Critical review

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Management

# Effects of knee orthoses on walking capacity and biomechanics in patients with knee osteoarthritis: A critical review

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## Abstract

**Introduction**

Gait modification is frequently used as conservative management in knee osteoarthritis (OA). Knee orthoses, such as knee sleeves and unloader knee braces, are nonpharmacological treatment for gait modification in symptomatic knee OA. Previous studies lack systematic investigation of biomechanical effect and functional capacity, particularly walking capacity. This study investigated effects of knee orthoses on biomechanics and walking capacity in patients with knee OA.

**Materials and methods**

A literature search was conducted in PubMed, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Physiotherapy Evidence Database (PEDro), and Cochrane Central Register of Controlled Trials (CENTRAL) according to inclusion criteria from 1966 to May 2013. Trials investigating the effects of knee orthoses on biomechanics or walking capacity were collected. Effect size was calculated exclusively according to biomechanical and walking capacity variables reported over 5 publications. Narrative analysis of the studies was performed.

**Results**

The database search provided a total of 1681 citations with 19 studies that investigated effect of neoprene sleeves and unloader knee braces, and satisfied the inclusion criteria. Of these, one was a randomized controlled trial; the other 18 studies were within-subjects, repeated measures designs. Study results indicated unloader knee braces could decrease knee adduction moment, particularly the 2nd peak during walking, compared to controls. However, unloader knee braces did not improve walking endurance, and effects on walking speed differed between studies.

**Discussion**

Load-reduction effects of unloader braces used while walking coincide with clinical observations of pain reduction. Our results suggest the mechanism of immediate decrease in knee pain may be due to decreased adduction moment especially at the 2nd peak, though this may not affect walking capacity. The conclusions of this review are limited by methodological considerations; therefore, high-quality randomized controlled trials concerning bracing biomechanical changes and functional capacity for knee OA are still necessary.


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## Introduction

Osteoarthritis (OA) of the knee is a common musculoskeletal disorder in adults that causes considerable pain, impaired physical function and disability[1]. Although knee OA is a multifactorial disease, biomechanics are an important factor in the pathophysiology of knee OA with previous studies showing dynamic alignment during gait to be a potent predictor of longitudinal progression[2]. Gait modification is frequently used as conservative management in knee OA.

Knee orthoses, such as knee sleeves and unloading knee braces, are used as nonpharmacological treatment for knee OA and are a potentially effective management for pain and impaired physical function. Previous reviews[3,4] showed the effectiveness of knee orthoses on knee pain and physical function. Biomechanical effect of knee orthoses may account for improvement of pain and physical function as shown in narrative reviews[5]; however, there are no reviews which systemically analyse the effect of knee orthoses on biomechanics during gait.

Previous systematic review[4] which analysed effect of knee orthoses on physical function consisted of self-report questionnaires and performance-based measures for assessing physical function. Self-reported physical function is generally used for interventional outcomes; however, in several studies, performance-based measures which indicate functional capacity provide complementary information on degree of disability in knee OA[6,7]. Therefore, in addition to the biomechanical effect of knee orthoses, understanding of the effect of knee orthoses on functional capacity, particularly walking capacity, is needed.

To evaluate the effect of knee orthoses on walking capacity and biomechanics, a systematic review of all studies evaluating walking capacity changes or biomechanical effect of knee orthoses in people with knee OA was conducted. The objective of this review was to systematically analyse the effect of knee orthoses on walking capacity and biomechanics of the knee.

## Materials and Methods

**Selection criteria for considering studies**

1. Studies which were published in a peer review journal.
2. Written in English.

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3. Patients were diagnosed as tibiofemoral OA.
4. Studies were designed as randomized controlled trials, controlled clinical trials, crossover studies, cohort studies, cross-sectional studies, case control studies, and case series studies. Studies which only reported data comparisons between healthy control groups and knee OA patients, or had no control or baseline comparisons, were excluded.
5. Intervention included all types of knee bracing (rigid knee braces, knee sleeves/supports) and orthotic devices.
6. Studies were required to include at least one measure of either walking capacity as assessed using an objective performance measure or biomechanics.

### Search strategy used for identification of studies

A literature search was conducted in PubMed, CINAHL, PEDro and CENTRAL from 1966 to May 2013. The search strategy used with database-specific truncation terms were the following: 1) knee or knee joint (#1) + brace; 2) #1 + orthotic device; 3) #1 + sleeve; 4) #1 + strap; 5) #1 + supporter. Two authors (HI and TI), working independently from one another, examined citations from the database search. Study eligibility was determined by reading the title and abstracts, and obviously irrelevant trials were excluded during this phase. Following this, two authors (HI and TI) read the full-text articles and independently decided whether the article met the selection criteria or not. Any disagreements between authors were adjudicated by consensus of both authors.

