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Walking Performance during Concurrent Cognitive and Motor Tasks in Individuals with Nonspecific Chronic Low Back Pain: A Case-Control Study

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Abstract

Background: The present study aimed to compare the effects of simultaneous cognitive and motor tasks on walking performance between individuals with nonspecific chronic low back pain (NSCLBP) and healthy controls.

Methods: A total of 20 patients with NSCLBP and 20 healthy controls participated in this study. They walked at their self-selected speed on a treadmill under 3 walking conditions in a randomized order: walking only, walking while performing a concurrent cognitive task, and walking while performing a concurrent motor task. Two-way repeated measure analysis of variance with additional post hoc comparison (Bonferroni test) was used to evaluate the effects of group and walking conditions on gait parameters.

Results: The result showed a significant main effect of the group for swing time ($P = 0.012$) and double support time ($P = 0.021$) in those with NSCLBP compared with healthy controls. Moreover, there was a significant interaction between the group and condition for cadence ($P = 0.004$) and step width variability ($P = 0.016$). Regarding stride length variability and stride time variability, the analysis indicated a significant effect of condition ($P = 0.002$ and $P = 0.030$, respectively). In both groups, no significant differences were observed in gait parameters between motor dual task and single walking ($P > 0.05$).

Conclusion: Our findings indicated that those with NSCLBP adapted successfully to walking performance to maintain the performance of the concurrent cognitive task under the cognitive dual-task walking condition. Moreover, the present study observed no dual-task interference under the motor dual-task condition.

Keywords: Nonspecific Chronic Low Back Pain, Walking, Cognitive Dual-Task, Motor Dual-Task

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Introduction

Chronic low back pain (CLBP) is identified as a prevalent musculoskeletal disorder. Approximately 70% to 85% of people experience CLBP at least once in their lifetime (1, 2). Also, about 85% of individuals with LBP are categorized as nonspecific CLBP (NSCLBP) with no known etiology (3). CLBP is usually associated with functional and psychological deficits (4). A recent study reported decreased walking tolerance as the most common impairment among 60 types of tasks impaired in those with CLBP during daily activities (5). Since walking is one of the human main functions, the effect of CLBP on gait performance has been explored in several studies (6). Gait analysis has

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↑***What is "already known" in this topic:***
This study aimed to compare the effects of simultaneous cognitive and motor tasks on walking performance between individuals with chronic nonspecific low back pain (NSCLBP) and healthy controls.

→***What this article adds:***
Walking performance in both groups was affected by cognitive loading. However, the motor dual-task had no effects on gait parameters. Future studies should investigate more difficult secondary motor tasks to obtain further information regarding gait changes under motor dual-task in those with NSCLBP.

demonstrated a decrease in walking speed, step length, and swing time in those with NSCLBP (7). Considering the complexity of the mechanisms that cause CLBP and the existence of a wide range of contributing factors for movement disorders in these patients, the effect of CLBP on walking performance is still not well understood and needs to be studied further (8).

Various studies revealed the critical role of cognition in the regulation of gait (9, 10). In daily activities, people frequently need to perform an additional cognitive task while walking (11). Investigating the effect of a secondary task (cognitive or motor) on gait control (ie, dual performance) is one of the common methods to study the role of attentional factors in healthy and abnormal gait control (11). Dual tasking can result in declining performance in one or both tasks termed as dual-task interference (12). In individuals with NSCLBP, researchers reported deficits in some domains of cognitive function, particularly attention, working memory, and executive function (9). Leveille et al (2009) indicated a negative relationship between chronic pain and executive function. Importantly, these authors suggested that this deficit can affect functional ability (13). Taken together, in individuals with NSCLBP, cognitive and walking performance deficits may influence walking ability under dual-task walking. However, dual-tasking's effects on walking performance remain unclear in this group. Lamoth et al (2008) observed that gait variability reduced under cognitive dual-task walking conditions in individuals with CLBP (10). However, Hamacher et al (2016) reported greater gait variability during cognitive dual-task walking in individuals with CLBP compared with healthy controls. The authors suggested that these changes may increase fall risk (14).

