lower extremities, and these movements are considered to be naturally symmetrical (Sadeghi et al., 2000). Different aspects of gait including its spatiotemporal characteristics, kinematic data obtained from lower extremity joints, ground reaction forces and muscle activities recorded by EMG were previously investigated in an attempt to demonstrate whether lower extremities show symmetric movement during gait in different conditions (Sadeghi et al., 2000; Ramakrishnan et al., 2018). Gait symmetry which focuses on the bilateral coordination of swing durations has been shown to be one of the major determinants of gait performance (Plotnik et al., 2013; Hoogkamer, 2017). Further, asymmetrical temporal

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characteristics are often interpreted as pathological since it causes asymmetric forces in the joints which are considered to be detrimental in the long-term (Ramakrishnan et al., 2018; Carpes et al., 2010).

As far as to our knowledge, there is no study investigating the gait symmetry in individuals with CINP. Individuals with CINP may show normal gait pattern as it is expected from persons whose limbs have equal capabilities (Seeley et al., 2008). However, asymmetric hip mobility was found to be more frequent in young adults with CINP than those without pain (Lee et al., 2013). Further, it could be suggested that individuals with CINP may demonstrate an asymmetrical gait pattern due to alteration of the cervical afferent inputs. Afferent inputs from the receptors in the muscles and joints of the cervical spine, which are linked to vestibular, visual and postural control systems through central and reflex connections, have important effects on postural control, orientation and perception of body schema (Pettorossi and Schieppati, 2014; Silva and Cruz, 2013; Zoete et al., 2017). Problems arising mainly from the neck joints and related soft tissues, and most mechanical neck pain appear asymmetric (Tsang, 2001). Further, a recent study has suggested that patients with chronic neck pain also have a distorted body schema due to neck pain (Moreira et al., 2017). These could be evidence of asymmetrical gait pattern in individuals with CINP.

Therefore, the aim of the study was to investigate if there was a significant difference in gait speed and gait asymmetry between individuals with CINP and healthy no-pain controls. We hypothesized that gait symmetry and gait speed variables are altered in individuals with CINP. The secondary aim was to investigate the relationship between gait speed and gait asymmetry. We hypothesized that there will be no relationship between GA and GS in both groups.

2. Materials and methods

2.1. Study design: case-control study

This study was conducted in the motion analysis laboratory of the X University between May and August 2017 following ethical approval. Ethical approval was obtained from the X University Institutional Non-invasive Research Ethics Board (No: 2017/08-26, Date: 13.04.2016), and all procedures were conducted according to the Declaration of Helsinki. The signed informed consents were obtained from all participants prior to the study.

2.2. Participants

A total of 20 individuals with CINP (12 female and 8 male) and 20 age-matched volunteers without neck pain (12 female, 8 male) were included in the study. This sample size has been determined based on the similar studies investigating different gait activities in individuals with chronic neck pain (Poole et al., 2008; Uthakshup et al., 2014). Inclusion criteria for individuals with CINP were being between 18 and 55 years of age, having neck pain persisting longer than three months, and a score higher than 10/100 obtained from Neck Disability Index (NDI). Inclusion criteria for control group were being between the ages of 18 and 55, having not experienced neck pain longer than 3 months, having no neck pain currently. Exclusion criteria for both groups were previous history of neck trauma, the presence of neurological deficits originating from neck disorders, other musculoskeletal problems that may affect walking performance, and other diagnosed conditions such as inner ear pathology, stroke, history of head injury, diabetes, neurological, circulatory and/or vestibular pathologies that may affect balance.

2.3. Neck Disability Index

The Turkish version of the Neck Disability Index (NDI) was used to evaluate the effects of neck pain on functional disability through the patient's self-report (Aslan et al., 2008). The maximum and the

minimum scores that can be obtained from NDI is 100 and 0, which indicates maximum functional disability and no disability, respectively.

