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Correlation between the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) Scores and the Stability Metrics in Patients with Knee Osteoarthritis

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ABSTRACT

Aims: The aim of the present study was to assess the correlation between the stability metrics related to the center of pressure excursion measurements and the WOMAC questionnaire scores.
Method and Materials: Fourteen patients with moderate knee osteoarthritis and fourteen healthy age-matched individuals were participated to stand with open and closed eyes, and on firm and rocking support on a force platform. The WOMAC questionnaire was obtained from the patient group. One-way ANOVA was utilized to determine the effects of knee osteoarthritis, vision, and support on postural stability metrics. Spearman's correlation was also used to indicate the correlation between the stability metrics and the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) sub scores.
Findings: The anterior-posterior variability of the center of pressure was significantly greater in patients (2.7 mm, p=.003). Elimination of the visual feedback and the rocking support affected the sway area and the AP (p<.001), and the ML variability (p<.024). The pain subscore of the WOMAC questionnaire was negatively and strongly correlated to the AP total mean velocity (open-eyes: r=-.466, closed-eyes: r=-.779). The pain was positively and strongly correlated to the AP variability (open-eyes: r=.796, closed-eyes: r=.744). Patients with knee osteoarthritis showed more postural instabilities.
Conclusion: The instability in the anterior-posterior was more eminent than in the lateral direction. The pain was the most role-playing factor in the destabilization of the posture among the patients with knee osteoarthritis but may be disregarded in physically-difficult conditions of standing.

Keywords: Knee Osteoarthritis; Postural Control, WOMAC Questionnaire, Pain, Center of Pressure.

Introduction

Providing stability during standing is the basic locomotion task for other daily activities which is intervened by Knee OsteoArthritis (KOA) [1-3]. The KOA causes to pain and stiffness, declined functional performances, and muscle weakness [4]. The detected instability in the standing of patients with KOA is often quantified by some linear or nonlinear metrics related to the Center of Pressure (CoP). The literature is well documented by studies that showed CoP-related instabilities due to uni/bi-lateral KOA could involve in different tasks and sensory conditions [5-7]. On the other hand, some studies have focused on the functional tests and also the self-administered questionnaires [8-10]. One of the most commonly-used questionnaire is the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) which quantifies the major symptoms like pain, stiffness, and physical performance in different daily tasks and functions [11]. The biomechanical assessments to reveal CoP-related metrics also design tasks that are the fittest ones to daily activities [12-14], or a bit more difficult to provoke hidden neuro-musculoskeletal reactions [15-17].

The relationship between the biomechanical assessment of stability and the functional self-described scores may unveil the underlying role-playing factors in postural destabilization. However, it has

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gained the attention of limited researchers. For instance, Debi et al. (2011) showed a negative correlation between the single-leg stance phase duration and the WOMAC scores [15]. Although Hirata et al. (2013) found that the pain intensity is correlated to the CoP range in the mediolateral direction only in the closed-eyed condition [2], Petrella et al. (2017) indicated that the WOMAC scores in pain and physical performance are negatively correlated to the anterior-posterior displacement and velocity of the CoP movement [18].

According the challenges that mentioned above, the aim of the present work was to evaluate the possible correlations between the WOMAC scores and the CoP-related metrics of stability for patients with KOA by considering different visual and support conditions. It was hypothesized that worse WOMAC scores are correlated to more sways and variations, and less sway velocities.

Method and Materials

In this cross-sectional study fourteen healthy individuals and fourteen patients with knee osteoarthritis have been participated. The patients had moderate knee osteoarthritis which were diagnosed by the radiographic imaging and it was assured that their K-L index was between grade II and III. Both healthy individuals and patient had no history of lower limb, back surgery or using of prosthesis. Moreover, they had no neurological, muscular, or orthopedic diseases that affect normal posture with an exception to the knee osteoarthritis for the patient group. All participants were informed about the test conditions and procedures and were asked to sign the written informed consent form. All ethical issues were considered in the study and the study procedures were approved by the ethical committee of Tarbiat Modares University (TMU).

