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ORIGINAL ARTICLE

Investigating spatiotemporal gait parameters and gait stability in individuals with chronic idiopathic neck pain

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Purpose: The aim was to compare gait speed, step length, cadence and gait stability ratio (GSR) between individuals with chronic idiopathic neck pain (CINP) and no-pain controls and investigate the relationship of disability with spatiotemporal gait variables and GSR in individuals with CINP.

Methods: Twenty-five individuals with CINP (17 females, 8 males) and 25 no-pain controls (17 females, 8 males) recruited into this study. All participants performed the 10-meter walking test in three walking conditions: Preferred walking (PW), walking with head rotation (HRW), walking at maximum speed (MAXW). Video analysis method involving slow-motion camera (120fps) was used to measure spatiotemporal gait parameters. GSR was calculated by dividing step counts per second to gait speed (m/s).

Results: Individuals with CINP had slower gait speed and cadence in all walking conditions ($p<0.05$). In individuals with CINP, step length was found to be shorter and GSR was significantly higher in only HRW ($p<0.05$). GSR values in all walking conditions were found to be moderately correlated with NDI ($r=0.507$, $r=0.533$, $r=0.516$ for PW, HRW and MAXW, respectively, all $p<0.01$). Step lengths in all walking conditions and preferred gait speed were found to be weakly correlated with NDI (For step lengths $r=-0.485$, $r=-0.440$, $r=-0.487$ for PW, HRW and MAXW, respectively, all $p<0.05$; for preferred gait speed $r=-0.473$, $p<0.05$).

Conclusion: Our results suggested that individuals with CINP have altered spatiotemporal gait variables. Assessment of spatiotemporal gait parameters and GSR may provide additional information for management of such disability, so should be addressed in clinical assessment of CINP.

Keywords: Neck pain, Spine, Gait.

Yürüyüşün zaman mesafe parametreleri ve yürüyüş stabilitesinin kronik idyopatik boyun ağrılı bireylerde incelenmesi

Amaç: Çalışmanın amacı kronik idyopatik boyun ağrılı bireyler ile ağrısı olmayan kontrolleri yürüyüş hızı, tempo, adım uzunluğu ve yürüyüş stabilite oranı (YSO) bakımından karşılaştırmak ve kronik idyopatik boyun ağrılı bireylerde özür düzeyinin yürüyüşün zaman mesafe parametreleri ve YSO ile ilişkisini incelemektir.

Yöntem: Çalışmaya 25 kronik idyopatik boyun ağrılı (17 kadın, 8 erkek) ve 25 ağrısı olmayan birey (17 kadın, 8 erkek) dahil edildi. Tüm katılımcılar 10 metre yürüme testini üç yürüme koşulunda gerçekleştirdi: Normal yürüme (NY), baş rotasyonlarıyla yürüme (BRY) ve maksimum hızda yürüme (MAKSY). Yürüyüşün zaman mesafe parametreleri 120 fps'de ağır çekim yapan kamera ile değerlendirildi. YSO, yürüyüş hızının (m/sn) saniyedeki adım sayısına bölünmesiyle hesaplandı.

Bulgular: Kronik idyopatik boyun ağrılı bireylerin yürüyüş hızı ve tempolarının tüm yürüme koşullarında daha düşük olduğu görüldü ($p<0.05$). Kronik idyopatik boyun ağrılı bireylerin adım uzunluğu sadece BRY koşulunda daha düşük bulundu ($p<0.05$) ve YSO sadece BRY koşulunda daha yüksekti ($p<0.05$). Tüm yürüme koşullarındaki YSO ile özür düzeyi arasında orta şiddette korelasyon bulundu (NY, BRY ve MAKSY için sırasıyla $r=0.507$, $r=0.533$, $r=0.516$, tümü $p<0.01$) Tüm yürüme koşullarındaki adım uzunluğu ve normal yürüme hızının ise özür düzeyi ile zayıf şiddette korelasyon gösterdiği bulundu (NY, BRY ve MAKSY koşullarındaki adım uzunluğu için sırasıyla $r=-0.485$, $r=-0.440$, $r=-0.487$, tümü $p<0.05$; normal yürüme hızı için $r=-0.473$, $p<0.05$).

