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ORIGINAL REPORT

INFLUENCE OF HIP AND KNEE OSTEOARTHRITIS ON DYNAMIC POSTURAL CONTROL PARAMETERS AMONG OLDER FALLERS

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Objective: **To compare the relationship between postural control and knee and hip osteoarthritis in older adults with and without a history of falls.**

Methods: **Fallers were those with ≥ 2 falls or 1 injurious fall over 12 months. Non-fallers were volunteers with no falls in the past year. Radiological evidence of osteoarthritis with no reported symptoms was considered "asymptomatic osteoarthritis", while "symptomatic osteoarthritis" was defined as radiographic osteoarthritis with pain or stiffness. Dynamic postural control was quantified with the limits of stability test measured on a balance platform (Neurocom® Balancemaster, California, USA). Parameters assessed were end-point excursion, maximal excursion, and directional control.**

Results: **A total of 102 older individuals, mean age 73 years (standard deviation 5.7) years were included. The association between falls and poor performance in maximal excursion and directional control was confounded by age and comorbidities. In the same linear equation model with falls, symptomatic osteoarthritis remained independently associated with poor end-point excursion (β-coefficient (95% confidence interval) −6.80 (−12.14 to −1.42)).**

Conclusion: **Poor performance in dynamic postural control (maximal excursion and directional control) among fallers was not accounted for by hip/knee osteoarthritis, but was confounded by old age and comorbidities. Loss of postural control due to hip/knee osteoarthritis is not a risk factor for falls among community-dwelling older adults.**

Key words: aged; osteoarthritis; accidental falls; dynamic postural control; lower limb.

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One-third of individuals aged 65 years and half of those aged 80 years and above fall annually (1–3). Fall-related injuries are leading causes of years lived with disability globally (4). Falls in older adults are multifactorial. Established risk factors for falls include increasing age, muscle weakness, balance impairment, visual loss, hearing impairment and cognitive decline (5). Serious consequences associated with falls in older adults include hip fractures, traumatic brain injuries, institutionalization, depression and premature death (6, 7).

Radiological changes consistent with severe osteoarthritis (OA) of the knee are present in 30% of individuals aged 75 years or above (8). The presence of OA is associated with balance deficits and impaired dynamic postural control compared with individuals without OA (9–15). The loss of balance associated with OA has been attributed to the symptoms of pain and stiffness (16, 17). A previous uncontrolled study reported that 50% of individuals with severe OA experience at least 1 fall in the previous year (18). Based on the above circumstantial evidence, OA has been considered a risk factor for falls in older adults.

While it would appear likely that falls occur in older adults with OA as the result of loss of postural control attributed to the symptoms of OA, this hypothesis has, however, not been substantiated by published evidence. Therefore, the aim of this study was to evaluate the role of OA in deficiencies in postural control observed among older adults with falls.

METHODS

Participants

Fallers were subjects 65 years and above and with 2 falls or 1 injurious fall over the past 12 months, recruited from the Departments of Emergency Medicine, Primary Care and Geriatric Medicine, in a teaching hospital in Kuala Lumpur, Malaysia, for a randomized controlled study on multifactorial interventions (Malaysia Falls Assessment and Interventional Trial, MyFAIT) (19). Control participants consisted of older volunteers (aged ≥65 years) with no history of falls over the past 12 months, recruited through media and word-of-mouth advertising. Participants from both case (fallers) and control (non-faller) groups received detailed baseline assessments to obtain information on socio-demographics, medical history and medications. This study complied with the Declaration of Helsinki 1975. It was approved by the University of Malaya Medical Centre Medical Ethics Committee (approval number 925.4). Written informed consent was obtained from all study participants.

Assessment of dynamic postural balance

Each participant was tested with 3 established groups of balance tests, using a long force-plate balance platform (Neurocom® Balancemaster, Natus Medical Incoporated, Pleasanton, CA, USA). The balance platform uses a fixed 18 × 60" dual-force plate to measure the vertical forces exerted through the participant's feet.

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Individual task outcome was recorded and analysed with the standard software supplied with the equipment. All tests were conducted at a hospital-based physiotherapy gym in a controlled environment by a trained researcher. The combination of all 3 tests took 20 min to complete.

