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Original Research

The Effect of Lateral Wedge Insole on Inter-joint Coordination during Walking in People with Medial Knee Osteoarthritis

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ABSTRACT

The purpose of this study was to investigate the features of inter-joint coordination in lower joints of osteoarthritis patients and compare them with healthy subjects. 10 patients with knee osteoarthritis and 10 healthy individuals volunteered to participate in this study. A Vicon 3D Motion Analysis System was used to record kinematic variables during walking under three conditions: (a) bare feet walking, (b) walking with shoes with a 5-degree lateral wedge insole and (c) 0-degree insole. In this research, the vector coding method was used to estimate inter-joint coordination. Repeated measurement and ANOVA were used for within and between group comparisons, respectively. The significant level was set at $p<0.05$ for all analysis. Within group comparisons in the osteoarthritis group showed that the overall use of insole did not significantly change the inter joints coordination ($p> 0.05$). The results showed that difference between the control group with the injured foot in the osteoarthritis group occurred only in the mid-stance phase, and in the barefoot walking condition and walking with the 5-degree lateral wedge insole. According to the results of the present study, in addition to the necessity of treatment for the injured foot, the healthy foot should also be used treatment in patients with knee osteoarthritis.

Keywords: Osteoarthritis, Inter-joint coordination, Gait

Introduction

Coordination in human movement is essential for organizing complex and redundant degrees of freedom of the musculoskeletal system [1]. In Dynamical Systems Theory, movement patterns are results of a synergistic organization of the neuromuscular system based on the constraints of anatomical structures, environmental factors, and movement tasks [2]. Precise control of human walking requires multi-joint coordination [3]. This includes higher levels of neuromuscular controls to regulate the initiation, intensity, and adaptability of locomotion [4].

Osteoarthritis (OA) is one of the most common causes of chronic disability in the older adults, which greatly affects their lives [5]. The tibiofemoral joint is commonly involved and OA changes are more prevalent in the medial compartment than the lateral compartment (nearly 10 times) [6, 7]. Studies in this area have clearly shown that knee OA not only changes the mechanics at the knee, but also at the other lower limb joints during functional activities [8, 9]. It has been shown that cartilage damage progresses due to high joint load in the medial compartment and that pain increases as the deterioration increases [10]. Therefore, reducing the joint load in the medial compartment of the knee acts to improve the disease or to relieve pain. There are several treatments for preventing pain and improving the mobility of patients. In the moderate to severe knee OA, surgical treatment is performed [11]. However, the use of an insole is recommended as a non-invasive method to reduce knee loading [10, 12], and therefore reducing pain [13-15] and increasing mobility [12] in OA patients.

The biomechanical changes associated with knee OA are well documented [7, 16], and the influence of knee OA on the inter-joint coordination during movement was investigated by wang et al. (2009) [5]. Their results showed that despite significant changes of the joint kinematics knee OA did not change significantly the way the motions of the lower limb joints are coordinated during obstacle-crossing [5]. According to the available reports, the purpose of this study was to investigate the impact of insole on inter-joint coordination and to compare it with healthy individuals. We therefore assume that the use of insole can lead to increased coordination in the lower limb joints of patients with medial knee OA.

Material and Methods

The study population consisted of patients with medial knee OA who referred to Hamadan medical clinics and healthy individuals who volunteered to participate in the study. To determine the sample size with G*Power software with α= 0.05 and statistical power= 0.80, 10 individuals were considered for each group. 10 patients with medial knee OA (OA group) and 10 matched healthy men participated as a control group. Participants in the OA group completed the Koos Quality Assessment Questionnaire, which included pain, quality of life, symptoms of illness, and daily activity. People who have had injuries (except for medial knee OA in the OA group) over the past six months in lower extremities or neurological (muscle disease) and orthopedic diseases (bone fracture, tendonitis, sprain, strain, and joint surgery) were excluded from the study. Subjects also completed the consent to participate in the test. The protocol of this study was approved by the Medical Ethics Committee of Hamadan University of Medical Sciences under IR.UMSHA.REC.1396.368 dated 29 July 2017.