One of the important factors that can affect dual-task performance is the type of secondary task (cognitive or motor) (15). Since the ability to perform a concurrent motor task while walking (eg, carrying an object while walking) is an essential component in many daily activities, it is important to study the effect of a concurrent motor task on walking performance. Similar to cognitive dual-task walking, previous studies demonstrated impaired walking performance under motor dual tasks in people with musculoskeletal and neurological disorders and older adults (15-17). However, to our knowledge, the effects of motor tasks on walking performance have not yet been investigated in those with NSCLBP. Moreover, no previous studies have reported the comparative effects of motor versus cognitive dual-task on walking performance in individuals with NSCLBP. Investigating the effects of the type of secondary task on dual-task performance may be helpful for clinicians to identify patients vulnerable to dual-task interference and plan a useful rehabilitative intervention to improve functional performance. Therefore, this study aimed to compare walking performance under motor and cognitive dual-task walking conditions between those with NSCLBP and healthy controls. We hypothesized that cognitive and motor dual tasks would affect walking performance differently in both NSCLBP and healthy control groups.

Methods

Participants

In this case-control study, 20 individuals with NSCLBP and 20 healthy controls were recruited. The sample size was calculated using G power software based on stride length variable with $F = 0.02$, 85% power, and $\alpha = 0.05$ equal to 36 people for 2 groups. Assuming a 10% dropout rate, 40 people are necessary to perform the study. Participants were grouped and matched based on sex, age, body mass index, and years of education. They were recruited by convenience sampling. The NSCLBP group (10 men, 10 women) was chosen among individuals referred by an orthopedic physician with NSCLBP diagnoses to physiotherapy clinics in Ahvaz, Iran. The inclusion criteria for the NSCLBP group were as follows: age 18 to 45 years, having LBP with unknown cause for at least 12 weeks, (18). Based on the Numerical Rating Scale (NRS), the average pain level was between 4 and 6 points in the last week (19), and disability level based on the Persian version of Oswestry Disability Index (ODI) (20) was ranged from 21% to 40% (minimal to moderate disability). The exclusion criteria for individuals with NSCLBP were as follows: spondylolisthesis, pregnancy, radicular pain to the lower limbs, any spinal or lower limbs' deformity, tumor or infection, history of fracture in lower limbs, any sensory or neurologic/orthopedic disorders, rheumatoid disease, diabetes, hearing impairment, cognitive deficit and using any medicine that could affect their gait.

A total of 20 healthy controls (10 men, 10 women) without any neurologic, orthopedic disorder, hearing and cognitive impairment participated in this study. They were enrolled as staff and volunteer students of Ahvaz Jundishapur University of Medical Science (AJUMS). An experienced physiotherapist carefully evaluated the participants for inclusion and exclusion criteria. Data collection was performed from March 2022 to October 2022 in the gait analysis laboratory at the Musculoskeletal Research Center of the Rehabilitation Science Faculty of AJUMS. The local Ethics Committee approved the study's procedure (IR.AJUMS.REC.1400.006). All participants signed an informed consent document to participate in the study.

Experimental Protocols

A 7-camera motion analysis system (Qualisys Inc) was used to examine gait performance during walking on a treadmill (Biometrix, length = 1.5 m, width = 0.5). Treadmill handrails were separated. Two infrared retroreflective markers mounted on the first metatarsal and the heel of both feet. The sampling frequency rate was at 100 Hz.

At the beginning of the gait assessment, the speed of the treadmill was set at 0.8 Km/h speed. The speed was then increased to 0.1 Km/h for 15 seconds until their self-selected walking speed was reported. When the participants first reported the self-selected speed to the experimenter, the treadmill speed was again increased and decreased at 0.1 km/h intervals until the participants confirmed the self-selected speed again. After several training trials, each participant was assessed during 3 walking tasks:

1. Single-task walking: The participants walked on the treadmill at their self-selected speed

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2. Cognitive dual-task walking: The participants performed an auditory Stroop task while walking at their self-selected speed. In this task, the participants listened to an audio recording that played 2 words (high and low) in both compatible (the word high with the high pitch and the word low with the low pitch) and incompatible (the word high with the low pitch and the word low with a high pitch). Participants were asked to immediately express the pitch of the word verbally, regardless of the actual word, with utmost accuracy and speed (21). Audio files for the cognitive task were generated using MATLAB program (MathWorks). The words were presented every 2 seconds and a random number of 45 stroop-cues were collected during each cognitive condition (cognitive-dual task walking and sitting).

