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Review

Factors associated with balance function in patients with knee osteoarthritis: An integrative review



Congying Liu¹, Qiaoqin Wan¹, Weijiao Zhou, Xiaolin Feng, Shaomei Shang^{*}

School of Nursing, Peking University, PR China

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ABSTRACT

This integrative review is to identify the factors associated with balance function in patients with knee osteoarthritis and explore the relationship between these factors and balance function. Osteoarthritis commonly occurs in elderly people. Patients with knee osteoarthritis have balance impairment, and maintaining knee stability is important for such patients to prevent accidental injuries caused by falling. Therefore, it is important to clarify the factors related to balance function in patients with knee osteoarthritis. The PubMed, Science Direct, CINAHL, Ovid, ProQuest, CNKI, WanFang databases were searched, and relevant articles published up to December 2015 were included. Twenty articles were included in the analysis. Age, gender, dominant limb, foot length, knee alignment, diurnal variation, and meniscus tears were the non-modifiable factors, whereas body mass index, knee pain, muscle strength, joint range of motion, severity, and cognitive loading were the modifiable factors. Knee sleeve and custom-molded insoles showed protective effects against knee osteoarthritis.

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1. Introduction

Knee osteoarthritis (KOA) is a common rheumatologic disorder that causes functional limitations and disability, and develops in elderly people [1–4]. In Korea, the prevalence of symptomatic KOA was 24.2%, although the prevalence of radiographic KOA was 37.3% in 2007 [5]. KOA not only affects the physical function in women and men, but also reduces the quality of life [6,7]. Moreover, it leads to an extremely serious economic burden due to the effects of disability and the costs of treatment [8,9].

Balance function is the ability to maintain the center of mass at the base of support. It is the interaction among sensory inputs from proprioception, visual and vestibular systems, motor systems (such as muscle strength and muscle activity), and cognitive components [10,11]. Balancing prevents falls and is required for many functional activities [12]. Reduced balance function is associated with an increased risk of falling, which is one of the leading causes of hospital admissions of elderly people, and could lead to other consequences such as fracture, joint dislocation, soft-tissue injury, loss of independence, and mortality [13,14].

Many studies have shown that patients with KOA have impaired balance, and maintaining knee stability is important for such patients to prevent accidental injuries caused by falling [1,15–17]. Patients with KOA lack proprioceptive sensation, which causes non-physiological joint loading and slow, progressive joint degeneration [18–21]. In addition, such patients have reduced muscle strength (particularly in the quadriceps muscles) and altered muscle-activation patterns, which could explain the poor balance [20–23]. Patients with KOA have 10–60% less strength in their quadriceps muscle as compared to healthy adults [22]. Moreover, patients with chronic pain including that from OA showed poor performance in tests like the variable attention and memory tests for cognitive deficit [24]. Thus, for patients with KOA, sensory, motor, and cognitive functions are poorer than those in healthy people and may be associated with balance impairment.

2. Aims

To identify the factors associated with balance function in patients with knee osteoarthritis and explore the relationship

^{*} Corresponding author. 38# Xueyuan Road, Haidian District Beijing, 100191, PR China.

E-mail address: mei916@263.net (S. Shang).

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¹ Both authors contributed equally to this work.

between these factors and balance function.

3. Methods

3.1. Design

3.1.1. Search methods

We used computer retrieval to search the literature published up to December 2015. We searched 7 electronic databases—PubMed, Science Direct, CINAHL, Ovid, ProQuest, CNKI and WanFang—using the key words “balance/equilibrium” and “knee osteoarthritis/arthritis/OA” together, which yielded the title or abstract of relevant articles.

Articles were included if (1) they were published in English language or Chinese language, (2) the sample included people with KOA, (3) they assessed the factors related to balance function in patients with KOA, (4) they included adults participants (aged >16 years), and (5) they were full-text articles. Articles were excluded if (1) the sample included patients with rheumatoid arthritis and (2) participants had had or would have the total knee arthroplasty or arthroscopic surgery.

3.1.2. Search outcome

The initial search identified 2170 articles, including 899

duplicates. After removing the duplicates, the titles and abstracts of 1271 articles were read. If the information provided by the title or abstract was insufficient, full articles were reviewed. After applying the inclusion and exclusion criteria, 20 papers were finally included in this review (Fig. 1).