### Calculating effect size for pooling data

To describe effects of knee orthoses objectively, effect size was calculated using the standardized mean difference (SMD) with the same outcome measures of biomechanics or walking capacity reported over 5 publications. The SMD was computed from the difference in means between the control (or baseline) and experimental condition divided by standard deviation of the control condition. Effect size magnitudes were interpreted based on Cohen's criteria[8] as small (0.2 – 0.5), medium (0.5 – 0.8), and large (>0.8).

## Results

### Studies included in the review

The search of databases provided a total 1681 citations from which 218 potential studies remained for full-text review (Figure 1). Nineteen studies satisfied the selection criteria. Of these, one was a randomized controlled trial (RCT); the other 18 studies were within-subjects, repeated measures designs. A list of the included studies is shown in Table 1 and Table 2. Nine studies[9-17] of within-subjects, repeated measures designs had no follow-up period after intervention.

### Effectiveness of knee sleeves

Effects of knee sleeves on walking capacity were evaluated in 2 studies[9,18] and biomechanical alterations were evaluated in one study[10]. One randomized controlled trial showed the 6-minute walking distance was not improved after 6 months of knee sleeve use compared to control (no sleeve)[18]. Another within-subjects study showed that the 8-meter walk test was immediately improved with knee sleeve compared to without knee sleeve[9]. Another evaluated biomechanical effect and showed that the loading rate (linear slope between the point of initial ground contact and the peak ground reaction force at heel strike) was decreased and the knee flexion angle at initial contact was increased with knee sleeve[10]. There were no