A Vicon 3D Motion Analysis System (Oxford Metrics, Oxford, UK) with four T20 series cameras with a frequency of 100 Hz was used to record kinematic variables during walking under different conditions. Kinematic data were recorded and analyzed using Vicon Nexus software (v1.8.2) 1,8,2 and Polygan software (v3.5.2). A total of 16 retro-reflective markers were positioned on the skin overlying specific bony landmarks or anatomical positions of the lower body based on the Plug-In Gait Marker Set (Vicon Peak, Oxford, UK)[17]. Each participant was walked with self-selected speed. The subjects' task in the laboratory consisted of: (a) bare feet walking, (b) walking with shoes with a 5-degree lateral wedge insole and (c) 0-degree insole. Each of these conditions was repeated 6 times and the average value was used for statistical calculations.

In this research, the vector coding method was used to estimate inter-joint coordination. The relative motion between the two segments can be quantified with the coupling angle (Formula.1), an angle subtended from a vector adjoining two successive time points relative to the right horizontal [18].

Formula 1:

$$\gamma_{j,i} = \tan^{-1}\left(\frac{y_{j,i+1} - y_{j,i}}{x_{j,i+1} - x_{j,i}}\right)$$

Where 0°≤ ≥360°, represents consecutive data points in a cycle (here expressed as a percent stance), and j identifies the multiple gait cycles. Once the corresponding vector is specified, this angle is denoted as the coupling angle. The mean coupling angle across the different gait cycles is again defined for each percentage (i) of the cycle (Formula.2) [18]:

Formula 2:

$$\bar{\gamma}_i = \begin{cases} \arctan(\bar{y}_i / \bar{x}_i)\, if \bar{x}_i \geq 0 \\ 180+\arctan(\bar{y}_i / \bar{x}_i)\, if x_i \leq 0 \end{cases}$$

Shapiro-Wilk test was used to evaluate the normality of the data and the possibility of using parametric tests. The experimental design of this study included two intra-group factors: (a) factor of walking with three-level (bare feet walking, walking with 0- degree insole and 5-degree lateral wedge insole), and (b) factor of foot with two levels (OA foot in OA group and the healthy foot for the OA group and the factor of gait phase with three-step (loading response, mid-stance, and push off); all data were analyzed in three sagittal, frontal, and horizontal planes. In this study, within group factor with two levels of OA (individuals with medial knee osteoarthritis) and control group (healthy individuals) was considered. According to the research design, repeated measure statistical method was used to compare within groups and ANOVA was used for comparison between groups. The calculations were done by SPSS (16.0 version), the statistical significance was assessed at p<0.05.

Results

The mean and standard deviation of participants' characteristics are presented in Table 1. As can be seen, the control group did not differ significantly in terms of demographic characteristics from the OA group.

Table 1. Mean and standard deviations of subjects' demographic variables in groups

	Groups		
Variables	OA	Control	Sig.
Age	51.70±5.70	50.75± 3.23	0.72
Height	1.70±0.72	1.73±0.31	0.18
Mass	74.10±14.66	82.34±5.79	0.12
BMI	26.72±5.21	27.34±1.69	0.72
Quality evaluation of koos			
Pain (0-100)	46.82±15.78	-	-
Symptoms of Disease (0-100)	53.20±16.35	-	-
Daily Living Activity (0-100)	47.78±17.19	-	-
Quality of life (0-100)	35.49±21.27	-	-

Note: abbreviations: SD: standard deviation, BMI (Body Mass Index, age in year, height in meters, mass in kilograms.

Tables 2-4 show a descriptive analysis of the variables. In this study, the inter joints coordination in three gait conditions was investigated in barefoot and using two insoles with 0° insole and 5° lateral wedge insole. Within group comparisons in the OA group showed that the overall use of insole did not significantly change the inter joints coordination (p>0.05). Also, the factor of foot had a significant effect on a sagittal and horizontal plane in the knee-hip joint and also on the horizontal plane in the ankle-hip joint (p< 0.05). Paired sample t-test results showed that there was a significant difference between injured and healthy legs in the mid-stance phase and in the ankle-hip joint. There were no significant differences in the other planes; injured and healthy foot. Therefore, there was no significant difference between the joints in both injured and healthy foot (p> 0.05).

