CHAPTER 2

Literature Review

2.1 Overview of knee osteoarthritis

2.1.1 Definition of knee OA

Osteoarthritis is the most common form of degenerative joint disease. Individuals with knee OA often complain of the major symptoms of dull ache at the knee joint that increases with activity and stiffness in the morning and following long periods of sitting. Persist knee pain, morning knee stiffness, and diminished function are the three symptoms that are included in the diagnosis of knee OA by the European League Against Rheumatism (EULAR). In addition, crepitus, restricted movement and bony enlargement are three signs that often present in knee OA (15).

OA is a condition in which the joint cartilage wears away and is also known as wear-and-tear arthritis. The surrounding tissues of the affected joint are also affected. Damage and loss of articular cartilage, remodeling of subarticular bone, formation of osteophyte, ligament laxity and weakening of periarticular muscles are among several changes occurring as a result of the disease. The knee joint is one of the most commonly affected parts of the body. Knee OA can be primary (idiopathic) or secondary to other disorders. In this study, primary knee OA will be of interest. OA of the knee tends to cause much burden to the population as joint pain and stiffness in this large weight-bearing joint often leads to limitation of movement and functional disability (16).

2.1.2 Diagnosis of knee OA

The diagnosis of knee OA can be usually made by clinical and/or radiographic judgment by rheumatologist, orthopedist, or an expert general practitioner. There are three American College of Rheumatology (ACR) classification criteria for knee OA that are used for early diagnosis of knee OA (17). They are including:

- The ACR Clinical classification criteria of knee OA
- The ACR Clinical/Radiographic classification criteria of knee OA
- The ACR Clinical/Laboratory classification criteria of knee OA

2.1.2.1 The ACR Clinical classification criteria for knee OA is a popular method of classifying knee OA. This method uses history and physical examination. According to clinical criteria, the presence of knee pain along with at least three of the following six items can classify the knee OA in the patients:

- Over 50 years of age
- less than 30 minutes of morning stiffness
- Crepitus on active knee motion
- Bony tenderness
- Bony enlargement
- No palpable warmth of synovium

2.1.2.2 In the ACR Clinical/Radiographic classification criteria, the presence of knee pain with at least one of the following three items along with osteophyte in knee X-Ray can classify the knee OA in the patients:

- Over 50 years of age
- less than 30 minutes of morning stiffness
- Crepitus on active knee motion

2.1.2.3 In the ACR Clinical/Laboratory classification criteria, the presence of knee pain along with at least 5 of the following 9 items can classify the knee OA in the patients:

- Over 50 years of age
- less than 30 minutes of morning stiffness
- Crepitus on active knee motion
- Bony tenderness
- Bony enlargement
- No palpable warmth of synovium
- ESR less than 40 mm/hour
- Rheumatoid Factor (RF) less than 1:40
- Synovial fluid signs of osteoarthritis

2.1.3 Classification of knee osteoarthritis

The classification for OA described by Kellgren and Lawrence (K-L) (18) is the most widely used radiological classification to identify and grade OA. Kellgren and Lawrence defined the severity of radiographic OA of the knee based on several important changes including: (a) formation of osteophytes on the joint margins or in ligamentous attachments, as on the tibial spines, (b) narrowing of joint space associated with sclerosis of subchondral bone, (c) cystic areas with sclerotic walls situated in the subchondral bone, and (d) altered shape of the bone ends. The World Health Organization (WHO) adopted these criteria as the standard for epidemiological studies on OA (19).

Knee OA are classified into five grades with grade 0 assigned to a normal, healthy knee and the highest grade, 4, assigned to severe OA. Conventionally, an individual is classified as having knee OA if their knee radiograph is scored as K-L grade 2 or above.

- K-L grade 0 OA is classified as normal knee. The knee joint shows no signs of OA and the joint functions without any impairment or pain.
- K-L grade 1 OA is showing very minor bone spur growth. Individual with grade 1 OA will usually not experience any pain or discomfort as a result of the very minor wear on the joint components.
- K-L grade 2 OA of the knee is considered a "mild" stage OA. Knee radiograph reveals greater bone spur growth, but the cartilage is usually still healthy size. Synovial fluid is also typically still present at sufficient levels for normal joint motion. Individuals with grade 2 OA may first begin experiencing pain after a long day of walking or running.
- K-L grade 3 OA is classified as "moderate" OA. In this stage, the cartilage between bones shows obvious damage, and the space between the bones begins to narrow. Individuals with grade 3 OA are likely to experience frequent pain and/or joint swelling when walking, running, bending, or kneeling. Joint stiffness after sitting for long periods of time or when waking up in the morning may also present.
- K-L grade 4 OA is considered "severe". People in stage 4 OA of the knee experience great pain and discomfort with weight bearing or moving the joint due to extended damage of the cartilage and reduced joint synovial fluid to friction among the moving parts of a joint.