2.4. Gait speed

Timing gate system (TC Brower Timing System, USA) measures walking and running speed with high accuracy by sending 1 kHz radio signals to the counter up to 1000 feet (Dennis et al., 2016). Two wireless timing gates were placed at the beginning and end of the 10-m distance in the middle of a 16-m walkway. When a person passes through the first gate, counter automatically starts to count. When the person passes through the second gate, the counter automatically stops, and the measured time is registered to the device's memory. The walking speed (m/sec) was calculated by dividing the distance (10-m) to the measured time.

2.5. Gait asymmetry

The right and the left swing phase durations over the 10-m distance in the middle of a 16-m walkway were measured using a pedobarographic device (PEDAR - Novel GmbH, Munich, Germany) for the calculation of gait asymmetry. The duration which was shorter in average was called the short swing duration (SSWD), and the duration which was longer in average was called the long swing duration (LSWD). The average of the left and right swing durations was calculated separately (Yogev et al., 2007). To calculate the gait asymmetry, the absolute value of the natural logarithm of the number obtained by dividing the short swing duration to the long swing duration was multiplied by 100.

Gait Asymmetry = $100 \times |\ln(\text{SSWD}/\text{LSWD})|$. A value of zero indicates perfect symmetry, while an increase in this value indicates the degree of gait asymmetry (Plotnik et al., 2013; Yogev et al., 2007).

2.6. Test procedure

Participants with neck pain completed the Turkish version of Neck Disability Index. All participants performed the 10-m walking test in three walking conditions: walking at preferred speed (PW), walking at preferred speed with head rotation (PWHR), walking at maximum speed (MAXW). The average of the three trials for each condition was considered for statistical analysis. One-minute rest was given between each trial. The order of walking conditions was randomized using a computer-generated random number list (MS excel 2016). Five walking trials were performed for demonstrating each walking condition before the actual tests. The investigator (MK) instructed the participant verbally "Please walk from the first line to the second line with a speed that you feel comfortable at" for PW, "Please walk from the first line to the second line with a speed that you feel comfortable at while turning your head continuously from one side to the other" for PWHR, and "Please walk as fast as you can from the first line to the second" for MAXW. Each participant was provided with a pair of size-matched standard shoes during the tests.

2.7. Statistical analysis

All participants completed the test procedure successfully and the total of 40 participants was included in statistical analysis. There were no missing data. Shapiro-Wilk test was used to analyse if the obtained data distributed normally. Gait speed data were normally distributed while gait asymmetry data did not show normal distribution. Independent Samples *t*-test was used to determine whether there was a significant difference between two groups in terms of gait speed, while Mann Whitney *U* test used to assess for the differences in gait asymmetry. Repeated-measures of ANOVA with Bonferroni correction was used separately for two groups to determine whether there were significant differences in gait speed between walking conditions, and

Table 1
Demographic characteristics of participants.

	Neck pain (n = 20)	Controls (n = 20)	p ^a
	Mean (SD)	Mean (SD)	
Age, year	35.85 (11.49)	35.35 (12.37)	0.895
Weight, kg	70.5 (12.28)	64.53 (12.27)	0.132
Height, cm	169.95 (7.79)	168.85 (6.94)	0.640
BMI, kg/m ²	24.40 (3.87)	22.53 (3.35)	0.466
Gender, (female),%	60	60	
NDI, %	24.65 (6.84)	–	

^a Independent Samples *t*-test, SD: Standard Deviation, BMI: Body Mass Index, NDI: Neck Disability Index, TSK: Tampa Scale of Kinesiophobia.

Friedman test was used separately for two groups to analyse the differences in gait asymmetry between walking conditions. Also, spearman correlation coefficients were calculated separately for the two groups for each test to determine whether there was a relationship between gait asymmetry and gait speed.

3. Results

Demographic characteristics including age, body weight, height, body mass index (BMI) and gender are presented in Table 1. There were no significant differences in terms of demographic characteristics between the groups ($p > 0.05$).

Gait speed data is presented in Table 2 with mean and standard deviation values and gait asymmetry data in Table 3 with median and quartiles in addition to the mean and standard deviation values.