For conducting this study, the participants were asked to stand barefoot with crossed arms in four different situations: 1) open eyes on the firm support, 2) open eyes on the rocking support, 3) closed eyes on the firm support, and, 4) closed eyes on the rocking support. The rocking support was a 40 × 55 cm wooden plate that was capable of rotating forth and back (pitch movement) because of three semi-ellipses (minor axis = 26 cm) attached beneath. The rocking plate was supported by a pair of springs (stiffness = 4 kN/m) in the front and rear. These situations were designed due to imposing further challenges on the balance in the knee osteoarthritis patients in a reduced and moving base of support and also in the absence of visual feedback. The order of standing conditions was randomized for each participant. Each situation had three 30-second trials.

For data collection, a 60 x 40-cm force platform (Kistler, type 9286AA, Winterthur, Switzerland) was utilized to measure the excursion of the participants' CoP with a sampling rate of 1200 Hz. In situations where the participants stood on the rocking support, it was placed on the force platform. In addition, the Farsi version of the WOMAC questionnaire was also utilized to assess self-administered pathological concerns about pain, stiffness, and physical functions of the knee (19, 20). The higher score of each part and total (which ranges from 0 to 96) imply worsened cases.

For data analysis, postural assessment of the participants in four test situations included calculation of three linear metrics of Sway Area (SA), Total Mean Velocity (TMV), and Variability (VAR), as well as one nonlinear Fractal Dimension (FD) metric. The SA is the area of an ellipse that encloses at least 95% of the swayed CoP data in the plane of anterior-posterior and

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mediolateral directions. The TMV is also the total path length of the CoP in each direction over the total duration time. The variability is the standard deviation of the CoP data in each direction. The FD is also calculated based on Higuchi's algorithm which considers the absolute slope of the log-log diagram of the path lengths against the measures' length [21].

To do statistical analysis, one-way Analysis of Variance (ANOVA) was used to assess the statistically-significant effects of the independent parameters of the group (knee osteoarthritis vs. control), vision (open vs. closed eyes), and support (firm vs. rocking) on the dependent postural control parameters extracted from the CoP data. This analysis was done after checking the normality of distribution of the outputs by the Kolmogorov-Smirnov test. Spearman's correlation test was also utilized to assess how the WOMAC questionnaire scores and stability metrics are correlated to each other. The statistical significance level was considered as 5% for the statistical analyses.

Findings

Totally 14 healthy individuals with age and Body Mass Index (BMI) of [age = 55.4 ± 5.6 year, BMI = 26.7 ± 2.4 kg/m^2] and 14 KOA patients with age and BMI of [age = 56.8 ± 6.1 year, BMI = 25.9 ± 3.8 kg/m^2] participated in the present study. The total WOMAC score for the patients with knee osteoarthritis was 41.1 ± 12.5. The pain sub-score was 9.1 ± 2.8, the stiffness was 4.0 ± 1.3 and the physical function sub-score was 27.2 ± 12.4.

Figure 1 shows the changes in the sway area among the control and KOA patient groups by removing the visual feedback and reducing the base of support. Sway area of the CoP was significantly increased in the KOA patients only in the open-eyes on the rocking support condition (p = .044, h^2 = 0.81).

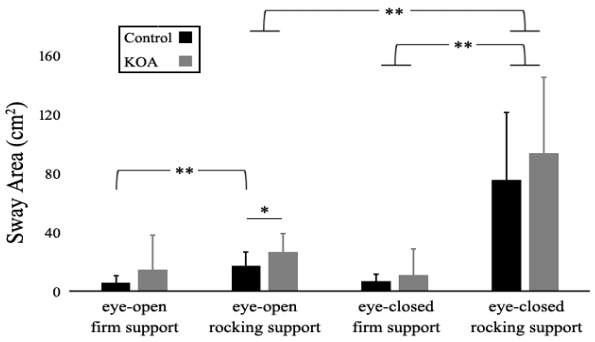

Fig 1) Sway area of CoP excursion for control and patient groups in four test conditions. *significance levels of p < .05 and ** significance levels of p < .001