A comparison of the within group results showed that the difference between the control group with the injured foot in the OA group occurred only in the mid-stance phase, as shown in Table 1-3 with *. The comparison between the control group and the healthy foot in the OA group also showed that there was a significant difference at the sagittal and horizontal planes in the mid-stance phase and between the knee-ankle joints as indicated in Table 1-3 with **. In all cases, there was a difference between groups in barefoot walking or walking with a 5-degree lateral wedge insole.

Table 2. Mean and standard deviations of inter joint coordination in frontal plane in groups

Variables						OA group					
			Control group			OA Foot			Healthy Foot		
Plane	Joint	phase	N	D5	D0	N	D5	D0	N	D5	D0
Frontal	Ankle-Knee	L	119.5	116.5	98.4	106.2	130.4	103.4	110.1	76.1	58.7
			(95.8)	(115.1)	(107.9)	(93.9)	(113.1)	(82.4)	(96.9)	(49.0)	(19.9)
		M	204.8	213.5	182.6	218.1	229.0	210.1	135.1	200.7	208.2
			(43.2)	(45.5)	(42.3)	(74.9)	(40.7)	(53.2)	(99.7)	(52.4)	(67.0)
		P	76.6	76.1	75.0	97.6	69.9	66.8	102.3	99.0	83.6
			(18.5)	(20.7)	(22.8)	(63.3)	(23.7)	(25.5)	(62.2)	(59.3)	(9.6)
	Ankle-Hip	L	67.39	66.9	71.2	67.6	133	158.1	115.4	73.6	76.5
			(22.5)	(12.6)	(9.8)	(61.1)	(112.2)	(117.6)	(104.5)	(45.3)	(59.6)
		M	224.3	240.6	222.5	168.7*	194.8*	208.5	192.8	199.5	183.3
			(51.6)	(12.3)	(52.2)	(59.3)	(40.3)	(96.6)	(92.5)	(59.4)	(67.4)
		P	269.2	255.6	314.8	254.6	252.5	233.0	157.9	242.6	264.6
			(112.7)	(91.8)	(26.7)	(110)	(115.2)	(115.0)	(129.5)	(109.4)	(91.9)
	Knee-Hip	L	90.1	59.8	74.3	47.2	139.5	134.5	128.2	81.1	67.8
			(96.8)	(31.3)	(25.1)	(29.5)	(132.8)	(151.4)	(115.9)	(99.5)	(65.7)
		M	227.0	249.3	232.4	149.6*	190.1*	173.4	203.2	203.2	172.6
			(70.8)	(37.8)	(66.7)	(63.9)	(63.7)	(44.3)	(90.3)	(76.9)	(67.1)
		P	212.5	267.7	296.5	267.8	241.4	272.7	197.4	265.4	279.3
			(170.9)	(140.2)	(106.4)	(130.1)	(154.1)	(128.8)	(165.2)	(133.4)	(138.4)

Table 3. Mean and standard deviations of inter joint coordination in sagittal plane in groups