CINP group had slower gait speed in all walking conditions compared to those of controls ($p < 0.05$ for PW, $p < 0.01$ for PWHR and MAXW) (Table 2). In PW and MAXW, gait was found to be significantly asymmetric in CINP group compared to those of control group ($p < 0.05$ for PW, $p < 0.01$ for MAXW) (Table 3).

Gait speed was found to be significantly higher during walking at maximum speed compared to other two conditions in both groups ($p < 0.001$). There were no significant differences in gait speed between PW and PWHR in the control group ($p > 0.05$). However, in the CINP group, gait speed was significantly slower during PWHR compared to PW ($p = 0.002$). There were no statistically significant differences between walking conditions in the aspect of gait asymmetry in both groups ($p > 0.05$).

There was no significant correlation between gait speed and gait asymmetry in both groups ($p > 0.05$) (Table 4).

4. Discussion

The aim was to investigate if there was a significant difference in gait speed and gait asymmetry between individuals with CINP and healthy no-pain controls. We hypothesized that gait speed and gait symmetry are altered in individuals with CINP. Our results showed that

Table 2
Group comparison of the gait speed in three walking conditions.

	Neck pain	Controls	p ^a
	Mean (SD)	Mean (SD)	
PW (m/s)	1.30 (0.14)	1.45 (0.21)	0.014*
PWHR (m/s)	1.15 (0.22)	1.41 (0.23)	< 0.001**
MAXW (m/s)	1.91 (0.24)	2.16 (0.23)	0.002**

* $p < 0.05$.

** $p < 0.01$.

SD: Standard Deviation, PW: Preferred walking, PWHR: Preferred walking with head rotation, MAXW: Walking at maximum speed.

^a Independent Samples *t*-test.

individuals with CINP presented a slower gait speed in all walking conditions and an asymmetrical gait pattern in PW and MAXW conditions compared to those of control group.

Gait speed was significantly slower in CINP group in all walking conditions, which confirms Uthaikhup et al. who concluded that adults with CINP had slower gait speed during walking with head rotation and walking at maximum speed compared to healthy adults (Uthaikhup et al., 2014). Several studies reported that individuals with sensory disorders tend to walk slower to increase stability during gait (Dingwell et al., 2000; England and Granata, 2007). However, local dynamic stability is expected to alter in relation to walking speed in different planes: During slow walking, stability was found to increase in antero-posterior and vertical directions. In contrast, fast walking was more stable in medio-lateral direction than slow walking (Bruijn et al., 2009). Field et al. showed that individuals with neck pain had greater balance deficits in antero-posterior direction than medio-lateral direction (Field et al., 2008). Individuals with neck pain probably compensate for their decreased anteroposterior stability by lowering the gait speed, which has also been suggested by Uthaikhup and Poole (Poole et al., 2008; Uthaikhup et al., 2014).

This is the first study to investigate the GA in individuals with CINP under different walking conditions. Plotnik et al. reported that GA did not differ significantly between self-selected usual, slow and fast walking in healthy individuals (Plotnik et al., 2013). In our study, the similar result that gait asymmetry did not differ between different walking conditions was found in both groups. However, gait was found to be asymmetric in neck pain group in PW and MAXW conditions compared to controls. We have assumed that this asymmetric gait in individuals with CINP may partially originate from the alteration of the cervical afferent inputs. Neck pain is often unilateral or worse on one side compared to the other (Tsang, 2001), which may provide asymmetric afferent input from the receptors in the soft tissues that have important effects on postural control, orientation and perception of body schema (Pettorossi and Schieppati, 2014; Silva and Cruz, 2013; Zoete et al., 2017). A recent study has suggested that individuals with chronic neck pain have a distorted body schema due to neck pain (Moreira et al., 2017). Further, Uthaikhup et al. suggested that neck pain causes altered sensory modulation from the neck to the central nervous system, and this altered modulation is possibly responsible for the poor sensorimotor performance (Uthaikhup et al., 2012). During walking, the sensory feedback from the lower extremities contributes to the neural loops between central pattern generators residing on the spinal cord (Plotnik et al., 2013). Since asymmetric hip mobility was reported to be more frequent in young adults with CINP than those without pain (Lee et al., 2013), similar underlying mechanism may also be relevant for asymmetrical gait pattern. Modulation of the sensory feedback due to distorted body schema caused by neck pain could therefore result in an asymmetrical gait pattern in individuals with CINP by creating an altered motor response on both lower extremities. We also found no relationship between gait speed and gait asymmetry in both groups, which suggests that the causes of GA should be further investigated.