Sonuç: Çalışmamızın sonuçları, kronik idyopatik boyun ağrılı bireylerin yürüyüş parametrelerinde olumsuz değişimler olduğunu gösterdi. Farklı yürüme koşullarındaki zaman mesafe parametreleri ve YSO'nun değerlendirilmesi özür düzeyine ilişkin bilgi verebileceği için kronik boyun ağrılı bireylerin klinik değerlendirmesinde yer almalıdır.

Anahtar kelimeler: Boyun ağrısı, Omurga, Yürüyüş.

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Neck pain is the second common musculoskeletal disorder that affects 70% of the general population at one point through their lifetime.[1] Although it is thought that neck pain has a favorable prognosis, the complaints of one-third of individuals who experience neck pain do not improve and continue to become chronic.[2,3] Recent studies have shown that individuals with chronic idiopathic neck pain (CINP) have altered spatiotemporal gait variables. It was shown that elders with CINP have lower gait speed and cadence during walking with head rotation compared to healthy elders.[4] Also, it was found that adults with CINP exhibit lower step length and gait speed compared to healthy adults during walking with head rotation and walking at maximum speed.[5] It was thought that negative alternations in gait variables in individuals with CINP are caused by decreased balance abilities.[4,5] Neck pain may negatively affect afferent input from cervical mechanoreceptors, which have important connections with vestibular, visual and postural control systems, and thus may lead to disturbed postural control, poorer postural stability and balance.[6-8]

Gait stability ratio (GSR) is represented by step counts per meter during walking. The changes in GSR is mostly dependent on the ratio of proportional changes in gait speed and cadence.[9] Higher GSR value means to increase in time spent on double support period and decrease in dynamic components of gait, which refers to more stable gait pattern.[10] According to our knowledge, there is no study investigating gait stability in individuals with neck pain. We have hypothesized that individuals with CINP have a more stable gait pattern compared to no-pain controls to compensate for their decreased balance abilities.

Neck Disability Index (NDI) is the most valid indicator of disability in activities of daily living due to neck pain, however, it contains items regarding activities related to cervical spine.[11,12] We have thought that the effects of CINP on activities related to cervical spine may be associated with gait variables. Uthaikhup et al. found that maximum gait speed of adults with CINP is moderately correlated with NDI, but other spatiotemporal gait variables in different walking conditions were not found to be significantly correlated with NDI.[5] Further, GSR was found to be a more sensitive measure of dynamic balance than other spatiotemporal gait parameters,[10,13] and thus, we have hypothesized that GSR in different walking conditions may be related to disability.

In the light of this information, the aim of the study was to compare gait speed, step length, cadence and GSR between individuals with CINP and no pain controls in different walking conditions and determine the relationship of disability with spatiotemporal gait variables and GSR in individuals with CINP.

METHODS

Ethical approval was taken from Dokuz Eylül Institutional Non-invasive Research Ethics Board (No: 2017/08-26, Date: 13.04.2017). The signed informed consent was obtained from all participants before their participation. This study was conducted in the motion analysis laboratory of the Dokuz Eylül University between June and July 2017.

Participants

Twenty-five individuals with CINP (17 females, 8 males, age: 37.28±13.47 years) and twenty-five no-pain controls (17 female, 8 male, age: 36.6±14.2 years) participated in this study. Inclusion criteria consisted of being between the age of 18 and 65 years, experiencing neck pain lasting longer than 3 months and scoring the NDI higher than 10/ 100.[5] Exclusion criteria consisted of experiencing a neck trauma, having other musculoskeletal problems that may affect walking performance, neurological deficits, and other diagnosed conditions that may affect balance such as inner ear pathology, stroke, circulatory disorder, diabetes, neurological and/or vestibular pathologies. The individuals who meet the inclusion criteria were directed to the study by the physician.