The limits of stability (LOS) battery of tests measures the maximum distance a person can intentionally displace their centre of gravity (COG) (20). Subjects were asked to lean their body in the forward, backward, lateral and intermediate directions without losing balance, stepping, or reaching for assistance. Directional control (DCL) (the amount of movement in the intended direction minus the amount of extraneous movement (off axis), expressed as a percentage), end-point excursion (EPE) (the distance travelled by the COG on the primary attempt to reach a target, expressed in percentage), and maximal excursion (MXE) (the furthest distance travelled by the COG) were measured through this test.

Diagnosis of osteoarthritis

Radiological osteoarthritis. Standardized radiographic images for the knees and hips were obtained in the antero-posterior (AP) view with the subject standing. A radiologist blinded to the clinical data and falls status assessed these images. The severity of OA was determined by the Kellgren–Lawrence (KL) grading scale (21). A score of 0 within the KL grading scale indicates the absence of any OA changes, while the maximum score of 4 represents severe OA changes (22). In this study, only subjects with KL grades of 2–4 (mild to severe OA) were classified as subjects with OA, while those with KL grade 0–1 (no or doubtful OA) were categorized as no radiological OA.

Osteoarthritis classification. Individuals with no radiological evidence of OA were considered the "non-OA" group. Those with radiological changes consistent with OA (KL grade 2–4), who had not reported any clinical symptoms of OA, such as pain or stiffness, were considered the "asymptomatic OA" group. Individuals with both radiological OA and presence of pain or stiffness in their affected joint were included in the "symptomatic OA" group (23, 24).

Power estimates and statistical analysis

The statistical power of the study was determined using G*Power 3.1 software (25). A sample size of 102 was calculated to provide 80% power to detect an effect size of 0.57 for differences in LOS between faller and non-fallers with hip and/or knee OA. This is considered a medium effect size. SPSS 20.0 (IBM SPSS Statistics) software package was used for statistical analysis. All continuous variables fulfilled normality criteria and were reported as means with standard deviations (SD). The differences between fallers and non-fallers were assessed using the independent sample *t*-test for continuous data and χ^2 test for categorical variables. Analysis of variance (ANOVA) with least significant difference (LSD) *post-hoc* test was used to compare dynamic postural control scores across fallers and non-fallers sub-groups without OA, with asymptomatic OA and symptomatic OA. Linear regression models were then constructed to determine the association between dynamic postural control parameters with falls and OA with and without adjustment for potential confounders. The relative influence of each variable on a postural control parameter would be expressed as odds ratios with 95% confidence intervals. A variable was considered statistically significant if the 95% confidence interval did not cross zero.

RESULTS

Demographic and clinical characteristics

A total of 102 subjects (60 fallers and 42 non-fallers) were recruited for the study. Fallers were significantly older than non-fallers, and significantly more likely to report a pre-existing diagnosis of diabetes mellitus. There was no significant difference in the presence of radiologically diagnosed hip or knee OA between fallers and non-fallers (Table I). Significantly lower MXE ($p=0.023$) and DCL ($p=0.031$) scores were present in fallers compared with non-fallers. No significant difference was observed in EPE ($p=0.185$) between fallers and non-fallers.

Within-group comparisons of postural control

Table II displays the EPE, MXE and DCL scores between the 3 categories: symptomatic OA, asymptomatic OA, and non-OA, within the 2 main groups of fallers and non-fallers. Among fallers, there was no significant difference in EPE, MXE or DCL during 3-way comparisons using ANOVA between the symptomatic OA, asymptomatic OA and non-OA groups. Among non-fallers, significant differences were present in EPE, MXE, and DCL. Using pairwise comparisons with *post-hoc* LSD, EPE, MXE and DCL were significantly different between the symptomatic OA and asymptomatic OA groups, as well as non-OA and symptomatic OA groups. No significant difference in EPE, MXE or DCL was observed between non-fallers with asymptomatic OA and non-fallers without OA (Table II).