There was no statistically significant difference in GA between groups in PWHR condition although individuals with CINP had a statistically more asymmetric gait pattern in PW and MAXW conditions. This could be related to the reduction in neck pain perception due to altered focus and level of attention that is diverted to follow up with the additional motor task (head rotation). A distraction of attention away from pain reduces pain perception (Bantick et al., 2002), and a concurrent task attenuates perceived pain intensity (Veldhuijzen et al., 2006; Vuong et al., 2018).

This study showed that gait was more asymmetric in individuals with CINP, but it did not provide any evidence regarding causes of asymmetric gait in this population. Gait asymmetry is regarded as an important clinical issue that should be evaluated as a part of the routine gait analysis since it causes asymmetric loading on joints which leads to

Table 3
Group comparison for the gait asymmetry in three walking conditions.

	Neck pain		Controls		p ^a
	Median (Q1/Q3)	Mean (SD)	Median (Q1/Q3)	Mean (SD)	
PW	2.28 (1.34/4.02)	3 (2.55)	1.31 (0.59/2.09)	1.70 (1.64)	0.035*
PWHR	2.29 (1.1/3.8)	2.76 (2.7)	1.84 (1.21/2.58)	2.03 (1.4)	0.547
MAXW	3.13 (1.46/4.5)	3.32 (2.17)	0.88 (0.23/1.86)	1.4 (1.6)	0.004**

*: $p < 0.05$.

** : $p < 0.01$.

SD: Standard Deviation, Q: Percentiles, PW: Preferred walking, PWHR: Preferred walking with head rotation, MAXW: Walking at maximum speed.

^a Mann Whitney *U* test.

Table 4
Correlation coefficients between gait speed and gait asymmetry.

Neck pain			Controls		
PW	PWHR	MAXW	PW	PWHR	MAXW
0.125	-0.256	0.065	-0.202	-0.299	0.150

PW: Preferred walking, PWHR: Preferred walking with head rotation, MAXW: Walking at maximum speed.

other musculoskeletal problems in the long-term (Ramakrishnan et al., 2018; Carpes et al., 2010). Therefore, future research is needed to clarify the reasons why gait is more asymmetric in individuals with CINP.

5. Limitations

There are several limitations need to be addressed. The main limitation of this study is that individuals with CINP have not been assessed whether neck pain location, neck kinematics or proprioceptive senses were asymmetric. The second limitation is that only duration of the swing phase was analysed for investigating the presence of gait asymmetry, kinematic and kinetic gait variables would have also been investigated. Thirdly, we have not measured the range of head rotation during PWHR condition due to technical reasons. Further, a recent study has suggested that performing a cognitive task during walking significantly altered gait parameters compared to motor dual-task (Mofateh et al., 2017). In our study, only motor tasks were administered during walking, however, the effects of cognitive tasks on gait speed and gait symmetry remain unknown in individuals with CINP.

6. Conclusions

Our results suggested that individuals with CINP have a slower and more asymmetric gait pattern compared to those without pain. This result has suggested that pain localized to the neck region may have an impact on gait performance. Also, since asymmetrical gait patterns may have long-term detrimental effects on musculoskeletal health, addressing the assessment of selected gait variables in individuals with chronic neck pain may be a useful component of general practice.

Declarations of interest

None.

Ethical approval

Ethical approval was obtained from the Dokuz Eylul University Institutional Non-invasive Research Ethics Board (No: 2017/08-26, Date: 13.04.2017), and all procedures were conducted according to the Declaration of Helsinki. The signed informed consents were obtained from all participants prior to the study.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.msksp.2019.03.001>.

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