2.1.4 Epidemiology of knee OA

Osteoarthritis is one of the most common chronic joint diseases and a leading cause of pain and disability among adults and elderly population. Reports of prevalence and incidence estimates are found to be varied across studies worldwide, but there is agreement that substantial proportions of adults are affected. In the United States Nutrition Examination Survey (NHANES), approximately 37% of participants aged 60 years or older had radiographic knee OA (20). According to a study in Sweden, the prevalence of radiographic knee osteoarthritis was 25.4% (21). The prevalence of OA knee in Thailand has also increased over the past decade due to increased population aging. According to a recent community survey in 2015, Thai elderly aged over 50 years, with a history of knee pain, and using radiography had the prevalence of knee OA ranged from 34.5% to 45.6% (3).

Prevalence of knee OA in women is higher compared with men. Worldwide estimates are that 9.6% of men and 18.0% of women aged over 60 years have symptomatic osteoarthritis (22). In the United States, among adults 60 years of age or older, the prevalence of symptomatic knee OA is approximately 10% in men and 13% in women (23). According to data produced by the Dutch Institute for Public Health, the prevalence of knee OA in those aged over 55 was 15.6% in men and 30.5% in women (24). In American and European population, radiographic knee osteoarthritis was reported in 14.1% of men and 22.8% of women aged 45 and over (22). In Thailand, also the prevalence in female was more than male (39.8% vs. 22.6%). Prevalence of OA knee showed increasing trend with advanced age. In the United States, the prevalence of knee OA was 1% of people aged 25-34 and this number increases to nearly 50% in those who are 75 years and above. The prevalence of radiographic knee OA was 19.2% in people aged over 45 years and the number rose to 43.7% in those over 80 years. Muraki et al (25) investigated the prevalence of radiographic knee OA in elderly Japanese people aged over 60 years and reported that the prevalence of K-L grade 2 OA and over in elderly Japanese were much higher than that of previous studies in Caucasians (47.0% and 70.2% in male and female, respectively). In Thailand, this prevalence of OA knee was 33.3% in 60-69 year old and increased to 37.8% in age over 70 years (4).

2.1.5 Etiology and risk factors of knee OA

Etiology and risk factors of knee OA are commonly explained in terms of its pathophysiology. Progression of osteoarthritis involves an interaction of mechanical, cellular, and biochemical processes leading to changes in the composition and mechanical properties of the articular cartilage and surrounding tissues of the joint. Cartilage matrix is mainly composed of water, collagen, and proteoglycans. As a person ages, the water content of the cartilage diminishes as a result of proteoglycan content reduction, thus causing the cartilage to be less resilient. The collagen fibers of the cartilage are also more susceptible to degradation and the degeneration of the cartilage become worse. The surrounding joint capsule is prone to inflammation due to breakdown products from the cartilage released into the synovial space, and the cells lining the joint attempt to remove them. In osteoarthritis, the normal remodeling process of the joint is disrupted leading to increased degenerative changes and irregular repair response. In addition with an attempt to improve the congruence of the articular cartilage surfaces, osteophytes or spurs can form on the margins of the joints. These bone changes in combination with surrounding tissue inflammation results in both painful and disabling joint (26).

Osteoarthritis appears to be the result of multifactorial etiologies, which occurs due to interplay between systemic such as age, gender, and race/ethnicity and local factors, such as mechanical loading, malalignment, overweight, and muscle weakness (27). Johnson and Hunter (28) provide a diagram as shown in Figure 1 explaining that a different set of risk factors may cause OA onset in any given individual.