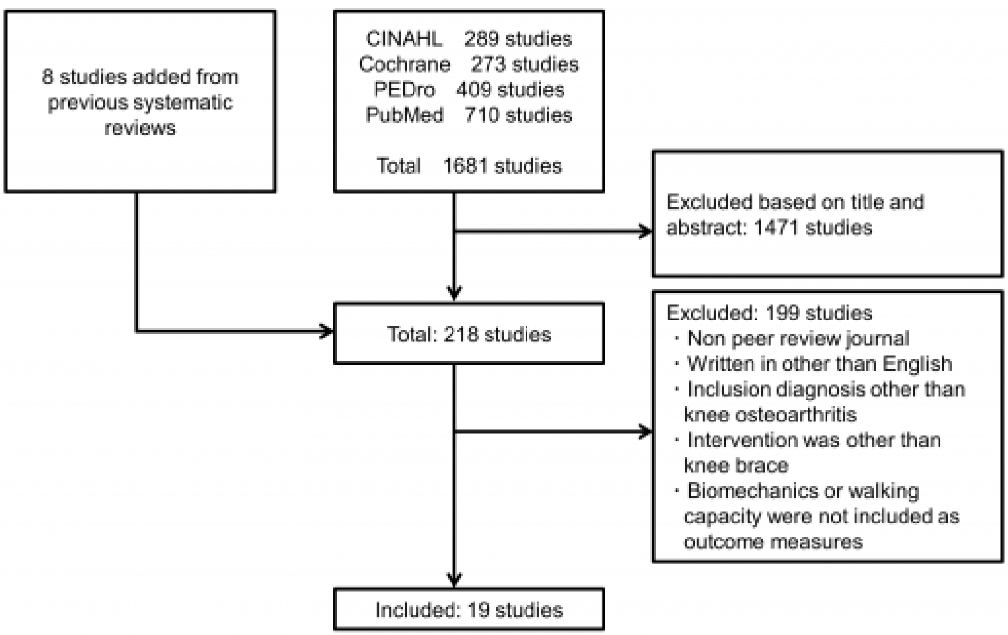


**Figure 1:** Trial flow chart of included and excluded studies.





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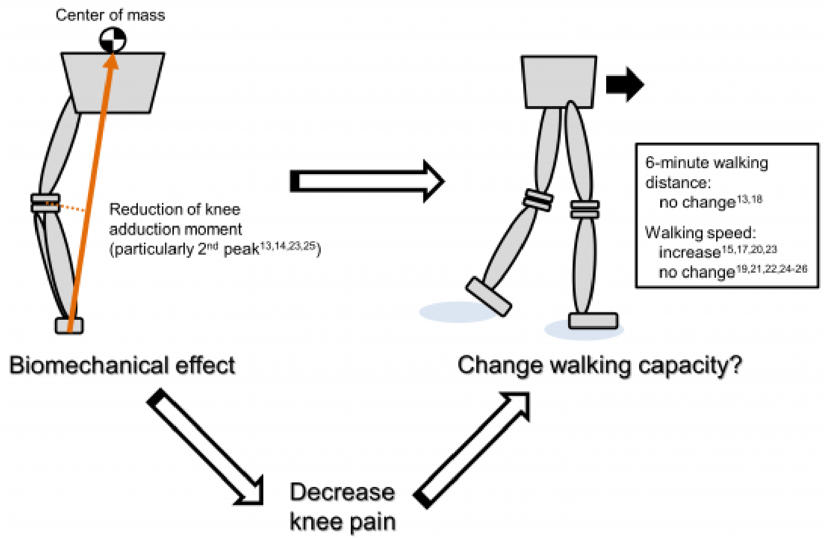


**Figure 2:** Effect of unloading knee braces on knee adduction moment and changes of walking capacity.

significant differences in these loading rates and kinetics data between knee sleeve and electrical knee sleeve condition[10].

**Effectiveness of unloader knee braces**

*Effect on walking capacity*

The effect of unloader knee braces on walking capacity was evaluated in 12 studies[13,15,17,18.19.20,21,22,23,24,25,26] with small to medium within-group effect sizes (Table 3) . In these studies, walking speed was used most often for outcome. Several studies demonstrated beneficial effect of unloader knee bracing on walking speed[15,17,20,23]; however, there were conflicting results in other studies which showed walking speed was not significantly changed[19,21,22,24,25,26]. Although cadence was increased with unloader knee braces[15,17], there were no changes in step length[15,17] or stride length[17,22]. Two studies evaluated 6-minute walking test showing no immediate effect[13] or after 6 months[18].

*Effect on biomechanics*

The biomechanical effect of unloader knee braces on gait was mainly evaluated using the following variables: external knee adduction moment[12,13,14,15,16,17,19,20,21,23,24,25,26], ground reaction force (GRF)[12,14,15,21,25,27] and joint angle[11,12,14,17,19,20,27].

The knee adduction moment is an indirect measure of medial tibiofemoral compartment loading. Change in the adduction moment means a change in load distribution across the knee joint. The multiple biomechanical studies showed knee adduction moment during walking decreased with unloader knee braces, although the results of each study varied widely (Table 3). Four studies[13,14,23,25] showed that knee adduction moment in 2nd peak was decreased more than 1st peak; however, another study[17] showed conflicted data. The maximal reduction rate of the knee adduction moment was 21% using 8° valgus unloader knee brace[14] and effect sizes of the studies examining the effects of unloader knee braces were small to large (Table 3).

Three studies[12,15,27] showed vertical GRF was increased with unloader braces; however, one study showed conflicted data[21]. Four studies showed mediolateral GRF without change[15,25] decreased[12] and increased[14] with unloader knee braces.

Joint angle data during gait was evaluated in a total of 7 studies of the hip[12,17] knee[11,12,14,16,17,20,27] and ankle joint[14]. Three studies showed knee adduction angle decreased with an unloader brace in stance phase[12,14] and the beginning of swing phase[11] . Although 2 studies showed no change with unloader braces on knee flexion angle during gait[19,27] another 2 studies showed knee flexion angle was increased in terminal swing phase[20] and in mid stance phase[28]. One study showed contralateral knee adduction angle and contralateral hip adduction angle were increased with unloader brace of the ipsilateral limb[17]. Only one study that evaluated change in ankle angle showed ankle eversion angle was decreased with unloader braces[14].

## Discussion

This review is the first study to systematically analyse the effects of knee orthoses on biomechanics and physical function, particularly walking capacity. Most of the included studies investigated the effects of unloader knee braces, but none of the randomized controlled trials investigated the biomechanical changes from use of knee orthoses.

One randomized control trial showed neoprene sleeves had no effect on increasing the 6-minute walking distance, although knee pain was decreased after 6 months of intervention[18]. There were 2 other studies that investigated the effect of neoprene sleeves with regard to increased walking speed[9] and kinetics changes[10]; however, these conclusions are limited by heterogeneity of interventional outcomes.

