THE EFFECT OF ANKLE JOINT POSITION SENSE ON GAIT KINEMATICS AND KINETICS OF HEMIPARETIC PATIENTS WITH STROKE

İNMELİ HEMİPARETİK HASTALARDA AYAKBİLEĞİ EKLEM POZİSYON DUYUSUNUN YÜRÜME KİNETİK VE KİNEMATİKLERİNE ETKİSİ

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ABSTRACT

Aim: To evaluate the effects of ankle joint position sense on gait kinematics and kinetics of hemiparetic patients with stroke.
Methods: A total of 97 consecutive hemiparetic patients (mean age, 61y), average of 9 months after stroke were divided into two groups according to their joint position sense (JPS) at the paretic ankle (JPS-impaired n=32; JPS-normal n=69). Clinical characteristics, lower extremity motor recovery level (using Brunnstrom stages), spasticity (Modified Ashworth Scale), JPS of the paretic ankle (positioning error) and activity level (FIM) of the patients were evaluated. Kinematic and kinetic variables of gait were evaluated using a three-dimensional computerized gait analysis system.
Results: There was no difference between the groups regarding age, sex, lesion type, hemiparetic side, time since stroke, spasticity level, lower extremity Brunnstrom scores and FIM scores. Patients with impaired JPS had greater pelvic obliquity than the patients with normal JPS (p=0.014). Ankle excursion in sagittal plane was significantly limited in both paretic and nonparetic sides of the patients with impaired JPS (p<0.001 and p<0.001, respectively). Peak extensor moment of the knee decreased in nonparetic side in patients with impaired JPS (p=0.048).
Conclusions: Impaired JPS effects gait after stroke and should be taken into consideration while prescribing gait training programs after stroke.
Key words: Stroke, joint position sense, gait analysis

ÖZET

Amaç: Inmeli hemiparetik hastalarda ayakbileği eklem pozisyon duyusunun (EPD) yürümenin kinetik ve kinematik değişkenleri üzerine etkisini değerlendirmek.
Metod: İnme sonrası geçen süreleri ortalama 9 ay olan 97 ardışık hemiparetik hasta (ortalama yaş 61 yıl) paretik ayakbileği eklem pozisyon duyusuna göre 2 gruba ayrıldı (EBD-bozuk: n=32, EPD-normal: n=69). Klinik özellikler, alt ekstremite motor iyileşme düzeyi (Brunnstrom'a evrelemesi kullanılarak), spastisite (Modifiye Aschworth Skalası), EPD (pozisyon hatası) ve aktivite düzeyi (Fonksiyonel Bağımlılık Ölçeği (FBÖ)) değerlendirildi. Yürümenin kinetik ve kinematik değişkenleri üç boyutlu bilgisayarlı yürüme analizi sistemi kullanılarak değerlendirildi.
Bulgular: Gruplar arasında yaş, cinsiyet, lezyon tipi, hemiparetik taraf, inme sonrası geçen süre, spastisite düzeyi, alt ekstremite Brunnstrom motor iyileşme düzeyi, FBÖ skorları açısından fark yoktu. Eklem pozisyon duyusu bozuk olan hastalarda pelvik rotasyon açısı EPD'su normal olan hastalara göre daha fazlaydı (p=0,014). Sagital düzlemdeki ayakbileği hareketi toplam hareketi EPD bozulmuş hastaların hem paretik hem paretik olmayan taraflarında anlamlı olarak azalmıştı (sırasıyla, p<0.001 ve p<0.001). Eklem pozisyon duyusu bozuk olan hastaların paretik olmayan taraflarında diz pik ekstensör momenti azalmış olarak saptandı (p=0,048).
Sonuçlar: Bozulmuş eklem pozisyon duyusu inmeli hemiparetik hastalarda yürümeyi etkiler ve inme sonrası yürüme eğitimi planlanırken dikkate alınmalıdır.
Key Words: İnme, eklem pozisyon duyusu, yürüme analizi

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INTRODUCTION

One of the major goals of stroke rehabilitation is to achieve independent ambulation by a safe and efficient gait pattern. It is important to determine the factors which affect the final gait pattern after stroke so that better rehabilitation programs can be developed. Sensory disturbances considered as one of the reason which affect the gait pattern and are related to the functional outcome of stroke patients (1). Following stroke, proprioceptive acuity may be impaired (2,3) and may contribute to disabilities in balance and walking (4). Joint position sense is considered to play an important role in motor control. It is critical to motor control for tasks involving multi-segmental movements, such as walking, and to motor learning.