The sample size was not calculated prior to the study but was determined based on the similar studies investigating the spatiotemporal gait variables in individuals with CNP.[4,5]

Test procedure

All participants performed the 10-meter walking test in three walking conditions: Preferred walking (PW), walking with head rotation (HRW), walking at maximum speed (MAXW). Gait parameters were assessed at 10 meter in the middle of the 16 meter walkway. First and last three meters of the walkway were not measured to allow participants distance to acceleration and deceleration. At least three trials were performed before tests to familiarize the participants with the walking conditions. It was instructed verbally for PW condition that "Please walk from the first line to the last line at your comfortable speed". For performing HRW condition investigator instructed verbally "Please walk from the first line to the last line at your comfortable speed while turning your head continuously from one side to the other side". For performing MAXW condition investigator instructed verbally "Please walk as fast as you can from the first line to the last". The 10-meter walking test was repeated three times and averaged in each walking condition. Also, the order of walking conditions was randomized and one-minute rest was given after each test. All participants were provided standard shoes fitting their shoe-size (Aertex-EW80W for females, Aertex-LT500M for males). Video analysis method involving slow-motion camera (120fps) was used to measure spatiotemporal gait parameters (gait speed, cadence and step length). GSR (step/m) was calculated by dividing total number of completed steps to distance (meter) walked with these completed steps.

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.[14]

Video analysis method

Before this study, a pilot study was performed to determine the validity and reliability of the Video analysis method. Teen healthy individuals recruited into the pilot study. A mobile phone's (Samsung, Galaxy Note 5) slow motion camera capturing 120 frames per second was used. As this study, assessments in the pilot study were performed in three walking conditions involving PW, HRW, MAXW and repeated three times in each walking conditions. Fifty cm long cartons separated by 10 horizontal lines and a photocell gates (Brower TC Timing System USA) were placed at the beginning and end of the 10 meter in the middle of the 16 meter walkway. The time taken to walk 10 meter was converted to meters/second (m/s) to calculate gait speed. The average step length and cadence were calculated by determining the total number of completed steps based on the horizontal lines. The cadence was calculated by proportioning the total duration of these completed steps to one minute. The distance walked with completed steps was divided to number of these completed steps to calculate step length. While the analysing of the recordings, the video speed was decreased to 1/8, which allows detailed viewing. The intraclass correlation coefficients (ICCs) were calculated by analysing the data measured in 72 hours apart. The correlation between the gait speed values measured by photocell gates, which are used in studies as a gold standard, and video analysis method was calculated to determine the validity of gait speed data.[15,16]

Statistical analysis

Shapiro-Wilk test was used to determine if data has a normal distribution. Independent samples t-test was used to compare groups for GSR and other gait variables. Repeated measures ANOVA was performed to determine the effects of walking conditions on gait variables in both groups. If significant differences were determined, Bonferroni correction was used to determine which conditions differ. Pearson correlation coefficients were computed to find associations between NDI and gait variables of individuals with CINP.

RESULTS

Video analysis method's reliability was found to be good in PW-cadence (ICC= 0.880) and was found to be excellent for all other variables (ICC> 0.9). The gait speed data measured by two devices showed an excellent correlation in all walking conditions (r> 0.90 for all). The results of the pilot study have shown that video analysis method is valid and reliable.

Demographic characteristics were presented in Table 1. There were no differences in demographic characteristics between both groups ($p>0.05$).

Individuals with CINP exhibited lower gait speed and cadence in all walking conditions compared to no-pain controls ($p<0.05$). In individuals with CINP, step length was found to be shorter in only HRW ($p<0.05$), and GSR was higher in only HRW ($p<0.05$) (Table 2).

In the control group, there were no differences in gait speed, step length, cadence and GSR between PW and HRW conditions ($p>0.05$). However, the study group had lower gait speed, step length and cadence (for gait speed and step length $p<0.001$, for cadence $p= 0.014$) in HRW condition compared to PW condition while there was no difference in GSR ($p>0.05$). Also, gait speed, step length and cadence in MAXW condition were found to be higher ($p<0.001$) in both groups compared to the two other conditions while GSR was lower ($p<0.001$) (Table 2).