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**Table 1: Results of the studies included in the review. C: control condition, E: experimental condition, N/A: not applicable, GRFs: ground reaction forces.**

| Study | Design | Subject Population | Condition | Intervention or test condition content | Outcomes |
|---|---|---|---|---|---|
| Bryk, 2011 (9) | Within subjects, repeated measures design | N = 74 (F = 54, M = 20) Age, 58.0±9.7 years | C<br>E | Walking without knee sleeve<br>Waking with elastic knee sleeve | Walking capacity: 8-meter walk test<br>Biomechanics: N/A |
| Collins, 2011 (10) | Within subjects, repeated measures design | N = 52 (F = 30, M = 22) Age, 61.2±9.6 years | C<br>E-1<br>E-2 | Walking without knee sleeve and electrical stimulation<br>Walking with knee sleeve/no electrical stimulation<br>Walking with knee sleeve/electorical stimulation | Walking capacity: N/A<br>Biomechanics: loading rate, mean forward velocity, knee angle, vertical GRFs |
| Davidson, 1998 (11) | Within subjects, repeated measures design | N = 12 (M = 12) Age, 55.0±5.0 years | C<br>E | Walking without knee brace<br>Walking with unloader knee brace | Walking capacity: N/A<br>Biomechanics: knee angle |
| Draganich, 2006 (19) | Within subjects, repeated measures design (crossover) | N = 10 Age, 50.8±5.4 years | C<br>E-1<br>E-2 | Walking without knee brace<br>Walking with off-the-shelf knee brace<br>Walking with custom knee brace | Walking capacity: walking speed<br>Biomechanics: knee angle, knee adduction moment |
| Esrafilian, 2012 (12) | Within subjects, repeated measures design | N = 2 Age, 53.0 years | C<br>E | Walking without knee brace<br>Walking with custom unloader knee orthosis | Walking capacity: N/A<br>Biomechanics: knee angle, hip angle, knee adduction moment, vertical and mediolateral force |
| Fantini Pagani, 2010 (13) | Within subjects, repeated measures design | N = 11 (F = 8, M = 3) Age, 55.5±5.5 years | C<br>E-1<br>E-2 | Walking without knee brace<br>Walking with neutral knee brace<br>Walking with 4° valgus brace | Walking capacity: the 6-minute walking test<br>Biomechanics: knee adduction moment, knee adduction angular impulse, orthosis moment, net knee adduction moment, net knee adduction impulse. |
| Fantini Pagani, 2012 (14) | Within subjects, repeated measures design | N = 10 (F = 8, M = 2) Age, 57.5±7.1 years | C<br>E-1<br>E-2 | Walking without knee brace<br>Walking with 4° valgus brace<br>Walking with 8° valgus brace | Walking capacity: N/A<br>Biomechanics: knee adduction moment, brace valgus moment, maximum net knee moment, knee angle, ankle angle, ankle eversion moment, GRFs |
| Gaasbeek, 2007 (20) | Within subjects, repeated measures design | N = 15 (F = 3, M = 12) Age, 52.0±11.0 years | C<br>E | Walking without knee brace<br>Walking with valgus knee brace | Walking capacity: walking speed, step length<br>Biomechanics: knee adduction moment, knee angle, foot progression angle (affected and unaffected leg) |
| Hewett, 1998 (21) | Within subjects, repeated measures design | N = 18 (F = 4, M = 14) Age, 41 (21–78) years | C<br>E | Walking without knee brace<br>Walking with unloader valgus knee brace | Walking capacity: walking speed<br>Biomechanics: knee addction moment, GRFs |
| Hurley, 2012 (22) | Within subjects, repeated measures design | N = 24 (F = 4, M = 20) Age, 57.8±8.1 years | C<br>E | Baseline measures<br>Custom valgus unloader knee brace | Walking capacity: walking speed, stride length<br>Biomechanics: N/A |

On the other hand, unloader knee braces seem to be effective in decreasing knee adduction moment (Table 3), which is consistent with previous narrative review[28]. In addition to previous review, the present study discovered that unloader braces could decrease knee adduction moment in 2nd peak of stance phase more than 1st peak[13,14,23,25] (Table 3). Effect sizes of three studies that showed 2nd peak of knee adduction moment decreased more than 1st peak were 0.3 – 0.5. Self[16] and Toriyama[17] showed conflicted data pointing to variances in the effect of unloader knee braces due to patient character and brace type.