Table 1 presents the mean values of the other stability parameters (i.e. FD, TMV, and VAR) for control and KOA participants with their group's statistical comparison in four standing tasks. Merely the anterior-posterior variability of the patients on the rocking support has been significantly increased (eye-open: 3.2 cm, P= .032, h^2 = 0.21; eye-closed: 6.1 cm, P = .034, h^2 = 0.21) rather than the healthy controls. Other parameters were not changed due to knee osteoarthritis. The main and interactive effects of the knee osteoarthritis, vision, and support conditions on the stability parameters in both mediolateral and anterior-posterior directions have been gathered in Table 2. Variability of the CoP in the anterior-posterior direction was significantly increased by the knee osteoarthritis, although the sway area and mediolateral variability were near to be significant. These three stability parameters (i.e. SA, VAR-AP, and VAR-ML) were also significantly increased by the removal of the visual feedback. Reduction of the base of support by standing on the rocking support also increased fractal dimension in the mediolateral direction as well as the sway area and variability in both directions. The interactive effects were not effective on the stability parameters unless the simultaneous vision and support effect increased significantly the sway area, anterior-posterior fractal dimension, and

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Table 1) Stability parameters of the participants of both groups with group effect's P-values (if significant with their h^2 effect size) in two AP and ML directions for four test conditions.

	Anterior - Posterior			Medio - Lateral		
	Control	KOA	p-value	Control	KOA	p-value
Open eyes – Firm support						
FD	1.49 (.09)	1.48 (.07)	.625	1.54 (.14)	1.51 (.15)	.576
TMV	.11 (.06)	.11 (.04)	.928	.13 (.05)	.15 (.05)	.451
VAR	4.97 (1.80)	6.71 (3.96)	.177	3.17 (2.00)	5.89 (5.55)	.142
Open eyes – Rocking support						
FD	1.56 (.06)	1.53 (.08)	.250	1.68 (.07)	1.54 (.13)	.986
TMV	.10 (.04)	.11 (.04)	.477	.14 (.05)	.15 (.05)	.362
VAR	10.16 (2.66)	13.40 (3.81)	*.032 (.21)	5.46 (2.00)	6.13 (1.91)	.441
Closed eyes – Firm support						
FD	1.55 (.06)	1.56 (.10)	.856	1.56 (.12)	1.54 (.13)	.758
TMV	.10 (.04)	.10 (.03)	.918	.13 (.05)	.15 (.05)	.514
VAR	6.13 (1.50)	5.94 (1.31)	.757	3.54 (2.04)	3.50 (1.36)	.957
Closed eyes – Rocking support						
FD	1.53 (.07)	1.48 (.08)	.116	1.67 (.08)	1.60 (.31)	.429
TMV	.13 (.06)	.13 (.05)	.928	.15 (.05)	.17 (.08)	.525
VAR	21.88 (6.83)	27.98 (5.70)	*.034 (.21)	9.03 (3.78)	9.34 (4.45)	.863

* Significant effects of the knee osteoarthritis ($p < .05$).
FD: Fractal Dimension , TMV: Total Mean Velocity , VAR: Variability and KOA: Knee OsteoArthritis

Table 2) The main and interactive effects of the knee osteoarthritis (KOA), vision and support conditions on stability parameters of sway area (SA), fractal dimension (DF), total mean velocity (TMV) and variability (VAR).

		Anterior-posterior			Mediolateral		
	SA	FD	TMV	VAR	FD	TMV	VAR
Knee Osteoarthritis	.077 [a]	.139	.809	.003 [b]	.323	.144	.057 [c]
Vision	< .001	.317	.323	< .001	.746	.541	.024 [d]
Support	< .001	.723	.203	< .001	< .001	.239	< .001
KOA × Vision	.327	.905	.794	.884	.662	.932	.531
KOA × Support	.229	.255	.798	.143	.847	.875	.799
Vision × Support	< .001	< .001	.100	< .001	.303	.591	< .001
KOA × Vision × Support	.228	.547	.654	.596	.466	.997	.282

The h^2 effect sizes are a = .030, b = .084, c = .034, d = .048.

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Table 3) The Spearman's rho correlation coefficients between the WOMAC questionnaire scores and stability parameters. The bold-faced coefficient numbers denote significant correlations ($p < .050$).