Also, the voice of the participants was recorded and the reaction time was calculated using the MATLAB program. A wireless headset (REMAX, RB-195hb) was used to play the sound and the examiner checks whether the answers are correct or incorrect.

3. Motor dual-task walking: The participants were asked to walk at their self-selected speed while carrying a tray with a cup filled with water using both hands.

The participants were asked to perform the motor or cognitive task simultaneously with walking without prioritizing the tasks. The duration of each trial was 90 seconds. To minimize the effect of fatigue, a 5-minute rest period was given between conditions.

Moreover, to measure cognitive performance, the cognitive task was assessed while sitting on a chair. This condition was considered a control or single-task condition for cognitive performance. All 4 conditions were tested in a randomized order. In addition, to minimize the learning effect for secondary cognitive tasks, no familiarization trials were given before data collection.

Data Analysis

To calculate spatiotemporal gait parameters, a custom-written MATLAB program was used. A Zeni velocity-based algorithm was used to evaluate spatiotemporal gait parameters (22). The parameters were calculated as follows: cadence (step/min), step width (cm), stride length (cm), swing time (%gait cycle time), and double support time (%gait cycle time). Moreover, gait variability was quantified using a coefficient of variation (CoV = SD /mean×100) for stride time, stride length, and step width parameters. In each trial, 70 consecutive walking cycles were used to calculate the parameters. To assess cognitive task performance, error ratio (ER) and response reaction time (RT) were calculated. The auditory Stroop software was designed in such a way that it calculated the reaction time in seconds from the end of the playing word to the beginning of the person's response. The ERs were calculated using the following formula: the number of incorrect responses divided by the total number of stimuli (21). Slower reaction time and higher number of ER indicate worse cognitive performance.

Statical Analysis

Statistical analysis was done using IBM SPSS Version 22.0 software. The Kolmogorov-Smirnov test was used to assess the normality of data distribution. To determine the differences in the demographic characteristics between groups, an independent samples t test was used.

Paired samples t test showed no significant differences between the right and left limbs for all spatiotemporal gait parameters. Thus, for statistical analysis, the mean values from both limbs of each participant were used. Two-way repeated measure analysis of variance (ANOVA) with additional post hoc comparison (Bonferroni test) was employed to evaluate the effects of group and walking conditions on gait parameters, with a group (2 levels: healthy controls and NSCLBP patients) as between-group factor and condition (3 levels: single-task gait, cognitive dual-task gait, and motor dual-task gait) as a within-group factor.

Furthermore, analysis of cognitive function was performed by using a 2-way repeated measures ANOVA with a group (2 levels: NSCLBP patients and healthy controls) as between-group factor and condition (2 levels: sitting versus walking) as within-group factor. Statistical significance was set at $P < 0.05$.

Results

The results of the independent samples t test showed no significant differences between the 2 groups in demographic characteristics (Table 1). Table 2 illustrates the mean and standard deviation of all gait parameters for the 2 groups during different walking conditions.

In the NSCLBP group, the self-selected speed was slower than the healthy controls ($P = 0.004$). A 2-way repeated measures ANOVA showed a significant main effect of the group for swing time ($P = 0.012$) and double support time ($P = 0.021$). The NSCLBP group showed shorter swing time and longer double support time compared with the healthy controls. Moreover, there was a significant interaction between the group and condition for cadence ($P = 0.004$) (Table 3). Further analysis by paired sample t test showed that the NSCLBP group had a lower cadence during the cognitive dual-task condition compared with the single-task condition ($P = 0.031$) and motor dual-task condition ($P = 0.021$). About the stride length, there was no significant effect of group ($P = 0.467$), condition ($P = 0.460$), or interaction between group and condition ($P = 0.851$) (Table 3). Similarly, for the step width, the results also indicated no significant effect of group ($P = 0.072$), condition ($P = 0.619$), or interaction between group and condition ($P = 0.372$) (Table 3).