3.2. Quality appraisal

To evaluate the quality of the included studies, we used the standard quality-assessment criteria of Alberta Heritage Foundation for Medical Research [25]. A total of 14 criteria were used to evaluate the research. Every criterion was assigned 2 points, 1 point, 0 points, or N/A. The total scores equaled the sum of all scores for every item. The total possible sum = 28-(number of “N/A”*2). We divided the total sum score by the total possible sum score, and obtained the summary score of every included study. Every paper was separately assessed by the first and second authors. Intraclass correlation coefficient was used to evaluate the agreement between the two evaluators by using IBM SPSS Statistics 18.0 [26] and a two-way mixed model. After the evaluations, all the summary scores were >0.65, and the intraclass correlation coefficient was 0.835 (95% confidence interval: 0.584 to 0.935). None of the papers were excluded. The summary scores of every paper are listed in the Table 1.

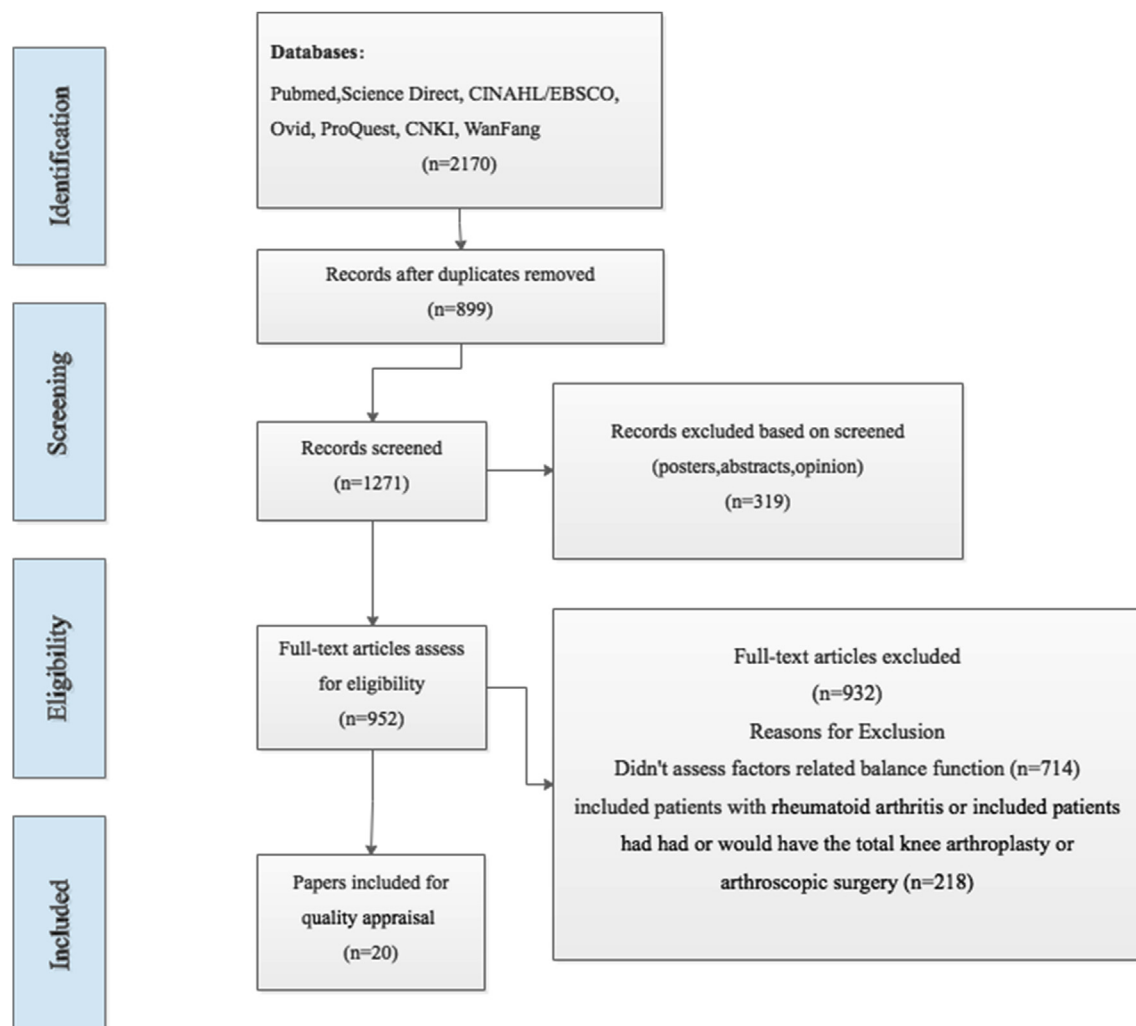


Fig. 1. Flow chart of articles.