		Anterior-Posterior			Mediolateral		
	SA	**FD**	**TMV**	**VAR**	**FD**	**TMV**	**VAR**
Open eyes – Firm support							
Pain	.388	***- .514**	***- .466**	***.796**	***- .601**	- .283	.494
Stiffness	.278	- .401	- .371	.094	***- .722**	- .014	.283
Physical Performance	.246	- .042	- .086	.548	- .166	- .051	.032
Total	***.660**	- .361	- .220	***.665**	***- .598**	.031	.588
Open eyes – Rocking support							
Pain	.276	- .388	- .377	.494	- .408	- .457	.009
Stiffness	.170	- .158	- .310	.283	**- .586**	- .319	- .202
Physical Performance	.162	- .140	.069	.393	- .007	- .091	- .183
Total	.398	- .403	- .062	**.656**	- .398	- .130	.032
Closed eyes – Firm support							
Pain	***.502**	- .184	***- .776**	***.744**	***- .585**	- .265	***.673**
Stiffness	.380	- .172	- .419	.461	- .373	- .005	.381
Physical Performance	.233	.140	- .441	.507	- .308	.020	.306
Total	***.524**	.009	***- .506**	***.843**	- .365	.070	***.738**
Closed eyes – Rocking support							
Pain	- .049	- .314	- .206	.231	***- .514**	- .287	- .042
Stiffness	- .392	- .290	- .210	.028	- .401	- .102	- .542
Physical Performance	.042	- .095	.069	.032	- .042	- .060	- .174
Total	.110	- .040	.070	.196	- .361	.042	.096

* Significant correlations ($p < .050$).
FD: Fractal Dimension , TMV: Total Mean Velocity , VAR: Variability

variability in both directions of the CoP excursions.

In order to investigate the relationship between the quantitative stability parameters and the self-reported clinical scale of the knee osteoarthritis, Table 3 presents the Spearman's correlation coefficients of the SA, FD, TMV and VAR, and the total score, pain, stiffness, and physical functions sub-scales. The pain subscale was the mostly-correlated clinical factor to the stability metrics. Among the standing tasks, the highest correlations were observed in the easier tasks i.e. standing on a firm support. While the eyes were open, the pain was highly and significantly correlated to the TMV and VAR in the anterior-posterior direction and the FD of both directions of the CoP excursions. In regard to the stability metrics, the FD in the mediolateral direction has revealed more correlations to the clinical scales.

Discussion

The present study was aimed to investigate the postural control of the patients with knee osteoarthritis and its relationship to the clinical features of the WOMAC

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questionnaire. It was indicated that patients with KOA have instabilities in the anterior-posterior direction which is significantly related to the WOMAC pain score.

The variability of the CoP in the anterior-posterior direction was the main measure in the discrimination of the effects of knee osteoarthritis. The variability, that is the standard deviation of the CoP excursions during the standing tasks, is a measure to elucidate the neuromuscular control of posture [22], whose increase balance instabilities. One reason behind the significant increase in the anterior-posterior CoP variability may be related to the impaired proprioception of the patients with KOA [8, 23]. Keeping the variability in a normal range for the individuals even during a quiet standing task is associated with the use of sensory feedback information [24, 25], mainly from the somatosensory which are shown to be not accurate enough in these patients [8, 23]. In addition, another reason for greater CoP variability among the patients with KOA rather than the healthy control people may be the painfulness of their osteoarthritic knee. It was stated that the pain, per se, is an explanatory factor for more postural sways in patients with KOA [8]. The pain also caused more muscle recruitments [26]. Although Masui et al. (2006) stated that the postural sways are more related to the radiographic Kellgren-Lawrence grades than the pain [27], Lyytinen et al (2010) showed opposed outcomes [28].

The elimination of visual feedback and support conditions also increased the CoP sway variability. Truszczyńska-Baszak et al. (2020) reported that the visual cues make no difference in the postural instabilities of the patients with severe KOA [29]. However, Hirata et al. (2013) showed that the existing vision is important for maintaining the balance in severe KOA patients [2]. The support condition also increased the variability of the AP CoP. Ivanenko et al. (1997) showed the difficulty of standing on an unstable platform even for the healthy controls [16, 30, 31]. The difficulty in standing for such a condition has originated from the narrow horizontal beam of the base of support where the semi-ellipses of the platform contact the ground. The body should keep the center of gravity inside this narrowed area. These endeavors led to a remarkable increase in the variability of the CoP sway in comparison with the firmed support condition.