Joint position sense (JPS) was experimentally changed in its function in healthy adults and shown to be altered gait patterns (5,6). An animal study also showed the relationship between the impaired knee position sense and reduction in muscle recruitment in walking (7). These studies suggest that JPS may have significant contribution to gait performance. Recent studies investigated the effect of JPS on time-distance characteristics of gait in patients with stroke (1,8-12) but not the kinetic and kinematic characteristics.

Time-distance characteristics especially walking velocity is preferred to assess outcome after stroke because they remain sensitive to change even after three months post-stroke. However, the disadvantage of walking velocity as an outcome parameter is that it does not inform about the movement patterns, even though normalization of movement patterns is one of the therapeutic aims. Ideally, kinematic and kinetic gait analysis should be used to guide the therapy and to optimize the success of therapeutic strategies as soon as the patient

The present study was designed to evaluate the effects of ankle JPS on gait kinematic and kinetics of hemiparetic patients with stroke using quantiative gait analysis.

METHODS

The study included 97 consecutive inpatients with hemiparesis resulting from stroke. Stroke was defined as an acute event of cerebrovascular origin causing focal or global neurological dysfunction lasting more than 24 hours, as diagnosed by a neurologist and confirmed by computed tomography or magnetic resonance imaging. Patients were recruited to meet the following criteria for inclusion in the study: 1: first episode of unilateral stroke with hemiparesis during previous 6 months, 2: a score between 1 and 3 inclusive on the Brunnstrom stages for the lower extremity, 3: ability to understand and follow simple verbal instructions, 4: ambulatory before stroke, 5: no medical contraindication to walking, and 6: ability to stand with or without assistance and to take several steps with or without assistance (14). They were excluded if they had a history of any other neurological pathology, conditions affecting balance, neglect, dementia, impaired vision or conscious levels or concomitant medical illness or musculoskeletal conditions affecting lower limbs. Ninety-seven patients fulfilled the inclusion criteria. The protocol was approved by Ankara University Ethics Committee and all subjects provided written informed consent prior to data collection.

The stage of motor recovery of the lower limbs was determined by Brunnstrom's Motor Recovery Stage (BMRS) (14). We assessed lower-extremity motor recovery using the Brunnstrom stages for the lower extremity because it reflects underlying motor control based on clinical assessment of movement quality. The Functional Independence Measure (FIM) was used to assess activity level (15). The reliability and validity of the Turkish version of the FIM has been previously documented (16).

Joint position sense

Joint position sense was used to evaluate proprioceptive sensation because of its high test-retest reliability compared with kinesthesia or other methods (17). Patient sat with the leg hanging vertically to the ground. The examiner moved the affected foot from a neutral position to 10° of dorsiflexion or plantarflexion and then signaled the patient to actively move the unaffected foot to match the joint angle of the affected ankle angle (1). We repeat the test for three times and recorded the result as normal or impaired.

Gait kinematics and kinetics

Three-dimensional gait data were collected with the Vicon 370 system (Vicon; Oxford Metrics Ltd, 14 Minns Estate, West Way, Oxford, OX2 0JB, UK. Bertec Corp, Colombus, OH, USA) and processed by the Vicon Clinical Manager (version 3.2) software. Anthropometric data collected included height, weight, leg length, and joint width of the knee and ankle. Fifteen passively reflective markers were placed on standard and specific anatomic landmarks: sacrum, bilateral anterior superior iliac spine, middle thigh, lateral knee (di-