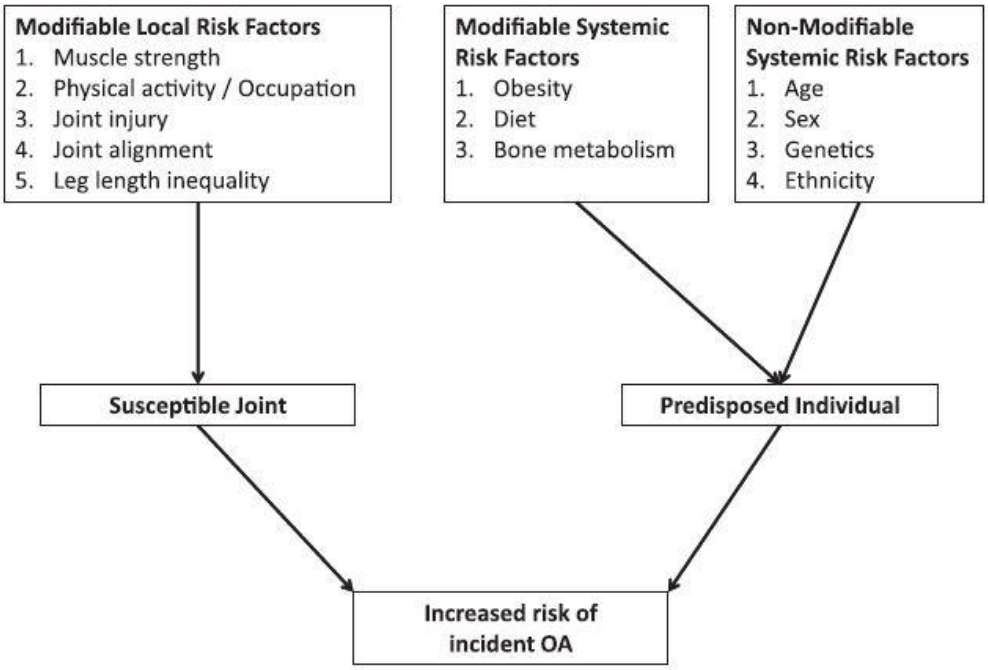

Figure 1 Diagram of potential risk factors for susceptibility to OA incidence.
Source: Johnson and Hunter (28)

2.1.5.1 Systemic risk factors

Aging has been recognized as one of the significant predictors of OA, although the exact mechanism explaining the increased prevalence and incidence of OA in elderly is not fully understood. Thinning of the cartilage, reduced muscle strength, poor joint proprioception, and oxidative damage are among biologic changes that occur with aging that may make a joint more susceptible to damage (23). In addition, a consequence of sarcopenia due to aging and impair bone turnover are also likely contributing factors to osteoarthritis (29).

Gender has been reported to be significant predictor of knee OA. Women are associated with a higher prevalence and are more often affected with hand, foot and knee OA compared to men (30). Hormone estrogen may unmask the symptoms of OA by enhancing pain sensitivity following menopause. Women may also experience higher severity of OA symptoms due to differences in bone and muscular strength, joint alignment, ligament laxity, and a reduced volume of knee cartilage. Obesity is also associated with OA of peripheral joints such as the knee and hip (31). Excess adipose tissue was found to produce humoral factors, altering articular cartilage metabolism.

Sports participation, previous injury to the joint, weakness of the muscles supporting joint, and joint laxity also play significant roles in the development of osteoarthritis (32).

The prevalence and characteristics of OA were found to vary among racial and ethnic groups. Prevalent radiographic and symptomatic knee OA was higher in African American subjects than did white subjects, whereas the prevalence in white and Mexican American subjects was comparable (2). Comparison of prevalence of knee OA between Chinese and Whites in the U.S. was reported by Zhang et al (33). Radiographic knee OA and symptomatic knee OA were more prevalent in Chinese women than white women, especially in the lateral compartment. Whereas Chinese men had less medial knee OA and more lateral knee OA compared to white men.

Other systemic risk factors include genetics and nutrition. Several previous investigators have pointed that OA is inherited and may vary by joint site. The heritable component of OA in Twin and family studies have estimated to be between 50% and 65% with larger genetic influences for OA of the hand and hip than for the knee (23). Heritability estimates for the influence of genetic factors in radiographic OA of the knee, hip, and hand are 39%, 60%, and 59%, respectively, with a similar range of estimates for cartilage volume change and progressive knee OA (34). Dietary factors are the subject of much interest in OA. Most studies have examined knee OA. Vitamins D, C, E, and K has been linked to OA prevalence, incidence, disease progression and treatment outcomes but supporting evidence has been conflicting. Intake of supplementary Vitamins was associated with a slightly lower risk of OA progression in some studies but did not improve pain or cartilage loss in some randomized trials (35).