Table 1
Details of studies included in the review.

Author/Year	Country	Study designs	Aim of the study	Population	Factors	Quality Score	
						Rater1	Rater2
Zhang Z, et al.(2015)	France	Balance control (static)	To investigate postural stability in older adult patients with symptomatic KOA during different periods in the daytime	Patients with KOA (<i>n</i> = 241)	gender, age, weight, knee pain	0.92	1.00
Takacs J, et al.(2015)	America	Dynamic balance	To identify potential neuromuscular factors associated with dynamic balance in individuals with KOA	Patients with OA aged above 50 years (<i>n</i> = 52)	Age, BMI, knee pain, muscle strength, joint range of motion	0.91	1.00
Park HJ, et al. (2013)	Korea	Static standing balance	To assess factors related to standing balance in patients with KOA	Female patients aged above 50 years with painful KOA (<i>n</i> = 37)	Age, pain, knee alignment, radiographic severity	0.95	0.95
Negahban H, et al. (2015)	Iran	Quiet standing	To determine the effects of a cognitive task (silent backward counting) on postural control in patients with KOA as compared with asymptomatic controls	Patients with KOA (<i>n</i> = 25) Asymptomatic controls (<i>n</i> = 25)	Cognitive loading	0.92	0.88
Lange A K, et al. (2007)	Australia	Static balance	To describe the prevalence and clinical correlates of degenerative meniscus tears in women with KOA.	Women aged above 40 years with OA in at least one knee (<i>n</i> = 41)	Meniscus tears	0.91	0.90
Kiss RM. (2012)	Hungary	Balance function after sudden perturbation	To assess equilibrium ability after sudden perturbation in patients with moderate and severe unilateral KOA, with regard to age, gender, and lateral dominance	Female (<i>n</i> = 45) and male (<i>n</i> = 45) healthy elderly subjects, female (<i>n</i> = 24) and male (<i>n</i> = 24) patients with moderate OA, and female (<i>n</i> = 24) and male (<i>n</i> = 24) patients with severe OA.	Age, gender, severity, dominant limb	0.95	0.95
Kim HS, et al.(2011)	Korea	Balance control (static and dynamic)	To investigate balance control according to the severity of KOA using clinical tests and tetra-ataxiometric posturography (Tetrax [®])	Patients with primary KOA (<i>n</i> = 80) Age-matched controls (<i>n</i> = 40)	Severity	0.83	0.95
Khalaj N, et al.(2014)	America	Dynamic and static balance	To evaluate balance and risk of fall in individuals with bilateral mild and moderate KOA	Subjects aged between 50 and 70 years (<i>n</i> = 60)	Severity	0.88	0.95
Jadelis K, et al.(2001)	North Carolina	Dynamic balance	To examine the relationship between muscular strength and dynamic balance in a sample of old adults with knee pain and determine the roles of obesity and severity of knee pain in the ability to maintain balance	Adults aged 65 years and above with knee pain (<i>n</i> = 480)	Knee strength, gender, BMI, severity, knee pain, foot length	1.00	0.91
Hunt MA, et al.(2010)	America	Single-leg standing balance	To identify factors related to single-leg standing balance in individuals with medial compartment KOA	Individuals with painful (<i>n</i> = 57; 3 of 10 on an 11-point numerical rating scale) medial KOA and genu varum	Age, knee severity, pain, lower extremity alignment, quadriceps strength	0.95	0.95
Hsieh RL & Lee WC (2014)	Taiwan	Balance control(dynamic balance)	To investigate the immediate and medium-term effects of custom-molded insoles in patients with KOA	Participants with a mean age of 61 years (<i>n</i> = 40)	Custom-moulded insoles	0.79	0.81
Collins AT, et al.(2012)	America	Postural control(single leg standing balance)	To determine whether the combination of stochastic resonance electrical stimulation and a neoprene knee sleeve could improve the center of pressure measures of postural sway during single-leg stance in patients with KOA	Subjects with radiographically determined, minimal-to-moderate medial KOA (<i>n</i> = 52).	Knee sleeve	0.83	0.91
Chuang SH, et al.(2007)	Taiwan	Static standing balance and dynamic balance	To investigate the effects of knee sleeves on static and dynamic balance in patients with KOA	Patients with KOA (<i>n</i> = 50)	Knee sleeve	0.88	0.79
Ünlüsoy D, et al. (2011)	Turkey	Postural dynamic balance	To assess postural dynamic balance in osteoporotic women and describe the factors affecting balance performance	Osteoporotic women with kyphosis (<i>n</i> = 20), osteoporotic women without kyphosis (<i>n</i> = 50), and healthy women (<i>n</i> = 30)	Quadriceps muscle strength	0.95	0.95
Adegoke BO, et al.(2012)	Nigeria	Dynamic balance	To explore the relationship between pain, body mass index, balance, self-report function, and physical function in a cohort including both patients with unilateral and those with bilateral KOA	Patients with radiography-confirmed KOA (<i>n</i> = 52; 46 women, 6 men)	Age, pain	1.00	0.95