Table I. Baseline characteristics of participants

	Fallers ($n=60$)	Non-fallers ($n=42$)	*p*-value
Age, years, mean (SD)	74.54 (6.07)	70.71 (4.66)	**<0.001**
Sex, female, *n* (%)	46 (80.7)	31 (68.9)	0.246
Ethnicity, *n* (%)			0.081
Malay	10 (17.5)	18 (40.0)	
Chinese	35 (61.4)	21 (46.7)	
Indian	11 (19.3)	5 (11.1)	
Others	1 (1.8)	1 (2.2)	
Body mass index, kg/m^2, mean (SD)	24.75 (4.48)	24.83 (3.48)	0.926
Comorbidities, *n* (%)			
Heart disease	1 (1.7)	1 (2.4)	0.807
Hypertension	34 (57.6)	19 (45.2)	0.219
Diabetes mellitus	25 (42.4)	6 (14.3)	**0.003**
Stroke	3 (5.1)	0 (0.0)	0.264
Radiological OA*, *n* (%)	51 (85.0)	29 (69.0)	0.640
Groups, *n* (%)			
Non-OA	8 (13.3)	7 (16.7)	0.640
Symptomatic OA	42 (70.0)	27 (64.3)	0.544
Asymptomatic OA	10 (19.0)	8 (16.7)	0.756
Dynamic postural parameters mean (SD)			
End-point excursion	51.03 (14.36)	55.38 (13.75)	0.129
Maximal excursion	65.02 (17.61)	72.62 (14.48)	**0.023**
Directional control	57.27 (13.88)	62.91 (11.09)	**0.031**

OA: osteoarthritis; SD: standard deviation.
*Hip or knee. Bolded numbers indicate significance at *p*-value <0.05.

Table II. Within-group comparisons for dynamic postural control parameters

	Fallers ($n=60$)				Non-fallers ($n=42$)			
	Non-OA ($n=8$) Mean (SD)	Asymptomatic OA ($n=10$) Mean (SD)	Symptomatic OA ($n=42$) Mean (SD)	p-value[a]	Non-OA ($n=7$) Mean (SD)	Asymptomatic OA ($n=8$) Mean (SD)	Symptomatic OA ($n=27$) (Mean (SD)	p-value[a]
End-point excursion	55.25 (12.77)	49.40 (13.91)	50.62 (13.65)	0.660	64.29 (13.05)*	65.13 (13.52)¥	50.19 (11.45)*¥	**0.003**
Maximal excursion	70.25 (13.61)	59.30 (14.58)	65.38 (18.83)	0.418	82.57 (10.64)*	78.50 (9.49)¥	68.30 (14.96)*¥	**0.026**
Directional control	59.50 (16.04)	55.60 (14.91)	57.24 (13.52)	0.843	68.57 (10.52)*	68.38 (10.38)¥	59.82 (10.56)*¥	**0.049**

Higher values indicate better performance for all 3 variables.
[a]p-value shows significance of one-way ANOVA analyses.
*Significant ($p<0.05$) in pairwise comparison (*post hoc* LSD) of non-OA vs symptomatic OA.
¥Significant ($p<0.05$) in pairwise comparison (*post hoc* LSD) of symptomatic osteoarthritis (OA) vs asymptomatic OA.

Symptomatic osteoarthritis, falls and dynamic postural control

To evaluate the association between symptomatic OA and falls on dynamic postural control separate linear regression models were run on all 3 LOS parameters, as explained above (Table III). Models B and C were unadjusted models with MXE and DCL as dependent variables and a history of falls as the independent variable. Models B and C demonstrated significant associations between recurrent and injurious falls with lower MXE (odds ratios (OR) –7.60, 95% confidence intervals (CI) –14.15 to –1.06) and DCL (OR –5.64, 95% CI –10.75 to –0.53) among fallers. These relationships, however, were no longer significant after controlling for age and diabetes mellitus (Model K; OR –5.02, 95% CI –12.02 to 1.97) and Model L; OR –4.15, 95% CI –9.59 to 1.30), suggesting that the impaired postural stability observed among fallers was confounded by increasing age and comorbidities. Symptomatic OA was significantly associated with lower EPE (Model D; OR –7.34, 95% CI –13.16 to –1.52). The difference remained significant even after adjustment for age and comorbidities (Model M; OR –6.75, 95% CI –12.11 to –1.40). When we entered both falls and symptomatic OA into the same linear regression equation in Model G, symptomatic OA was independently associated with poorer EPE regardless of the presence of falls, and remained significant after adjustment for confounders (Model P; OR –6.80, 95% CI –12.14 to –1.42). Falls, on the other hand, were independently associated with worsening MXE (Model H; OR –7.34, 95% CI –13.88 to –0.81) and DCL (Model I; OR –5.42, 95% CI –10.58 to –0.32) independent of symptomatic OA, but these associations were no longer significant after adjustments for age and diabetes mellitus in Model Q (OR –4.47, 95% CI –11.12 to 2.19) and Model R (OR –3.79, 95% CI –8.64 to 1.05), respectively (Table III).