Variables						OA group					
			Control group			OA Foot			Healthy Foot		
Plane	Joint	phase	N	D5	D0	N	D5	D0	N	D5	D0
Sagittal	Ankle-Knee	L	88.9	73.9	92.9	68.6	83.6	96.5	87.1	78.1	60.7
			(89.9)	(11.0)	(24.7)	(88.5)	(58.9)	(70.2)	(89.7)	(59.1)	(37.0)
		M	327.3	332.4	332.5	296.5*	232.5	228.8	248.3	195.6**	263.2
			(25.2)	(14.1)	(12.3)	(164.7)	(152.9)	(136.6)	(149.5)	(146.5)	(128.3)
		P	122.2	109.3	105.2	107.8	108.9	96.4	111.3	114.8	103.9
			(50.9)	(10.1)	(10.2)	(9.6)	(7.6)	(26.6)	(21.2)	(31.3)	(11.7)
	Ankle-Hip	L	264.6	274.5	244.6	239.4	280.3	257.1	263.1	280.0	277.8
			(82.4)	(18.9)	(46.2)	(108.3)	(26.7)	(55.5)	(58.7)	(25.7)	(30.9)
		M	260.7	284.0	288.5	263.1	286.2	266.4	261.7	282.2	288.0
			(61.1)	(9.3)	(17.4)	(83.9)	(12.2)	(55.4)	(73.3)	(14.8)	(15.0)
		P	118.8	127.5	136.9	133.4	127.2	174.1	134.6	127.1	129.3
			(20.35)	(10.8)	(31.5)	(25.2)	(10.6)	(86.5)	(34.6)	(27.2)	(30.6)
	Knee-Hip	L	302.5	320.8	291.0	236.9	304.5	247.5	266.3	298.5**	308.8
			(65.7)	(12.3)	(87.6)	(121.1)	(21.8)	(112.4)	(86.4)	(17.7)	(25.1)
		M	262.5	269.1	262.7	255.9	270.4	228.9	255.5	270.8	268.4
			(27.5)	(3.1)	(18.0)	(59.1)	(8.2)	(87.4)	(53.5)	(8.1)	(14.1)
		P	44.0	28.3	94.4	61.2	29.6	92.0	62.1	63.7	64.3
			(38.0)	(5.8)	(136.7)	(103.9)	(4.9)	(140.2)	(99.2)	(95.4)	(101.2)

Table 4. Mean and standard deviations of inter joint coordination in horizontal plane in groups

Variables			Control group			OA group					
						OA Foot			Healthy Foot		
Plane	Joint	phase	N	D5	D0	N	D5	D0	N	D5	D0
Horizontal	Ankle-Knee	L	158.4 (70.9)	135.0 (18.7)	147.5 (61.0)	126.6 (50.9)	128.8 (27.5)	133.4 (32.1)	142.8 (73.1)	141.4 (64.4)	139.3 (30.2)
		M	302.5 (104.8)	290.8 (100.5)	329.5 (17.1)	219.3 (148.1)	224.9 (150.3)	168.1 (143.8)	183.8** (130.2)	221.5 (150.5)	314.5 (56.9)
		P	155.4 (62.4)	109.5 (29.4)	116.3 (38.7)	115.0 (41.2)	139.7 (47.9)	108.4 (35.6)	140.5 (45.9)	120.3 (31.1)	120.0 (38.6)
	Ankle-Hip	L	149.8 (48.5)	163.4 (25.0)	167.6 (35.3)	183.1 (94.6)	185.4 (38.9)	181.6 (52.8)	164.4 (82.1)	160.2 (63.4)	161.7 (40.5)
		M	66.0 (97.9)	41.1 (20.9)	23.2 (10.8)	132.4 (142.6)	191.4* (161.9)	188.7 (142.0)	101.1 (101.4)	124.4 (151.7)	70.4 (103.0)
		P	132.8 (46.1)	135.8 (51.1)	141.0 (49.6)	143.4 (57.5)	141.6 (27.5)	181.8 (66.8)	125.4 (49.9)	169.7 (51.6)	119.6 (40.0)
	Knee-Hip	L	80.4 (110.5)	64.2 (106.1)	122.2 (155.9)	153.2 (150.2)	198.8 (159.5)	199.2 (147.2)	112.5 (105.1)	114.0 (124.7)	105.5 (129.1)
		M	137.2 (51.5)	127.7 (27.4)	149.8 (17.3)	134.1 (92.8)	212.6* (63.7)	196.2 (83.3)	155.9 (104.6)	167.6 (62.3)	161.5 (39.1)
		P	84.7 (98.1)	95.2 (138.3)	116.3 (148.5)	108.4 (125.4)	37.1 (30.5)	119.1 (144.0)	92.9 (88.6)	95.1 (118.7)	79.8 (97.5)

Discussion

The purpose of this study was to investigate the effect of insole on the lower limbs inter joints coordination in three dimensions in patients with medial knee OA during walking. The results of within group comparisons in the OA group showed that overall insole use did not cause a significant change in inter-joint coordination. Many studies have investigated the effect of insole or anti-pronation shoes on biomechanical variables during walking [19-22]. Jafarnejadgero et al., 2020 showed that prolonged use of the insoles improves coordination and coordination variability between lower extremity joints in people with flat foot during walking [23].