Wang JX, et al.(2014)	China	Static balance	To observe the changes of isokinetic muscle strength of knee flexors and extensors in patients with KOA and its relationship with knee pain and function	Patients with KOA($n = 23$), Age-matched Control($N = 14$)	Knee extensor muscle strength	0.79	0.82
Guo YM, et al.(2013)	China	Static and dynamic balance	To understand the relationship among, ontology sensory afferent activity and dynamic and static balance in KOA patients	Patients with KOA($n = 32$;23 men, 9 women)	Pain	0.82	0.80
Guo YM, et al.(2012a)	China	Static and dynamic balance	Analysis of the balance function and risk of falls in elderly patients with single and double knee pain by static and dynamic balance tests	Subjects with KOA at one knee($n = 30$); Subjects with KOA at two knees($n = 32$) and healthy subjects($n = 30$)	Dominant limb	0.79	0.73
Guo YM, et al.(2012b)	China	Static and dynamic balance	To collect the characteristic factors of the disease in patients with KOA by a variety of clinical test methods to identify the characteristic factors why patients with KOA who had worse balance than those without KOA.	Patients with KOA($n = 89$)	Muscle strength	0.80	0.90
Xu GH, et al.(2009)	China	Static balance	To investigate the changes of knee flexion and flexion and static balance in elderly patients with knee osteoarthritis (KOA)	Patients with KOA($n = 59$) and healthy control($n = 50$)	Flexion and extensor strength	0.72	0.68

Note:KOA, knee osteoarthritis; BMI, body mass index.

3.3. Data abstraction

For each article, we abstracted the author, year, country, study design (dynamic balance/static balance/single-leg standing balance), population, aim of the study, and factors associated with balance function in patients with KOA. The quality scores assessed by the first and second authors were listed in Table 1.

4. Results

Factors associated with balance function in patients with KOA were categorized as modifiable (e.g., body mass index [BMI] and knee pain), non-modifiable (e.g., age and gender), and protective factors. The frequency of these factors is presented in Fig. 2.

4.1. Non-modifiable factors

4.1.1. Age

Four studies reported that age was negatively associated with balance function [2,27–29]. Takacs et al. used multiple linear regression to identify factors associated with dynamic balance. One model that included age, BMI, and knee pain indicated that older patients showed lower scores on the Community Balance and Mobility Scale (CB&M; $\beta = -0.6$, $P < 0.001$), which is a scale used to assess community-level functional deficits in dynamic balance [27]. For standing balance, in both univariate regression analysis and multiple linear regression model, age was positively associated with the mean speed of the center of pressure (COP) displacement in the anteroposterior direction with eyes open (for univariate regression, $\beta = 0.01$ and $P = 0.005$; for multiple linear regression, $\beta = 0.011$ and $P = 0.001$), which indicated age-related deterioration in balance [2]. Kiss categorized patients into three groups according to the degrees of KOA: moderate OA (mOA), severe OA (sOA), and healthy. The study showed that in both healthy subjects and patients with mOA, age was negatively associated with the D values (the Lehrs' damping ratio, represents balancing capacity after sudden perturbation), which indicates that balancing function after sudden perturbation decreases with age. However, in patients with sOA, no significant differences were noted between the groups of different ages [28]. In contrast to these findings, Hunt et al. tested the predictors of single-leg standing balance between two groups—those who could and could not complete all single-leg balance trials—and found that those who could not complete all trials were significantly older than the other group [29].