For stride time variability, there was no significant interaction between the group and condition ($P = 0.904$). The results of the analysis showed that the condition had a significant effect on stride time variability ($P = 0.030$). Post hoc analysis results showed that in all participants stride time variability was decreased under the cognitive dual-task walking compared with the single and motor-dual task walking conditions ($P = 0.030$). Nonetheless, the difference was not significant between the motor dual-task and single walking conditions ($P = 0.990$) (Table 3).

Regarding stride length variability, the analysis indicated a significant effect of condition ($P = 0.002$). There were no significant effects of the group ($P = 0.367$) and no significant interaction between the condition and group ($P =$

Table 1. Demographic and clinical characteristics of the NSCLBP group and healthy controls

Characteristic	Group		*P*-value
	Control (n = 20)	NSCLBP (n = 20)	
Age (years)	32.2 ± 10.6	36.04 ± 7.2	0.183
Gender			
Female	10 (50 %)	10 (50 %)	
Male	10 (50 %)	10 (50 %)	
BMI (kg/m$^{2)}$	25.4 ± 3.3	26.46 ± 3.7	0.351
Height (cm)	167.61 ± 10.0	166.95 ± 6.1	0.800
Years of education (years)	15.05 ± 1.6	14.19 ± 2.2	0.174
ODI	N/A	29 ± 7.4	
LBP Duration(months)	N/A	27.09 ± 7.5	
NRS (0-10)	N/A	4.8± 0.7	

NSCLBP = Non specific chronic low back pain; BMI = Body mass index; ODI= Oswestry disability index; NRS: Numeric rating scale; N/A: not applicable. All variables were reported as mean ± standard deviation, except Gender reported as number (percent).
p<0.05 difference between the control group and the CLBP group.

Table 2. Mean ± SD of gait parameters in single and dual-task condition for NSCLBP group and healthy controls

	Groups	
	NSCLBP	Healthy control
Single task gait		
Velocity	1.78 ± 0.4	2.22 ± 0.4
Cadence	124.60 ± 16.8	124.94 ± 14.3
Stride length	86.90 ± 30.3	88.68 ± 12.7
Double support time	21.58 ± 2.7	19.91 ± 1.9
Swing time	43.64 ± 3.6	46.28 ± 2.8
Stride length variability	0.08 ± 0.03	0.07 ± 0.02
Stride time variability	0.04 ± 0.01	0.04 ± 0.01
Step width	11.24 ± 2.8	10.01 ± 2.8
Step width variability	0.17 ± 0.07	0.17 ± 0.05
Cognitive dual-task		
Velocity	1.78 ± 0.4	2.22 ± 0.4
Cadence	121.40 ± 14.7	123.89 ± 14 .5
Stride length	87.26 ± 29.03	89.21± 11.4
Double support time	21.54 ± 2.5	19.76 ± 2.0
Swing time	43.79 ± 3.3	46.36 ± 3.04
Stride length variability	0.07 ± 0.02	0.06 ± 0.01
Stride time variability	0.03± 0.01	0.03± 0.01
Step width	11.37 ± 3.1	9.55 ±3.2
Step width variability	0.14 ± 0.06	0.18 ± 0.09
Motor dual-task		
Velocity	1.78 ± 0.4	2.22 ± 0.4
Cadence	124.73 ± 14.4	125.58 ± 14.1
Stride length	85.38 ± 17.01	87.72 ± 13.1
Double support time	21.57 ± 2.9	19.69 ± 1.70
Swing time	43.28 ± 3.7	45.98 ± 3.1
Stride length variability	0.08 ± 0.02	0.08 ± 0.03
Stride time variability	0.04 ± 0.01	0.04 ± 0.01
Step width	11.30 ± 2.6	9.48 ± 2.7
Step width variability	0.18 ± 0.04	0.17 ± 0.06

Scales: Velocity (km/h), Cadence (steps/min), Stride length (cm), Swing time (%gait cycle), Stride length variability (CoV%), Stride time variability (CoV%), Step width (cm), Step width variability (CoV%), CoV: Coefficient of variation.