One possible reason for the difference in the results of the present study with Jafarnejadegro et al., study is that the present study was investigated the immediate effect of insole, while in that research was evaluated the effect of long-term use of the insole.

The results showed that there was a significant difference between injured and healthy foot in the mid-stance phase at the horizontal plane and ankle-hip joints. The difference was that the coordination between the ankle-hip joint on the frontal plane at the injured foot was anti-phase whereas in the healthy foot this coordination was in-phased. The injured foot is the movement of the hip toward adduction and the ankle motion toward the eversion, whereas in the healthy foot the thigh movement is towards the abduction and the ankle joint is directed toward the eversion. Increasing the hip joint adduction angle in the closed kinetic chain (lateral shift of the pelvis) can reduce injury of ankle eversion, caused by the ankle inversion, because it moves the center of mass more towards the lateral edge of the foot [24].

The findings of the present study showed that the ankle and hip joints have compensatory movements in the injured foot which can reduce the load on the joints. However, due to the pattern of coordination observed in the frontal plane between the ankle and hip joints during the mid-stance phase, there may be a long-term injury in the healthy foot. According to the results of the present study, in addition to the necessity of treatment for the injured foot, the healthy foot should also be used treatment in patients with knee OA.

However, the insole used in the present study did not show a change in the pattern of coordination between the lower extremity joints in both healthy and injured foot during walking in subjects with knee OA.

The present study has some limitations such as the low statistical sample size of the present study. On the other hand, in this study, only the immediate effect of using the insole was evaluated, while long-term use of insoles may show different results.

Conclusion

According to the results of the present study, in addition to the necessity of treatment for the injured foot, the healthy foot should also be used treatment in patients with knee osteoarthritis. However, the insole used in the present study did not show a change in the pattern of inter joints coordination between the lower extremity in both healthy and injured foot during walking in subjects with medial knee osteoarthritis.

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چکیده فارسی

تأثیر کفی کفش با لبه خارجی بر هماهنگی بین مفصلی طی راه رفتن در افراد دارای استئوآرتریت داخلی زانو

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هدف از این مطالعه بررسی هماهنگی بین مفاصل اندام تحتانی بیماران مبتلا به استئوآرتریت و مقایسه آن‌ها با افراد سالم بود. در این مطالعه ۱۰ بیمار مبتلا به استئوآرتریت داخلی زانو و ۱۰ فرد سالم و مشابه که داوطلب شرکت در این مطالعه بودند، شرکت کردند. برای ثبت متغیرهای کینماتیکی گام-برداری تحت شرایط مختلف از یک سیستم تحلیل حرکت وایکان استفاده شد. وظیفه افراد در آزمایشگاه شامل: (الف) گام‌برداری با پای برهنه، ب) گام-برداری با کفش دارای کفی با لبه خارجی ۵ درجه و (ج) گام‌برداری با کفش دارای کفی با لبه خارجی صفر درجه بود. در این پژوهش، از روش برنامه-نویسی برداری برای برآورد هماهنگی بین مفاصل استفاده شد. مقایسه درون‌گروهی در گروه استئوآرتریت نشان داد که استفاده از کفی تاثیر معنی‌داری بر هماهنگی بین مفاصل ندارد ($P> 0.05$). همچنین نتایج نشان داد که تفاوت بین گروه کنترل با پای آسیب‌دیده در گروه استئوآرتریت فقط در مرحله میداستانس رخ داده است، که در وضعیت گام‌برداری پابرهنه و راه رفتن با یک کفی ۵ درجه اختلاف معنی‌دار بوده است. با توجه به نتایج مطالعه حاضر، علاوه بر ضرورت درمان پای آسیب دیده، مداخلات درمانی برای پای سالم نیز باید در بیماران مبتلا به استئوآرتریت زانو نیز ستفاده شود.

واژه‌های کلیدی: استئوآرتریت زانو، هماهنگی درون مفصلی، گام‌برداری