4.1.2. Gender

Two studies focused on the correlations between gender and balance function [28,30]. In Kiss' study, significantly higher D values were observed for women in the healthy group and the mOA group as compared to those in the sOA group, suggesting that women had better balancing function after sudden perturbation [28]. The other study focused on the dynamic balance by developing several regression models. When both knee strength and gender were included in the regression model, gender was not found to be a significant independent predictor, but in the univariate model, gender was significantly associated with balance ($\beta = -0.62$, $P < 0.001$) [30].

4.1.3. Dominant limb

The D values were significantly lower for standing on the non-dominant limb as compared to that for standing on the healthy limb or on both limbs. Further, there was no difference between the values for standing on the dominant limb and on both limbs [28].

Elderly patients with single knee pain has dynamic balance decreased, as well as, KOA patients with double knee pain both

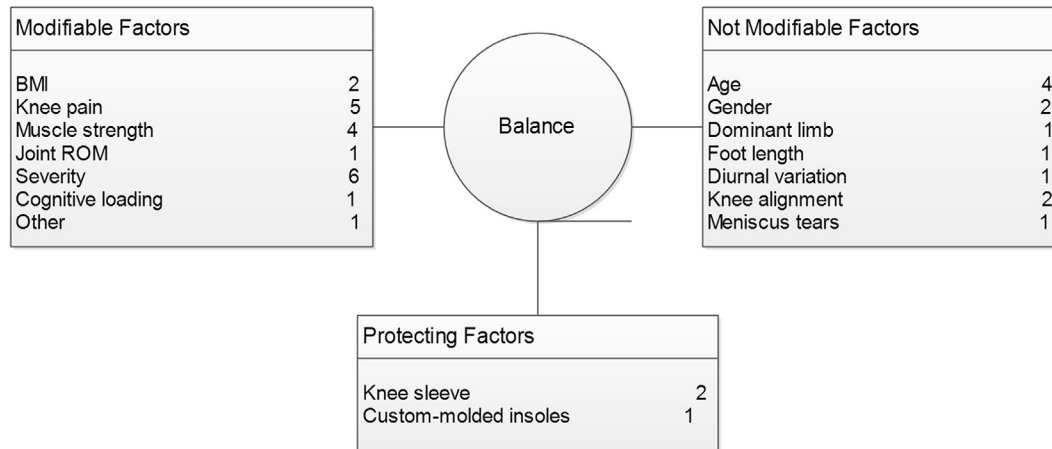


Fig. 2. Factors associated with balance function in patients with KOA BMI, body mass index; ROM, range of motion.

static and dynamic balance were decreased [31].

4.1.4. Knee alignment

Knee alignment was used to describe the varus or valgus knees. Two studies considered knee alignment as a factor associated with balance [2,29]. According to Park et al., in both univariate regression analysis and multiple linear regression, knee alignment was negatively associated with balance function (for univariate regression, $\beta = 0.013$ and $P = 0.042$; for multiple linear regression, $\beta = 0.012$ and $P = 0.041$) [2]. For single-leg standing balance, lower extremity alignment in addition to the following variables was included in the multiple linear regression model: disease severity, symptoms, pain as per the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), and quadriceps torque. The study concluded that better balance was related to varus malalignment ($\beta = -2.73$, $P = 0.01$) [29].

4.1.5. Meniscus tears

Meniscus tears may result from the cartilage-degeneration process in patients with KOA. In a previous study, meniscus tear was associated with poor balance, as assessed by the Chattecx Dynamic Balance System [32].

4.1.6. Foot length

A large base of support is known to enhance stability. As such, in a previous study, a univariate model showed that foot length was significantly related with balance. However, in the regression models including gender and strength, foot length was not significantly related with balance. This could be because the effects of gender and strength may have masked the effect of foot length [30].