0.820). Post hoc analysis results revealed that in all participants, stride length variability decreased during the cognitive dual-task condition compared with the motor dual-task and single walking condition (*P* = 0.002). The results showed no significant difference between the motor dual-task and single walking conditions (*P* = 0.994) (Table 3).

For step width variability, the analysis showed a significant interaction between group and condition (*P* = 0.016). Further analysis by paired sample t test showed that the NSCLBP group decreased step width variability during the cognitive dual-task compared with the single task (*P* = 0.012) and motor dual-task walking condition (*P* = 0.025). However, in the healthy controls, there was no significant difference between the single-task and cognitive dual-task conditions (*P* = 0.236), single-task and motor dual-task conditions (*P* = 0.212), and cognitive dual-task and motor dual-task conditions (*P* = 0.101).

The mean (SD) results of the reaction time were 0.86 (0.14) and 0.79 (0.12) in sitting and walking conditions for the NSCLBP group and 0.91 (0.82) and 0.97 (0.10) for healthy controls. There was no significant interaction between the group and condition (*P* = 0.321) or condition (*P*

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Table 3. Summary of analysis of variance of dual-task costs for each gait parameter. F-ratios and P-values by variable

Source of variation		Cadence	Swing time	Stride length	Step Width	Double support time	Step width variability	Stride time variability	Stride length variability
Group	F	2.51	6.49	0.54	3.47	5.78	1.62	0.44	0.83
	P	0.141	0.012	0.467	0.072	0.021	0.210	0.510	0.367
Condition	F	1.57	0.26	0.78	0.48	0.51	1.22	3.67	6.89
	P	0.257	0.483	0.460	0.619	0.476	0.675	0.030	0.002
Interaction									
Group × condition	F	2.13	0.04	5.09	0.98	0.14	4.22	0.10	0.19
	P	0.004	0.838	0.851	0.372	0.701	0.016	0.904	0.820

P = P-value, F = F-ratio
Significant P-values ($P < 0.05$) are presented in bold.

= 0.785). However, the main effect of the group was significant (P = 0.002). The NSCLBP group had a slower reaction time compared with healthy controls. For the ER, there was no significant interaction between the group and condition (P = 0.141) and between the main effect of group (P = 0.273) and condition (P = 0.219).

Discussion

The present study aimed to compare the spatiotemporal gait parameters during single-task walking, cognitive dual-task walking, and motor dual-task walking between healthy controls and those with NSCLBP. The findings showed differences in spatiotemporal gait parameters in individuals with NSCLBP compared with healthy controls. Cadence and step width variability could reveal deficits in cognitive dual-task performance during walking between those with NSCLBP and healthy controls. Furthermore, in all participants stride length variability and stride time variability decreased while preserving cognitive function under cognitive dual-task walking compared with single walking and motor-dual task walking conditions. In addition, in the 2 groups, no significant differences were observed in gait parameters between motor dual task and single walking.

Congruent with previous studies, those with NSCLBP walked slower and with shorter swing time and longer double support time than healthy controls (23, 24). Several studies stated that people with NSCLBP walk more slowly than healthy controls (2, 25). One reason for this may have been that individuals with NSCLBP restrict their spine movements to reduce pain, which leads to a decrease in walking speed. Moreover, increased double support time and decreased swing time may indicate an adaptive strategy of individuals with NSCLBP to reduce pain and increase stability during walking (26).

The results of the current study indicated slower cadence and lower step width variability during cognitive dual-task walking compared to other conditions in individuals with NSCLBP. Consistent with the finding of this study, lamoth et al (2006) found less variability in upper body movement and diminished flexibility in trunk coordination during cognitive dual-task walking in those with NSCLBP. They concluded that the concurrent cognitive task reduces the walking adaptability to cope with greater processing demands (10).