2.1.5.2 Local risk factors

There are several local biomechanical factors that increase the risk of developing OA of the knee. Of those often assessed in the subjective and objective examination in physical therapy practice include neuromuscular factor, alignment and history of joint injury.

Muscle strength is always of interest in the physical examination in patients suffering from the joint disease. It has been postulated that weakness of the quadriceps may involve with knee OA. Deficits in muscle strength, activation and proprioception are commonly found in patients with knee OA. These deficits are likely to occur as a consequence of less use of muscle due to pain avoidance. In previous studies, there is some evidence that muscle weakness may predispose to the onset and potentially the progression of knee OA. Ikeda et al (36) found that reduced cross-sectional area of quadriceps muscle was significantly in women with asymptomatic radiological OA, compared with aged- and body mass-matched controls. Muscle fiber atrophy was reported in individuals with OA knee in later disease states. Investigation was done in patients prior to knee replacement. The quadriceps lean muscle cross-sectional area was found to be 12% lower in the affected limb compared with the contralateral limb (37). Thus, it is likely that reduction in muscle strength associated with OA may be attributable to the loss of muscle cross-sectional area.

Muscle weakness and subsequent muscle atrophy commonly associated with knee OA had been thought to be the result of disuse and pain-avoidance. Weakness of knee extensor muscle was reported to be a significant risk factor for knee osteoarthritis, particularly in women (38). In a recent systematic review and meta-analysis, it was confirmed that knee extensor muscle weakness is related with an increased risk of developing knee osteoarthritis(39). This meta-analysis, including five cohort studies with 5,707 patients (3,553 males and 2,154 females), revealed an increased risk of knee osteoarthritis after 2.5-14 follow-up years in patients with baseline knee extensor muscle weakness. The increased risk was reported in both men and women. However, the risk of development of either symptomatic and/or radiographic knee osteoarthritis were not different between men and women when considering the difference in knee extensor muscle strength between gender.

It has not been clarified why quadriceps weakness may also increase the risk of structural damage. Quadriceps muscle is the primary antigravity muscle of the lower limb and plays important role in controlling the lower limb during gait and would help protect the knee joint surfaces during loading. However, the effects of knee extensor muscle strengthening on reducing the onset or progression of knee osteoarthritis is still conflicting. Previous study reported improvement in muscle function in people with knee OA, especially strength through strengthening exercise including reduced joint pain and improved function (40). On the other hand, Mikesky et al (41) reported no relationship between muscle strength and joint space narrowing in people participating in a 3-month strength exercise program.

The association between malalignment and risk of incident knee OA is not clearly understood. Alignment of joints of the lower extremity affects load distribution at the knee during movement. Thus, malalignment may be a cause or consequence of OA. A study of alignment during static weight-bearing radiographs showed limited evidence of an association between varus alignment and incident radiographic OA (42). Hunter and colleagues (43) investigated knee joint alignment by use of four measures including the anatomic axis, the condylar angle, the tibial plateau angle, and the condylar tibial plateau angle and reported that no association of these measures with an increased risk of radiographic knee OA. It was speculated that malalignment may not be a major risk factor in the development of radiographic knee OA but the can be used as a marker of disease severity or progression. However, a recent study supports that malalignment is associated with progression of radiographic knee OA such that varus alignment was associated with a greater risk of radiographic medial OA and valgus alignment was associated with a greater risk of radiographic lateral compartment OA. The role of varus or valgus malalignment on the risk of OA progression was evidence in knees with more severe baseline radiographic disease than those with mild or moderate severity (44).

One of the dominant risk factors for knee OA is the history of injury. Previous injuries to the joint structures, such as a transarticular fracture, meniscal tear or cruciate ligament injury are closely related to an increased risk of OA development (45). The prevalence of meniscal tear was much higher among patients with radiographic knee OA (82%) than those without knee OA (25%) and also increased with higher K-L grade (46). After knee injury, men had a five to six-fold risk and women had a three-fold for knee OA development compared to non-injury controls (47). According to a study by Lohmander et al (48), 50% of patients with torn anterior cruciate ligament, in combination with concomitant injuries to the meniscus or knee ligaments, develop symptomatic knee OA after 10 to 20 years follow-ups.

Other local mechanical risk factors for the incidence of knee OA include physical activity and occupational load. The risk of development of knee OA in men whose their work required improper postures such as kneeling or squatting are twice greater than those whose their duty did not require activities involving weight bearing on knees (49).