4.1.7. Diurnal variation

Zhang et al. observed diurnal variation in balance control among patients with KOA and found that balance control differed significantly between different periods of the day; the function of balance control was particularly impaired in the late morning (10–12 a.m.). Importantly, male patients with KOA who were overweight and aged above 65 years showed evident diurnal variation in balance control [1].

4.2. Modifiable factors

4.2.1. BMI

Two studies indicated that BMI was inversely related with balance capacity [27,30]. One of the models developed by Takacs et al.

included age, BMI, and knee pain and showed that patients with a high BMI had low CB&M scores ($\beta = -0.9$; $P = 0.03$), indicating poor dynamic balance [27]. Jadelis et al. reported similar findings: obese patients were weaker than normal-weight persons, as per the univariate model ($\beta = -0.03$; $P = 0.001$) and multiple linear regression model ($\beta = -0.040$; $P < 0.001$) [30].

4.2.2. Knee pain

Six studies examined the relationship between knee pain and balance [2,27,29,30,33]: four of them indicated a negative relationship between pain and balance [27,29,30,34], and two of them indicated no significant relationship between the two factors [2,33].

Considering dynamic balance, in one multiple linear regression model including age, BMI, and knee pain, knee pain was negatively related with the CB&M scores ($\beta = -1.6$; $P = 0.008$) [27]. Jadelis et al. found that there was a significant relationship between knee pain and knee strength. When knee strength was high, pain was not related to dynamic balance; however, when knee strength was low, high levels of pain were related to poor balance [30]. With regard to the single-leg standing balance, a multiple linear regression model showed that WOMAC pain was significantly associated with the COP path length, which indicates that better balance was related with less pain ($\beta = 2.57$; $P = 0.005$) [29].

Adegoke et al. showed no significant correlation between knee pain and dynamic balance [33]. Another study showed that there was no significant correlation between pain and static balance in a multiple linear regression model, which included pain, knee alignment, and disease severity ($\beta = -0.01$; $P = 0.570$) [2].

4.2.3. Muscle strength and joint range of motion (ROM)

Takacs et al. developed two multiple linear regression models: one included lower-extremity muscle strength and knee-joint ROM, which represented the sole neuromuscular variables ($R^2 = 50\%$). The second model included age, BMI, knee pain, and lower-extremity muscle strength ($R^2 = 68\%$). Both regression models indicated the important role of muscle strength, but in the second model, knee-joint ROM was no longer significant [27]. Jadelis et al. focused on knee strength and ankle strength and found that the best condition to maintain balance was a combination of strong ankles and strong knees, and the second-best condition was strong knees and weak ankles. However, independent of knee strength, the balance scores with only strong ankles were also high [30]. In another multiple linear regression model, the torque of quadriceps was significantly associated with single-leg balance

($\beta = -7.94$; $P = 0.03$) [29]. Similarly, Unlusoy and colleagues found a negative relationship between stability indices and muscle strength, indicating that muscle strength was positively corrected with balance. Moreover, their study showed that quadriceps muscle strength was the most important factor affecting postural balance [35]. Another three studies also indicated that muscle strength is important to improve KOA patients' balance function [36–38].

4.2.4. Disease severity

Six studies investigated the relationship between balance and disease severity, of which four studies identified negative correlations between them, one reported a positive correlation, and one study reported no significant relationship between balance and disease severity [2,10,28–30,39].

Park and colleagues found that disease severity was negatively related with mean speed of COP displacement in the anteroposterior direction, with the eye open, in multiple linear regression ($\beta = -0.067$; $P = 0.028$). Univariate regression analysis showed that disease severity was not significantly related with mean speed of COP displacement ($\beta = -0.004$; $P = 0.231$).

Kiss examined the effects of disease severity on balance function after sudden perturbation. For the mOA group, when patients stood on both limbs or on the dominant limb, the D values were not significantly different from those of the healthy group. However, the D values were significantly lower in the sOA group than in the mOA group and the healthy group when patients stood on the affected limb [28].

Kim and colleagues used the following clinical assessments to test various aspects of the correlations between balance and knee osteoarthritis severity: the Berg balance scale, the timed up-and-go test (TUG), and the tetra-ataxiometric posturography (Tetrax[®], Sunlight Medical Ltd, Ramat Gan, Israel) test. Both the clinical assessment and Tetrax indicated significant differences among the mild group, moderate-to-severe group, and control group [10].