DISCUSSION

This study demonstrates that, while among older individuals with no known history of falls in the preceding year, postural control is influenced by symptomatic hip and knee OA, this relationship does not exist among older individuals with a history of 1 injurious fall or 2 or more falls. While older fallers have significantly poorer postural control in MXE and DCL compared with non-fallers, this relationship is confounded by

Table III. Linear regression on the association of poor postural control, falls and symptomatic osteoarthritis (OA) ($n=102$)

	End-point excursion OR (95% CI)	Maximal excursion OR (95% CI)	Directional control OR (95% CI)
Unadjusted Models	Model A	Model B	Model C
Falls	–4.35 (–9.98 to 1.29)	**–7.60 (–14.15 to –1.06)**	**–5.64 (–10.75 to –0.53)**
	Model D	Model E	Model F
Symptomatic OA	**–7.34 (–13.16 to –1.52)**	–5.02 (–12.02 to 1.97)	–4.15 (–9.59 to 1.30)
	Model G	Model H	Model I
Falls	–3.94 (–9.45 to 1.57)	**–7.34 (–13.88 to –0.81)**	**–5.42 (–10.58 to –0.32)**
Symptomatic OA	**–7.09 (–12.89 to –1.29)**	–4.56 (–11.43 to 2.32)	–3.81 (–9.17 to 1.56)
*Adjusted Models**	Model J	Model K	Model L
Falls	0.828 (–4.91 to 6.57)	–3.17 (–10.11 to 3.78)	–0.51 (–5.59 to 4.56)
	Model M	Model N	Model O
Symptomatic OA	**–6.75 (–12.11 to –1.40)**	–4.60 (–11.23 to 2.04)	–3.81 (–8.62 to 1.01)
	Model P	Model Q	Model R
Falls	1.14 (–4.46 to 6.74)	–2.96 (–9.88 to 3.97)	–0.34 (–5.38 to 4.74)
Symptomatic OA	**–6.80 (–12.14 to –1.42)**	–4.47 (–11.12 to 2.19)	–3.79 (–8.64 to 1.05)

*Adjusted for age and diabetes mellitus. Bold font indicates significance at $p<0.05$.
Models A to F: unadjusted models with falls or symptomatic OA as independent variables. Models G to I: unadjusted models with falls and symptomatic OA as independent variables. Models J to O: falls or symptomatic OA as independent variables adjusted for age and diabetes mellitus. Models P to R: falls and symptomatic OA as independent variables adjusted for age and diabetes mellitus.
OR: odds ratio; CI: confidence interval.

increasing age and comorbidities, but not by symptoms of OA. Furthermore, symptomatic OA among older adults was significantly associated with poorer EPE, which was not associated with falls. The current study therefore suggests, rather controversially, that, while OA does affect dynamic postural control in older individuals, the impairments in dynamic postural control that exist among older fallers are not attributable to OA symptoms. In addition, the loss of postural control found in individuals with OA is not associated with increased risk of falls.

Postural stability is a complex and interactive system in the human body. With increasing age, the ability to maintain the body's COG over the base of support in a given sensory environment reduces, and this usually occurs as a result of an accumulation of physical deficits (26). Previous studies have shown that subjects with knee OA swayed significantly more while standing than control subjects in both lateral and anteroposterior directions (11, 17, 27, 28). Few studies have, however, evaluated dynamic postural control among individuals with OA, or evaluated the effects of OA on dynamic control among older fallers (27). Furthermore, the literature behind the relationship between OA and falls has been conflicting (29). We measured dynamic postural control on a balance platform that assesses directional control, EPE and maximal excursion. These measures are expected to reflect the individual's ability to maintain their stability while performing activities of daily living. While impaired dynamic postural control is expected to increase the risk of falls, the actual occurrence of falls is also dictated by the likelihood of the individual exceeding their limits of stability. This may not occur if the individual has good awareness of their limitations and is equipped with compensatory mechanisms to overcome their deficits.