2.2 Measurement of function in knee osteoarthritis

Measurement of physical function in knee osteoarthritis patients is useful for examining and monitoring changes in outcomes of management or treatment. Several self-report and performance-based measures have been used to assess physical function (50). Performance-based measures are defined as assessor-observed measures of tasks classified as activities and are usually assessed by timing, counting or distance methods. Performance-based measures assess what an individual can do rather than what the individual perceives they are capable of (51). A self-report measure requires an individual to give their opinion on selected items whereas a performance measure requires individual to perform some specific tasks in a standardized manner using preset criteria, such as counting repetitions or timing to complete the activity (52). Literature suggests that performance-based measures provide a different construct of function and are more likely to demonstrate or detect a change in body function than using self-reported measures alone (53, 54). Both types of measures should be considered when evaluating or monitoring changes in functional outcomes in people with OA (55).

2.2.1 Self-reported measures

One of the most widely used disease-specific questionnaire in arthritis of the hip and knee is the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC). The WOMAC has been introduced to osteoarthritis research for almost 30 years (56). Using visual analog scales, its 24 items cover three dimensions including pain (5 items), stiffness (2 items), and functional difficulty (17 items). The score of each dimension is an average of the component item scores. The WOMAC total score is determined by averaging the scores of all dimensions. The higher score indicates worse pain and stiffness and poorer physical function (range: 0-100, with 0 meaning totally unaffected and 100 indicating the worst possible state) (57). The WOMAC has versions in both 5-point Likert and visual analogue scales.

The reliability, validity, and responsiveness of WOMAC questionnaire have been shown. Acceptable internal consistency reliability for the pain and stiffness scales ($\geq$ 0.70) and excellent internal consistency reliability for the function scale ($\geq$ 0.90-0.95) have been established. Test-retest reliability was acceptable for the pain and function scales, although weaker for the stiffness scale ($<$ 0.70) (58).

A reduced version of the WOMAC was developed in 2003 (59). Evidence has shown that the short-form WOMAC function scale consisting of seven items of function is practical, valid, reliable and responsive alternative to the full WOMAC scale. It can be used for the evaluation of patients with knee OA (60) and those following total joint arthroplasty (59).

The WOMAC is available in more than 80 language versions. The WOMAC was first translated into Thai version in 2000 but its psychometric properties were not yet reported (61). In 2007, a modified Thai version of WOMAC was later developed (62) and its psychometric properties (validity and reliability) was evaluated. It was reported that the modified Thai WOMAC had convergent validity to the algofunctional Lequesne index in pain and function dimensions as indicated by Spearman's correlation coefficients. The test-retest reliability was moderate with coefficients ranging from 0.65 to 0.71. The internal consistency was good to excellent with alpha coefficients ranging from 0.85 to 0.97. In the modified Thai version of WOMAC, two questions bending to the floor (F05) and lying in bed (F12) were not included due to some cross-cultural differences.

Other questionnaires for assessment of self-perceived function of the lower extremity that have been translated to Thai version are the Knee Injury and Osteoarthritis Outcome Score (KOOS) and 12-item Oxford (Oxford-12) outcome questionnaire and Short Form 36 (SF-36). Thai version of KOOS was translated for use in Thailand in 2009 (63). The KOOS questionnaire can also be used to evaluate the functional status and quality of life of patients with knee osteoarthritis and knee injury such as ACL injury, meniscus injury, or chondral injury and patients who undergo orthopedic procedures such as total knee arthroplasty (TKA), Anterior cruciate ligament (ACL) reconstruction, and meniscectomy (64). The KOOS has been reported with good evidence for reliability, content validity and construct validity and responsiveness. Thai version of Oxford knee score and Short Form 36 (SF-36) general health questionnaire was validated in 2005 in Thai patients who having total knee replacement (TKR). Thai version of Oxford knee score was also used to determine the efficacy of Ayurved Siriraj Wattana Recipe for knee osteoarthritis alternative treatments for knee OA patients (65). Thai versions of Oxford-12 and SF-36 was found to retain their original characteristics and are considered a reliable tool for assessing patient's quality of life after knee replacement (66).

2.2.2 Performance-based measures

The Osteoarthritis Research Society International (OARSI) recommended tests for older people with established OA contains three functional tests (30-s chair stand test, 40 m fast paced walk test, a stair test). The minimum core set of tests was selected based on global expert opinion, feasibility and available measurement property evidence (14).