Tablo-I

Demographic properties of the patients

		Impaired JPS* (n=32)	Normal JPS* (n=69)	P
Age (years)		61.9±8.7	61.5±12.2	0.933
Time since SVA(months)		7.3±3.2	10.7±13.8	0.755
Brunnstrom stage		4.2±1.0	4.0±0.9	0.450
MAS**		2.1±0.3	2.4±0.5	0.545
FIM ***		86.4±19.3	81.3±16.5	0.123
Gender	Female	9	31	0.195
	Male	11	38	
Hemiparetic side	Right	13	29	0.895
	Left	19	40	
Lesion type	Ischemic	23	50	0.705
	Hemorrhagic	6	9	
	Hematoma	2	10	

*JPS: joint position sense, **MAS: Modified Aschworth Scale,*** FIM: Functional Impairment Scale

rectly lateral to axis of rotation), middle shank (the middle point between the knee marker and the lateral malleolus), lateral malleolus, and heel and forefoot between the second and third metatarsal head. After subjects were instrumented with retroreflective markers, they were instructed to walk at a self-selected speed over a 10-m walkway, during which data were captured. Five cameras recorded (at 60Hz) the 3-dimensional spatial location of each marker as the subject walked.

Walking velocity, cadence, step length and double support time were documented for the paretic and non-paretic sides of both groups. Excursions (the difference between peak and valleys of the curve in degrees) of pelvis, hip, knee and ankle for both paretic and nonparetic sides were documented in sagittal and coronal plane. Peak extensor moment of the hip and knee and peak plantar flexor moment of the ankle at the paretic and non-paretic sides during stance were documented for both groups.

Statistical Analysis

We analyzed the data using SPSS version 9.0 for Windows (Version 9.0. SPSS Inc, 233 S Wacker Dr, 11th Fl, Chicago, IL 60606). The group means between the JPS-impaired and the JPS-normal groups were compared using Mann-Whitney U Test. Significance was set at 0.05.

Results

Ninety-seven patients were included into the study. Thirty-two patients have impaired JPS and 65 patients have normal JPS. Demographic and clinic characteristics of the patients are presented in e-I. The two groups were similar in terms of age, gender, time since stroke, type of injury, paretic side, lower extremity motor recovery and activity level. The comparison of the groups in terms of gait kinematic and kinetic characteristics is presented in Table-II and Table-III.

There was no difference regarding time-distance parameters between two groups. Patients with impaired JPS had greater pelvic joint rotation degrees in coronal plane (obliquity) than the patients with normal JPS (p=0.014). Ankle excursion in sagittal plane was significantly limited in both paretic and nonparetic sides (p=0.0001 and p=0.0001, respectively) for the patients with impaired JPS. A decrease of the peak exten-

Tablo-II

Time-distance parameters of the patients

	Impaired JPS* N=32	Normal JPS* N=69	P	Impaired JPS* N=32	Normal JPS* N=69	P
	Paretic side			Non paretic side		
Walking Velocity (m/s)	0.419±0.33	0.367±0.13	0.324	0.426±0.36	0.338±0.14	0.508
Step time(s)	0.971±0.53	0.974±0.29	0.291	0.957±0.57	0.838±0.25	0.715
Step length (m)	0.332±0.15	0.295±0.09	0.296	0.308±0.19	0.298±0.12	0.927
Double support time (s)	1.018±0.69	0.797±0.33	0.490	1.031±0.71	0.892±0.46	0.798

* JPS: joint position sense

Tablo-III

Time-distance parameters of the patients

	Impaired JPS* (n=32)	Normal JPS* (n=69)	P	Impaired JPS* (n=32)	Normal JPS* (n=69)	P
	Paretic side			Non paretic side		
Pelvic tilt(degrees)	7.678±6.10	7.273±4.26	0.501	7.003±6.29	7.500±4.24	0.147
Pelvic excursion in sagittal plane	5.190±3.27	6.291±2.71	0.127	5.394±2.81	6.435±2.88	0.115
Pelvic excursion in Coronal plane	12.449±5.74	10.215±4.40	0.137	12.412±5.28	10.334±6.01	**0.014**
Hip excursion (degrees)	27.462±16.70	24.372±7.72	0.149	33.072±12.78	34.996±8.35	0.911
Knee excursion (degrees)	35.791±17.54	32.106±10.53	0.612	40.650±11.38	42.865±9.26	0.687
Ankle excursion (degrees)	10.199±7.24	21.895±15.04	**0.001**	11.252±5.77	18.214±7.55	**0.001**
Peak extensor moment of the knee	0.283±0.29	0.305±0.32	0.747	0.159±0.23	0.355±0.32	**0.048**
Peak plantar flexor moment of the ankle	0.923±0.41	0.782±0.44	0.298	0.882±0.34	0.849±0.44	0.685