Within the control group in our study, we were able to demonstrate distinct differences in dynamic postural control performance between those with symptomatic OA and those with asymptomatic OA as well as those with no OA. This result is in concordance with the previous findings that showed OA symptoms affected dynamic postural control (9, 12, 17, 27). In contrast, while postural control was impaired among fallers compared with non-faller controls, the presence of OA regardless of symptoms was not associated with any changes in the limits of stability among the fallers in the current study, despite there being similar numbers of fallers with radiological OA. This suggests the possibility that the presence of OA does not influence dynamic postural control among older individuals with recurrent falls. Alternatively, as it is well established that falls occur due to the presence of multiple risk factors, therefore fallers universally have impaired dynamic control, which may occur due to numerous risk factors (30).

Our previous study has suggested that radiological OA subjects with mild symptoms had a lower risk of falls compared with those with asymptomatic OA (31). Within our present study, while non-fallers with asymptomatic OA had better dynamic postural control than non-fallers with symptomatic OA in both within- and between-groups comparisons, this relationship was not observed among fallers. This would again support our previous hypothesis that individuals with radiological changes consistent with OA in the absence of OA symptoms were more likely to take risks, as they were unaware of their joint limitations. However, it is also possible that fallers with asymptomatic OA are falling due to other risk factors.

In the multivariate analyses, the significant association between impaired dynamic postural control (MXE and DCL) and falls was confounded by age and comorbidities. As individuals who are older with comorbidities such as diabetes mellitus also had an increased likelihood of developing OA, the extent with which diabetes mellitus, age and OA individually influence falls risk remains unclear (32, 33). The consistency of the relationship between symptomatic OA and EPE even after adjustment, however, suggests that a poorer EPE score was not due to old age or comorbidities. Since EPE measures the distance travelled by the COG on the "primary attempt" to reach the target, a poorer EPE score is related to balance strategies. We therefore postulate that falls do not occur, despite the presence of knee joint pain or stiffness, due to effective compensatory strategies adopted by the individuals with OA; for instance, by taking more time and avoiding body positions which compromise their stability (34, 35). Furthermore, the individuals with symptomatic OA, DCL and MXE remained relatively intact, while in fallers, DCL and MXE were impaired during unadjusted analysis. The pattern of loss of postural control in individuals with symptomatic OA is therefore different from the pattern of postural control impairment observed in fallers.

In essence, this study challenges previous assumptions that OA was associated with increased risk of falls as a result of loss of dynamic postural control (36, 37). In fact, as increasing age and the presence of comorbidities are also associated with other established falls risk factors, including dementia and polypharmacy, and these were not assessed in this study, it is possible that the loss of dynamic postural control observed in fallers only leads to falls in the presence of other established risk factors, which have yet to be elucidated.

Study limitation

A selection bias was introduced because the study excluded fallers who had difficulty performing the tests on the balance platform, and these fallers probably represented the individuals with the worst balance scores. However, we had specifically selected subjects who were at high risk of future falls by including only those individuals with injurious or recurrent falls, and excluding individuals with one fall without injury. The current study only took into account the presence of knee and hip OA. OA affecting the spine or feet is also expected to affect postural control, but this was not assessed in this study.

Conclusion

The pattern of loss of postural control observed in symptomatic hip or knee OA was a reduction in EPE, while loss of maximal excursion and directional control were associated with increased risk of recurrent or injurious falls. Furthermore, the impairment in postural control observed among fallers was not attenuated by the presence of symptomatic OA in multivariate analysis. The findings of the current study therefore challenge previous assumptions that lower limb OA is linked with falls via reduced dynamic postural control. It is likely that older individuals with recurrent and injurious falls developed impaired dynamic postural control due to a variety of mechanisms, including OA. However, additional risk factors, which have yet to be elucidated, are required to sustain an actual fall event.

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The authors declare no conflicts of interest.

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