GSR values calculated in three walking conditions were found to be moderately (positive) correlated with NDI ($r= 0.507$ for PW, $r= 0.533$ for HRW, $r= 0.516$ for MAXW, all $p<0.01$). Step lengths in three walking conditions were found to be weakly (negative) correlated with NDI ($r= -0.485$ for PW, $r= -0.440$ for HRW, $r= -0.487$ for MAXW, all $p<0.05$). A negative and weak correlation was also found between preferred gait speed and NDI ($r=-0.473$, $p<0.05$) (Table 3).

DISCUSSION

The results of this study suggested that individuals with CINP have lower gait speed and cadence in all walking conditions compared to no-pain controls. In individuals with CINP, step length was found to be lower in only HRW condition. Also, when compared to no-pain controls GSR was found to be higher in only HRW condition in individuals with CINP.

Poole et al. found that elders with CINP have lower cadence and gait speed and higher gait cycle duration during walking with head rotation at the 14-meter walkway compared to healthy elders, but during walking with head straight they found only higher gait cycle duration.[4] Another study comparing adults with CINP and healthy adults suggested that adults with CINP demonstrate lower gait speed and step length in walking with head rotation and walking at maximum speed at the 8-meter walkway, but no difference was found in walking with head straight.[5] Unlike these, our results suggested that there are differences in gait speed and cadence during walking with head straight between individuals with CINP and no-pain controls. This inconsistency may have resulted from the difference between studies regarding age groups or walking distance where gait assessments were performed. However, to our knowledge, there is no study comparing the effects of neck pain on gait variables between different age groups or investigating the differences in spatiotemporal gait variables between different walk distances. There is only one study comparing gait speed values measured at 4-meter and 10-meter walking tests in healthy older adults and aforementioned two walking tests were not found to be sufficiently correlated to be used interchangeably.[17] Further studies investigating spatiotemporal gait parameters of individuals with and without CINP and in different walking distances are needed to identify whether these tests may be used in place for another.

Our results suggested that in HRW condition individuals with CINP exhibit lower gait speed, step length and cadence compared to PW condition while no-pain controls did not exhibit any differences between PW and HRW conditions. Rotation of the head, which is a natural stimulus for the semicircular canal and may stimulate otolith organs, produces vestibular sensory signals.[18,19] CINP may lead to a secondary vestibular deficit because the pain has a negative impact on inputs from numerous cervical mechanoreceptors which have the central and reflex connection with the vestibular system.[7,20] The purpose of the decrease in gait speed and related spatiotemporal variables in HRW condition compared to PW condition may be to compensate for the loss of vestibular function or increase in abnormal vestibular inputs.[4,5] In addition to these, walking with head rotation is more challenging walking condition including an additional motor task. There has been a lot of research suggesting that there is a significant association between dual-task performance and balance abilities and individuals with better postural control have better performance during walking with additional motor tasks.[21-24] Numerous studies have shown that individuals with CINP have decreased balance abilities,[6,8,20] and reduced dual-task performance in individuals with CINP may be a consequence of their decreased balance abilities.

Table 1. Demographic characteristics of both groups.

	Neck Pain (N=25) X±SD	Controls (N=25) X±SD	
Age (year)	37.28±13.47	36.6±14.2	*
Body weight (kg)	69.76±12.51	65.65±11.26	*
Height (cm)	168.92±7.37	167.48±7.1	*
Body mass Index (kg/m^2)	24.57±4.16	23.39±3.63	*
Gender (Female/Male) (n(%))	17/8±68/32	17/8±68/32	
Neck Disability Index (%)	23.92±5.96		

* p<0.05, ** p<0.01.

Table 2. Gait parameters in preferred walking, walking with head rotation, and walking at maximum speed conditions for both groups.