2.2.2.1 30-s chair stand test

The ability to perform the sit-to-stand (STS) movement is basic in daily living in order to maintaining physical independence. For elderly, the sit-to-stand task places a sufficient demand on the knee extensors and was proposed for use as a measure of lower extremity strength for older adults (67, 68). Csuka and McCarty (69) introduced the first standardized test to quantitatively assess the movement of STS in clinical setting. In 1985, this test was originally called the timed-stands test which determines the time spent to perform 10 repetitions of the sit-to-stand movement. Several alternate forms of the STS movement have been developed, including the five-repetition sit-to-stand test (70) and a 30-s chair-stand test (71). The STS test has demonstrated good clinical feasibility and test-retest reliability for the elderly (72).

The 30-s chair-stand test was the selected test by OARSI to represent the sit-to-stand activity. Chair height should be standardized to compare the outcomes in individuals over time. A chair without armrests and with a seat height of approximately 43 cm (17-inch) or adjustable chair to fit each participant height is recommended (71, 73). Test-retest reliability of the 30-s chair-stand test was determined by administration of the test-retest on the same day by the same rater in patients awaiting total hip or knee replacement surgery (73). Intraclass correlation coefficient (ICC) values were reported to range from 0.97 to 0.98. Excellent criterion validity of the chair stand compared to weight adjusted leg performance was also reported (r = 0.71) (71). Excellent correlation to the WOMAC (r = -0.62) also indicates construct validity of the 30-s chair-stand test (74).

2.2.2.2 Self-paced walk test

Walking test is a physical function measure commonly used in clinical settings and research studies to monitor changes in patients' physical function over time. For the self-paced walk test, individuals are asked to walk at their own pace quickly and safely without overexerting themselves. For individuals with hip or knee OA, the distance used for testing is typically less than 50 meters or 150 feet. A number of different distances have been reported for self-paced walk test in osteoarthritis population such as 6 meters, 13 meters, 20 meters, or 40 meters (75-77). An outcome of the self-paced walk test is measured by time (seconds taken to cover the set distance) and/or gait speed which is calculated using distance in meters and time in seconds. Minimum reporting standards for the self-paced walk test should include the use of any gait-aid devices such as a cane or other device that individual normally use at the time of testing (14).

The self-paced walk test has been administered in many population groups, including patients with hip or knee osteoarthritis (OA). Reliability of the self-paced walk test using 13-meters walkway was reported to be high for both within day and across sessions with 1-week apart. Intraclass correlation coefficients (ICC) for intra- day and inter-day sessions were 0.97 and 0.88, respectively. There was a significant correlation between walking time of the 13-meter walk test and the Lequesne Index of Severity for Knee OA (r = 0.66) indicating validity of the self-paced walk test (75). High test-retest reliability was also reported for within sessions trials for the 20-meter walk test (correlations between trials, $r \geq 0.90$) (78), and for the 40-meter self-paced walk test (r = 0.91) (79). For individuals with knee OA, sufficient practice trials to allow familiarization with the test are also advised prior to a valid measure of a participant's walk time and gait speed (78).

2.2.2.3 A stair climb test

Testing the ability to negotiate steps has also been commonly used in clinical and research settings. Stair climbing is a physically demanding task as it places greater demands on lower limb joint range of motion and strength than level walking (80). It is a simple way to measure higher functional ability as well as functional progress in individuals with hip or knee osteoarthritis and after joint replacement.

Variations of the stair climb test have been developed for testing in different patient groups such as people with musculoskeletal conditions, cardiopulmonary problems, and older adults. Test variations in people with hip and knee OA include the number of steps, the task requirement (ascent only or ascent/decent combined). In a systemic review by Whitchelo et al (81), several characteristics of the stair climb test is described. The most common outcome of the stair climb test is the total performance time to ascend and descend a flight of stairs. Few studies reported the ascent and descent time separately or reported only the ascend stairs time. The number of stair step used in the stair climb test varied from 3 to 27 for patients with OA and from 5 to 12 for patients who underwent a total knee arthroplasty. Most research studied permitted patients with OA or post-surgical conditions to use a handrail as needed during assessment of the stair climb test.