According to various studies, individuals with NSCLBP use cognitive resources in regulating their walking, and when cognitive resources are spent on an attentional secondary cognitive task, they reduce the complexity of preserving their gait pattern, which reduces the variability of walking (25, 27). Previous studies showed that reducing the degree of freedom in individuals with NSCLBP leads to the ability to deal with perturbation (25, 27). This allows them to walk more slowly and have more control over walking. Furthermore, an additional cognitive task intensifies this behavior. Gait variability has emerged as a marker that provides indirect information on motor control of locomotion. Thus, decreased variability was related to the ability to maintain gait stability (10). It is important to note that according to the dynamical system theory, decreased variability demonstrates decreased locomotor system adaptability and flexibility. In addition, less variability is a sign of frequent movement of segments in a very small range, which can cause more repeated stresses on the soft tissue, resulting in repetitive stressing and degenerative changes (28).

During the cognitive dual-task condition, all participants decreased variability in stride time and stride length. However, the performance of cognitive task reminded unchanged. Our findings are in agreement with those of Lövden et al (2008) who reported decreased stride length variability in older adults during a cognitive dual-task condition (29). In addition, Mofateh et al (2017) found that stride length variability decreased in patients with multiple sclerosis and the healthy group while performing cognitive dual-task (11). A possible explanation for these results may be that in the cognitive dual-task condition, the cognitive task is given priority over walking. In such a situation, attentional resources are diverted from walking and allocated to cognitive performance. It seems that participants effectively adopted their gait pattern to preserve cognitive performance because more attentional resources are required for a precise cognitive task (30).

Our results are in contrast to a study by Hamacher et al (2016) conducted on individuals with NSCLBP that revealed increased stride length variability and stride time variability during dual-task walking (31). One of the reasons for the discrepancy in the results could be that the mean age of participants in the Hamacher et al study was high and aging can affect the outcomes (31). Moreover, the overground walking in the hamacher et al study can be another factor that caused inconsistency in the results of the present study, which is done by treadmill walking. By using

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the treadmill, we could control the walking speed and evaluate the net effect of cognitive tasks on gait parameters. Also, the type of cognitive task was different and the result of the cognitive task was not reported.

According to the findings of this study, performing a simultaneous motor task while walking did not cause any changes in walking performance compared with single-task walking. It can be described that the cognitive demand of the simultaneous motor task used in this study may not be enough to interfere with walking. In future studies, it is recommended to use a more difficult motor task to understand the effect of the simultaneous motor task on walking performance in people with NSCLBP.

We found that individuals with NSCLBP performed significantly worse on auditory Stroop tasks compared with healthy controls and had slower reaction times. This finding is consistent with previous studies indicating that chronic pain leads to impaired cognitive function (32). A large body of literature suggests alterations in brain structure and cognitive function in individuals with NSCLBP, including slowed information processing, reduced ability to change, and impaired decision-making (33). Thus, therapeutic strategies for individuals with NSCLBP should take a multidisciplinary approach that focuses on improving cognition ability as well as motor performance.

Some limitations of this study must be acknowledged. First, we evaluated those with NSCLBP with low pain and disability. Future studies should consider the effect of different levels of pain and disability on cognitive dual-task and motor dual-task walking performance in this group. Second, the performance of the secondary motor task was not quantified. Further studies should be conducted in this regard. From the clinical perspective, the result of this study may be useful for clinicians to consider cognitive dual-task training for the improvement of walking performance in those with NSCLBP.

Conclusion

Our findings indicated that individuals with NSCLBP adapted successfully to walking performance to maintain the performance of the concurrent cognitive task under the cognitive dual-task walking condition. Moreover, the present study observed no dual-task interference under the motor dual-task condition. Future studies should investigate more difficult secondary motor tasks to obtain further information regarding gait changes under motor dual tasks in those with NSCLBP.

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Conflict of Interests

The authors declare that they have no competing interests.

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