	Neck Pain (N=25) X±SD	Controls (N=25) X±SD	
Preferred walking			
Gait speed (m/sec)	1.29±0.17	1.43±0.20)	**
Step length (cm)	69.47±8.46	72.62±5.68)	**
Cadence (steps/min)	112.43±6.32	117.71±8.95)	**
Gait stability ratio (step/m)	1.46±0.17	1.38±0.11)	*
Walking with head rotation			
Gait speed (m/sec)	1.14±0.22	1.39±0.22)	**
Step length (cm)	64.83±8.76	71.01±6.62)	**
Cadence (steps/min)	103.28±14.68	116.79±10.75)	**
Gait stability ratio (step/m)	1.54±0.21	1.42±0.13)	**
Walking at maximum speed			
Gait speed (m/sec)	1.89±0.23	2.10±0.26)	**
Step length (cm)	81.66±9.66	85.82±7.24)	*
Cadence (steps/min)	139.17±11.66	147.78±12.41)	**
Gait stability ratio (step/m)	1.24±0.14	1.18±0.1)	*

* p<0.05, ** p<0.01.

Table 3. Correlation coefficients between disability and gait parameters of individuals with chronic idiopathic neck pain.

	Neck Disability Index		
	Preferred walking	Walking with head rotation	Walking at maximum speed
Gait speed	-0.473*	-0.394	-0.396
Step length	-0.485*	-0.440*	-0.487*
Cadence	-0.121	-0.182	0.136
Gait stability ratio	0.507**	0.516**	0.533**

* p<0.05, ** p<0.01.

To the best our knowledge, our study is the first study investigating GSR in individuals with CINP. It was suggested that the relationship of balance ability during dynamic weight-shifting with GSR is significantly stronger than with gait speed or cadence and GSR may be more useful to determine dynamic balance ability related to walking. Also, GSR was thought to be a more sensitive measure of dynamic balance during walking than other spatiotemporal gait parameters.[10,13] Results from our study suggested that individuals with CINP display higher GRS values compared to no-pain controls in HRW condition, this indicated that they have more stable gait pattern in this condition. The increased GSR value also means to decreased step length, which is consistent with our results suggesting that individuals with CINP have lower step length in HRW condition compared to no-pain controls.[9]

In this study, we found no differences in GSR between PW and HRW conditions in both groups. This issue may have resulted from a compensation strategy for protecting gait stability in more challenging walking condition, HRW condition, by modifying spatiotemporal gait variables. Individuals with CINP exhibited significantly lower gait speed, cadence and step length in HRW condition compared to PW condition while no-pain controls did not. The decreases in spatiotemporal gait variables of individuals with CINP during HRW may have led to maintain gait stability, which provides compensation for decreased balance abilities. However, walking in more challenging conditions than this study may cause an increase in GSR because proportionally more decrease in gait speed than cadence may be needed. Thus, there is a need for future studies investigating spatiotemporal gait variables and GSR values in challenging walking conditions such as a concurrent cognitive task, visual challenge or walking while simultaneously performing two or more different tasks.

Uthaikhup et al. found that maximum gait speed is moderately correlated with NDI, but other spatiotemporal gait variables is not significantly correlated.[5] Our results showed that GSR values in all walking conditions are modarately correlated with NDI, also step length values in all walking conditions and preferred gait speed are weakly correlated with NDI. This association may be a reflection of the suggestion that GSR is a better indicator of dynamic balance than cadence and gait speed.[10,13]

Limitations

Our study involves individuals with CINP scoring mild to moderate disability in NDI and it is not known how GSR and other spatiotemporal gait parameters are affected in individuals with a more severe disability. Further, we did not use a power analysis to determine the optimal sample size.

Conclusion

Our results suggested that individuals with CINP have altered spatiotemporal gait variables. Also, they have a more stable gait pattern during HRW compared to no-pain controls. Assessment of spatiotemporal gait parameters and GSR in different walking conditions may provide additional information for management of such disability, so should be addressed in clinical assessment of CINP.

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