At present there is no current standard for a stair climb test. The feasibility of stair negotiation tests is largely dependent on the environmental setting. Based on measurement-property evidence and practicality, the Osteoarthritis Research Society International (OARSI) recommended the test of nine stair step with steps heights of 16-20 cm and avoid external distractions (14). Minimum reporting standards for the stair climb test include the number of steps and step height. The tester should record the use of handrail including the side and/or assistive devices used by the patients.

2.3 Type of knee bracing for knee OA

Malalignment of mechanical axis of lower extremities such as genu valgus or genu varus condition may place OA knee patients at higher risk for disease progression. Knee orthoses are external devices used for support, align, prevent, or correct deformities in order to improve function of the knee joint. Knee orthoses are recommended as part of nonpharmacological approaches for management of knee OA by the European League Against Rheumatism (EULAR) (7). In addition, the osteoarthritis Research Society International (OARSI) provides an update to their evidence-based, consensus recommendations for the treatment of the hip and knee OA including the use of knee orthoses in conservative management of knee OA.

The common aim of knee bracing is to modify the mechanical load applied to the symptomatic joint compartment by correcting joint alignment and increasing joint stability. In addition, wearing knee brace may also help reducing articular contact stress and improve lower limb muscle function. In a systemic review by Raja and Dewan (82), it was suggested that knee braces and foot orthoses were effective in joint pain reduction, decreased joint stiffness, and lower drug dosage and also improved physical function, with insignificant adverse events. Consequently, the therapeutic effects of knee brace include reduce pain and improve function during daily activities, and may lead to reduce disease progression. In addition to the direct effect of knee braces on changing mechanical alignment, bracing may also improve articular sensorimotor function in knee OA patients (10). There are some contraindications to wearing knee braces including flexion contracture of more than 10°, peripheral vascular disease, or intractable contact dermatitis (83).

For knee osteoarthritis, bracing for knee OA can be generally divided into three main types including rest orthoses, knee sleeves, and unloading knee braces (9).

2.3.1 Rest orthoses

Rest orthoses are prescribed for joint immobilization. Function of the rest orthoses does not include any dynamic, corrective, or functional effect. Rest orthoses are crested by a stiff composite using casting or a line. There has been no study report on therapeutic effect or effectiveness of rest orthosis for hip or knee OA. Rannou et al (9) suggested that it could be used for transient immobilization in knee osteoarthritis presenting with effusion problem.

2.3.2 Knee sleeves

Knee sleeves are the most common form of accommodative brace used in OA knee patients or sport injury. Knee sleeves are elastic non-adhesive orthoses and made from cotton elastic or from neoprene, nylon other synthetic fibers. Knee sleeves are popular for general use because they are simple, inexpensive, and ready for use (10). Mechanical role of knee sleeves in OA knee patients are assisting in patellar alignment and enhancing frontal tibio-femoral stabilization (9). Kirkley et al (13) reported the effect of wearing neoprene knee sleeve in OA knee patients as it helped relieve knee joint pain during walking and stair climbing as compared to those without knee sleeve. Wearing a simple neoprene sleeve also had superior effect of pain relieve compared to analgesic medications but not as great as the use of corrective knee braces (13). Improvement in static and dynamic balance performance has been shown in patients wearing neoprene knee sleeve (12). Chuang et al (12) suggested that knee sleeves may provide analgesic effect through enhancing joint proprioception.

2.3.3 Unloading knee braces

Unloading knee braces are corrective bracing also known as rigid realigning braces. Unloading knee braces are functional devices composed of external stems, hinges, and straps. There are many designs or models of realigning brace for OA knee patients such as single upright with hinge, single upright with strap, double upright with hinge and others. Unloading knee braces for knee OA are often called Arthritis or OA knee brace for commercial purposes. The expected benefit of using knee braces is to alter loads by correcting an abnormal varus or valgus force and stabilize knee joint. Some of adjust patellar sleeve in the brace can induce medial or lateral traction. One study has shown that valgus realignment brace can reduce medial compartment load approximately 11%-15% at the 4º setting and 17% at the 8º setting (84). Adjustment of the hinge had a greater effect on medial load than increasing strap tension in the frontal plane, although both are necessary for individual used. Moreover the result of several studies (7, 9) have demonstrated positive results of unloading-knee bracing such as an increase in medial tibio-femoral space during foot strike, a change in adductor moment to decrease and signifies a change in load distribution (depends on mechanical alignment and the ground reaction force), and decrease tibio-femoral compressive loads.