Khalaj et al. categorized the study sample into a healthy group, bilateral mild KOA (grade II) group, and moderate KOA (grade III) groups. They used the TUG tests and the Biodex stability system (BBS; Biodex Medical System Inc., Shirley, NY, USA) to assess differences among the three groups and found a significant difference between the groups in all tests.

For single-leg standing balance, disease severity and symptoms were included in the multiple linear regression model, which indicated that better balance was related to radiographic severity and bilateral symptoms (for disease severity, $\beta = -17.72$; $P < 0.001$; for symptoms, $\beta = -7.94$; $P = 0.05$) [29].

According to Jadelis et al. and [30] neither the univariate model nor the multiple linear regression model showed a significant correlation between balance and radiographic scores.

4.2.5. Cognitive loading

One study identified the posture-cognition interaction during quiet standing when patients were asked to complete a cognitive task (silent backward counting) during postural control. The results showed that both the healthy group and the KOA group swayed less when completing the counting-backward task during standing as compared to patients who did not count backwards [40].

4.2.6. Other factors

With eyes open or close, the differences between the healthy group and the KOA group were significant during standing on the Bertec 4060-10 force platform (Bertec Corporation, Columbus, OH, USA). Under the eye-open condition, there was no significant difference between the two groups but under the eye-close condition, there was a significant difference. This result may suggest that visual information played a more important role than proprioceptive

information in maintaining balance [40].

4.3. Protective factors

4.3.1. Knee sleeves

Two studies determined the effects of knee sleeves on balance and reported contrasting conclusions [41,42]. Amber proposed that the combination of electrical stimulation and knee sleeve would improve balance, but no significant improvements were found in the experimental group as compared to the control on single-leg standing balance [41]. On the contrary, Chuang et al. found an increased balance ability in both static balance and dynamic balance in the treatment group as compared to the control group [42].

4.3.2. Custom-molded insoles

Only one study determined if the use of custom-molded insoles was associated with balance. However, after 6-months of follow-up, there were no significant correlations between the use of insoles and balance [43].

5. Discussion

The aim of the study was to identify the factors associated with balance function in patients with knee osteoarthritis and explore the relationship between these factors and balance function.

We identified several factors associated with balance function in patients with KOA, and the relationships between balance function and certain factors such as age, BMI, and muscle strength were evident. This finding could help improve the balance function in patients with KOA.

Many researchers believe that proprioception functions in older patients are poorer than those in younger patients [44–46]. As Alpini et al. reported, aging affects the musculoskeletal system, multiple sensory inputs, and the central nervous system that performs sensorimotor integration, which could explain the negative association between balance and age [29]. In Kiss' study, the correlation between age and balance function was weak in sOA patients. This was probably because the impact of disease severity was larger than the impact of age in these patients [28].

BMI was inversely related with balance ability. Low BMI reduces compressive forces in joints and slows the degeneration of cartilage, which leads to more flexible body mobility and knee-pain relief [1]. Further, obese men had lower muscular strength than non-obese men [47]. Considering both the abovementioned reasons, the relationship between BMI and balance was particularly negative.

Good balance function is known to be associated with strong muscle strength; however, it is thus far unknown as to which specific muscles play the most important role in balance and muscle strength. Thus, further research is needed on this issue. One study indicated that either concentric or eccentric strength results in improvement of balance function [27]. Another study showed that strong knees as well as strong ankles help to maintain balance [30]. Two other studies highlighted the important role of quadriceps muscle strength in maintaining postural stability [29,35]. To improve balance ability, improving muscle strength is necessary, and further research is needed to determine which muscle position is the most powerful.

The relationships between balance function and other factors such as gender and disease severity were slightly complex. Two studies showed that gender was significantly associated with balance function in certain conditions, but reported contrasting results [28,30]. The results of the study by Jadelis K. et al. indicated that the impact of gender on balance control could be represented by muscle strength [30]. On the contrary, the other study showed that

balance function was better in women than in men. This is probably because men were more influenced by visual deprivation than women [48]. Further studies are required to identify the difference in balance function and other factors between genders.