* JPS: joint position sense

sor moment of the knee in nonparetic side (p=0.048) was also observed, compared to patients with normal JPS.

DISCUSSION

In the present study, kinematic and kinetic gait characteristics of hemiparetic patients with stroke were found to be effected by ankle JPS. Patients with impaired JPS had greater pelvic obliquity than the patients with normal JPS. Ankle excursion in sagittal plane was significantly limited in both paretic and nonparetic sides of the patients with impaired JPS. Hemiparetic gait is characterized by slow speed, a short stance phase, poorly coordinated movements, and decreased weight-bearing on the paretic leg (18,19). Previous studies on hemiparetic gait showed not only the time-distance characteristics but also the altered kinetic and kinematic gait profiles compared to controls (20-22). Recent studies regarding the effect of JPS on hemiparetic gait, did not evaluate the gait kinetics and kinematics (1,9). Our study is the first (to our knowledge) which evaluates the effect of the ankle JPS on whole lower extremity morbidity by using 3-dimensional gait analysis.

Control of functional locomotion requires continuous sensory afferent input (23). Impaired sensory function may affect the ability of muscle activity during walking (1). Patients who suffer from impaired sensory function may tend to be slower to regain functional ability (8,24). In the present study there is no difference between the groups regarding FIM scores. Further studies should be developed to assess the predictive value of JPS on functional ability by evaluating FIM scores even after rehabilitative interventions, in patients with impaired JPS.

It has been reported that the tactile and proprioceptive impairments of the affected leg influence the walking velocity in stroke patients (1,8-11). Despite the results of these studies, insignificant correlations between the JPS and gait velocity have also been observed (12,24). In the present study walking velocity of the patients with impaired JPS was found to be decreased but not reached to statistically significant values. The reason of the different results of the studies may be probably due to the different measurement technique of gait velocity such as cinematography, interrupted light photography, GaitMAT II, Vicon motion analysis system, GAITRite system etc. On the other hand, patients might have improved their gait velocity by using the compensation technique better in the present study.

There is a general consensus that most moments are reduced, being smaller on the paretic than the non-paretic side, and smaller in both limbs of stroke patients compared to controls (25). Decrease of joint excursions in sagittal plane in hip, knee and ankle was reported by Chen et al (26). In a recent study, paretic hip and ankle are found to display abnormally large external rotation throughout the gait cycle (27). In the present study, we found decreased ankle excursion in sagittal plane in both sides of patients with impaired JPS. In a previous study investigating the gait deviations of patients with diabetes mellitus (DM) (28) same limited ankle mobility in sagittal plane was reported in patients with diabetic sensory neuropathy. The authors attributed this result to impaired proprioception due to neuropathy as well as hyperglisemic alterations in locomotor system. Diabetes mellitus is a very common comorbidity of stroke patients however we did not document its frequency in our study group. In the present study, both paretic and nonparetic sides revelaed limitation in ankle mobility which might be due to a more systhematic cause such as DM than a stroke.

Patients with impaired JPS had greater pelvic joint rotation degrees in coronal plane (obliquity) than the patients with normal JPS. Hemiparetic patients with impaired JPS tend to use coronal plane pelvic compensations in order to move the lower extremity forward. In addition to that, impaired JPS decreases the range of ankle motion degree in sagittal plane as well as restricts the knee extensor moments and make walking more difficult for these patients.

In conclusion, impaired JPS effects gait pattern in hemiparetic patients after stroke. Rehabilitation programs for stroke should focus on improving ankle proprioception or promote compensations for safe ambulation.

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