The variability in the mediolateral direction was also discriminative for the main effects unless the role of the knee osteoarthritis was near to significant. The elimination of vision and unstable support conditions were also significantly increased the variability in the mediolateral direction. Since the patients in this research were all unilaterally suffered from the KOA, it was expected to have more significant effects in the mediolateral direction due to the unloading of the involved leg as reported by Hinman et al. (2002) who stated more instabilities in the mediolateral direction in the patients [5]; but pairwise comparisons in this study (shown in Table 1) reflected opposite outcomes. The excursion of the CoP in the mediolateral direction is, in general, the result of con-contractions between the gluteus medius muscles (hip abductors). Duffell et al. (2014) showed that the electromyographic activity of the gluteus medius of the unaffected side is considerably more than the controls unlike the KOA affected side [32].

Total mean velocity was not changed because of any independent variables in this study. This metric is the averaged velocity of the CoP movement i.e. the total path traveled in the force platform divided by the total time which is the same for all cases. The direction of the velocity or other nonlinear metrics based on the velocity of the CoP might differ between the groups since it is

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more related to the activation of muscles. Fractal dimension had roughly the same condition against the independent variables of the study. This nonlinear metric measures the fine variations of a signal but only could detect the role of support condition in the ML direction. Ashtiani and Azghani (2017) used this metric to show the effective role of the cognitive loads while standing after rotational perturbations. They indicated that the elimination of vision does not change the fine fluctuations of the individuals' center of mass movements [33].

The correlation between the WOMAC scores and the postural indices of stability confirmed the adverse effects of the painful knee on balance maintenance in accordance with the previous studies [2, 15, 18]. The variability of the AP CoP was significantly and positively correlated to the WOMAC pain score to imply more sense of pain in the knee with osteoarthritis cause higher variability in the posture disregarding the presence of visual feedback. However, standing on the unstable platform reduced this correlation. This meant that when the balance is jeopardized by the rocking support, the pain is not the priority of the Central Nevus System (CNS). Roughly none of the correlation coefficients between the WOMAC scores and postural balance is significant for the rocking support conditions (see Table 3). In other words, standing in a physically-difficult condition vanished the correlations between pathological and postural concerns. Total mean velocity was also significantly negatively correlated to the WOMAC pain score indicating that more painful knee causes slower CoP movements again in the standing on firm support lonely. The literature also has reported the negative correlation between the AP velocity and the WOMAC pain score [18]. Furthermore, Robon et al. (2000) showed that the gait velocity for the patients with knee osteoarthritis is significantly less than the aged-matched control subjects and this is a kind of compensatory mechanism to reduce joint forces [34]. This information implies that the patients with KOA ignored the pain sensation while standing on the rocking support.

This study has faced some limitations. The rocking support was only able to wobble in the pitch direction. Moreover, this study excluded the patients with severe grade of the knee osteoarthritis which might cause diverse effects on the postural outputs

Conclusions

Patients with knee osteoarthritis have more postural instabilities than healthy people. Elimination of visual feedback and standing on rocking support caused instability in posture for both healthy and KOA-suffered individuals. The instability in the anterior-posterior was more than in the lateral direction. The pain was the role-playing factor in destabilizing the posture among the patients with knee osteoarthritis. The painful knee was neglected when physical difficulties were imposed on the CNS during the control of posture.

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Authors Contribution

IH has acquired the data and analyzed them. He has also participated in discussions and writing of the manuscript. MNA has developed the main idea of the study and designed the experiments. He also analyzed the data, helped with discussions, and wrote the manuscript. FB has participated in the development of the main idea, design of experiments, discussions, and writing of the manuscript.

Conflict of Interest

No conflict of Interest declared by authors.

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Ethical Permission

This study approved by the ethical committee of Tarbiat Modares University (TMU). The ethical code is IR.MODARES.REC.1398.094.

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