With regard to knee alignment, one study showed that varus malalignment was negatively associated with balance function, because of the reduced muscle reflexes and the joint innervation [29]. However, Park et al. reported that varus malalignment was positively related with balance function [2]. Lim et al. believed that the positive relation between malalignment and balance was due to varus malalignment and was related to increased quadriceps strength, which, in turn, improved balance capacity, but improved balance capacity to a limited extent [49].

The inverse relationship between pain and balance could be explained by the fact that knee pain may reflexively inhibit muscle activity around the knee, which could affect the motor responses during postural control [1]. Hassan and colleagues found that a reduction in knee pain resulted in increased maximum voluntary contraction [50]. In addition, Jadelis K. et al. assessed the correlation between balance and knee pain and found that the negative effect of knee pain was evident only when the knees were weak; however, if the knees were strong, knee pain did not appear significant to the balance function. Therefore, they suggested that muscle strength plays a more important role than knee pain in maintaining balance [30]. Another study with similar results indicated that the aging process increased balance impairment more than knee pain [33].

With regard to the relationship between disease severity and balance capacity, patients with more advanced disease and more co-contractions of the quadriceps muscles and hamstrings had more rigid limbs and increased joint stability and balance [29]. In contrast, balance function was reduced with more advanced disease, which could be due to musculoskeletal fatigue and motor function decline [10].

Other factors such as cognitive loading and use of insoles were included in only one study. Meniscus tears were not only associated with a traumatic event, but also with OA. Considering the negative influence of a meniscus tear on balance function, physicians should be aware of the potential mobility impairment due to the “non-typical” clinical meniscus tear in order to reduce the prevalence of falling, fractures, and other injuries [32].

In terms of the diurnal variation in balance control, pain was elevated in the morning. As pain may particularly influence balancing function in patients with KOA [51], postural performance in the late morning could be explained by OA pain.

The postural sway decreased under cognitive loading due to the posture-first principle, limited capacity of attention, and increased arousal. Elderly persons could not consider the attention requirements of both cognitive tasks and postural tasks. Therefore, they chose the postural task to avoid falling [40].

Knee sleeves and the use of custom-molded insoles could protect against KOA. There were no significant correlations between the use of insoles and balance, but both physical functioning and physical activity were improved. Therefore, it is important to explore the long-term effectiveness of the use of insoles [43].

Despite our important findings, this study had a few limitations that need to be addressed. First, we only considered published articles from the literature, and grey literature was not assessed. Therefore, there may have been a publication bias. Moreover, the articles included in this integrative review reported more than one significant result; as such, it was difficult to determine if each factor had a significant correlation with balance function.

Balance function includes static balance and dynamic balance as well as other types of balance such as single-leg standing balance, balance capacity after sudden perturbation, and postural control;

all these types of balance could be used to evaluate balance function. In addition, the measures of balance function show wide variation. However, in this study, we concentrated only on the relationships between these factors and balance function; therefore, the differences among different patterns of balance function and different measurements were limited.

6. Conclusion

KOA is common in elderly people and contributes specially to functional limitations and disability. Balance impairment occurs in patients with KOA, and maintaining knee stability is important for such patients to prevent accidental injuries caused by falling. In this study, the following factors were associated with balance function in patients with KOA: BMI, knee pain, muscle strength, joint ROM, severity, and cognitive loading, which were modifiable factors, age, gender, dominate limb, foot length, diurnal variation, knee alignment and meniscus tears, which were non-modifiable factors, and protective factors (knee sleeve and custom-molded insoles).

7. Relevance to clinical practice

The relationship between balance function and certain factors, such as age, muscle strength and BMI, were relatively clear, whereas that between balance function and others factors, such as gender, BMI, and disease severity, were complex. Further, some factors such as cognitive loading and use of insoles were only included in one study. Thus, they require further assessment.

To improve the balance function in patients with KOA, they can:

- For obese people, appropriate to reduce weight.
- Do proper exercise to strengthen the muscle.

Further studies should focus on determining the mechanism by which these complex factors influence balance function in patients with KOA and the application of the modifiable factors and protective factors to improve the balance function in patients with KOA.

Contributions

Study design: QW,CL, SS, WZ, XF; Data collection and analysis: CL and QW; Quality appraisal: CL and WZ; Manuscript preparation: CL.

Conflict of interest

There is no personal conflicts of interest.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.ijnss.2017.09.002>.

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