In terms of benefit of unloading knee braces on symptoms, Briem and Ramsey (85) reported that using brace can improve stability of a knee and enhancing proprioception. Beaudreuil et al (7) reported short-term and mid-term benefits for pain and disability with the effectiveness of unloading-knee brace greater than with knee sleeves. Although wearing brace may present with positive effects, several negative effects have also been presented. A study on gait analysis reported that wearing knee brace resulted in significant reduction in knee flexion during swing phase. It lead to reduce foot clearance and a shorten strike (82). Moreover, adherence to using the unloading-knee brace is of concerned. The unloading-knee brace are not easy to apply, discomfort during movement due to skin irritation and/or poor fit, and difficulties in supporting for prolonged period (9).

2.4 Related research about the effect of knee braces on function in subjects with knee osteoarthritis

Chuang et al (12) examined the effect of knee sleeve on static and dynamic balance in patients with knee osteoarthritis. Fifty participants aged 40-78 years old who experienced knee pain and were diagnosis wit knee OA according to ACR guideline participated in the study. Custom-manufactured neoprene sleeves (CB0601; Zong-Hsin Factory, Kaohsiung, Taiwan) were used. Participants were tested static and dynamic balance with a balance system machine equipped with tilt sensors. Balance performance score was calculated from measuring the distance from tilt position to the reference position and adding up the absolute numbers over 30-sec duration. Comparison of balance scores between wearing knee sleeve and without knee sleeve conditions were compared using paired t-test. The results demonstrated an improvement in both static and dynamic balance after wearing neoprene sleeves in the knee OA patients compared to without knee sleeve condition. The authors suggested knee sleeves may provide firm compression that may enhance joint proprioception and symptomatic relief. Therefore, wearing knee sleeves may result in better joint proprioception which in turns providing improvement of static and dynamic activities.

Bryk et al (11) assessed the immediate efficacy of elastic knee sleeve on pain and ability to perform functional tasks of individuals with knee OA. Seventy four patients with symptomatic knee OA were assessed by three functional tests: the stair climb power test (SCPT), Timed Up and Go (TUG) and 8-meter walk (8MW) tests. The visual analog scale (VAS) for pain was also assessed during performing the tests. The tests were performed in two conditions: with and without knee sleeves. Elastic knee sleeves without patellar openings (Tensor®-ANVISA/MS registration 80017170005) were used. The authors reported a reduction in pain during the SCPT test with the knee sleeve use ($p < 0.001$). There were statistically significant differences in 8MW and TUG tests ($p < 0.05$), but not in SCPT with the knee sleeve use. The authors suggested that wearing knee sleeve was effective in improving the functional capacity and pain of individuals with knee OA.

Kirkley et al (13) compared two common types of knee orthoses: knee sleeves and unloading braces in knee osteoarthritis (varus gonarthrosis) patients. The study design was a prospective, parallel-group, randomized clinical trial. 119 patients who had varus gonarthrosis were screened for eligibility and were randomly assigned to one of three treatment groups: medical treatment only (control group), medical treatment and use of a knee sleeve, or medical treatment and use of an unloading knee brace. Knee sleeves made of neoprene material were used. For unloading knee brace, a Generation II valgus-producing functional knee (unloader) braces (Generation II Orthotics, Richmond, British Columbia, Canada) were used. The primary outcome measure was the change in the WOMAC score and the McMaster-Toronto Arthritis Patient Preference Disability Questionnaire (MACTAR), the six-minute walk (6-MW) and 30-second stair-climbing tests between the baseline, 6 weeks, 12 weeks and 24 weeks evaluations. It was reported that, compared to no brace and knee sleeve conditions, wearing unloading knee brace had more favorable effect on pain perception during activity but no differences on functional outcomes (a six-minute walk test and a 30-second stair climbing test). A significant improvement was found at the six-month follow-up with a better score of the disease-specific quality of life (p = 0.001) and WOMAC function subscore (p < 0.001) in both the knee sleeve group and the unloading knee brace group compared with the control group. A significant difference between the unloading knee brace group and the knee sleeve group with regard to pain was also reported after both the six-minute walking test (p = 0.021) and the 30-second stair-climbing test (p = 0.016). There was a strong trend toward a significant difference between the unloading knee brace group and the knee sleeve group with regard to the change in the WOMAC aggregate (p = 0.062) and WOMAC physical function scores (p = 0.081). The authors concluded that patients who have knee pain form varus gonarthrosis may benefit significantly from use of a knee brace in addition to medical treatment.