Previous studies[3,4] showed knee bracing to have beneficial effects on knee pain in people with knee OA. Unloader knee braces are designed to reduce the load on the painful medial compartment by application of an external valgus moment through a three-point force system of action about the knee joint. In the past, several studies showed the load-

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**Table: 2 Results of the studies included in the review (continued). RCT: randomized controlled trial, C: control condition, E: experimental condition, N/A: not applicable, GRFs: ground reaction forces.**

| (Continued) Study | Design | Subject Population | Condition | Intervention or test condition content | Outcomes |
|---|---|---|---|---|---|
| Jones, 2013 (23) | Within subjects, repeated measures design (crossover) | N = 28 (F = 12, M = 16) Age, 66.3±8.2 years | C<br>E | Baseline measures<br>Unloader knee brace set at 6° valgus alignment | Walking capacity: walking speed<br>Biomechanics: knee adduction moment, knee adduction angular inpulse |
| Kirkley, 1999 (18) | RCT | N = 119 (F = 33, M = 86) C, n = 40; E-1, n = 41; E-2, n = 38 Age, >50 years | C<br>E-1<br>E-2 | Receiving an educational pamphlet and instruction in home exercise program<br>Unloader knee brace<br>Neoprene knee sleeve | Walking capacity: the 6-minute walking test<br>Biomechanics: N/A |
| Lindenfeld, 1997 (24) | Within subjects, repeated measures design | N = 11 (F = 3, M = 8) Age, 47.5±14.0 years | C<br>E | Baseline measures walking without knee brace<br>Unloader knee brace | Walking capacity: walking speed<br>Biomechanics: knee adduction moment |
| Moyer, 2013 (25) | Within subjects, repeated measures design (crossover) | N = 16 (F = 8, M = 8) Age, 55.0±7.0 years | C<br>E | Walking without orthosis<br>Walking with custom-fit unloader valgus knee brace | Walking capacity: walking speed<br>Biomechanics: knee adduction moment, GRFs |
| Pollo, 2002 (26) | Within subjects, repeated measures design | N = 11 (F = 1, M = 10) Age, 53.2±9.8 years | C<br>E-1<br>E-2<br>E-3<br>E-4 | Walking without orthosis<br>Walking with normal valgus knee brace<br>Walking with 4° valgus brace<br>Walking with 4° tight valgus brace<br>Walking with 8° valgus brace | Walking capacity: walking speed<br>Biomechanics: knee adduction moment, brace valgus moment, maximum net knee moment, medial compartment load |
| Richards, 2005 (27) | Within subjects, repeated measures design (crossover) | N = 12 (F = 5, M = 7) Age, 60.2 (50–75) years | C<br>E-1<br>E-2 | Baseline measures without knee brace<br>Valgus knee brace<br>Hinged knee brace | Walking capacity: N/A<br>Biomechanics: knee angle, knee angular velocity, GRFs |
| Schmalz, 2010 (15) | Within subjects, repeated measures design | N = 16 (F = 8, M = 8) Age, 56.0±9.0 years | C<br>E | Walking without knee brace<br>Walking with unloader knee brace | Walking capacity: walking speed, cadence, step length<br>Biomechanics: brace valgus moment, GRFs, knee extension and flexion moment, knee adduction moment, knee angle |
| Self, 2000 (16) | Within subjects, repeated measures design | N = 5 (F = 1, M = 4) Age, 49 (41-55) years | C<br>E | Walking without knee brace<br>Walking with custom unloader knee brace | Walking capacity: N/A<br>Biomechanics: brace valgus force, knee adduction moment |
| Toriyama, 2011 (17) | Within subjects, repeated measures design | N = 19 (F = 17, M = 2) Age, 68.4±7.8 years | C<br>E | Walking without knee brace<br>Walking with unloader knee brace | Walking capacity: walking speed, cadence, stride length, step length<br>Biomechanics: knee and hip moment (ipsilateral and contralateral), knee angle, hip angle |

reducing effects of braces to coincide with clinical observations of pain reduction while walking with braces[24,26]. Results of our study suggested the mechanism of immediate decrease in knee pain might be the result of decreased adduction moment, especially at 2$^{nd}$ peak.

The results of this review suggest that unloader knee bracing may have little effect on increasing walking speed in people with knee OA (Table 3). In addition, one high-quality randomized controlled study[18] and one crossover study[13] showed unloader knee bracing had no effect on 6-minute walking distance. Therefore, these studies prompt the question of whether using the unloader knee brace in the osteoarthritic knee can improve walking capacity directly or by decreasing knee pain (Figure 2). Some previous studies showed self-reported physical function was increased with unloader knee braces[21,24,29] indicating performance-based function and self-reported function should be definitively divided with regard to patient outcome of knee brace intervention.

Caution is required because of methodological considerations, such as poor study quality. There were no randomized controlled trials that investigated the effect of knee brace use on walking speed and biomechanical changes with the most common study design being within subject, repeated measures design a portion of which had no follow-up period after intervention. Therefore, the long

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**Table 3: Within-group effect sizes for the walking speed and knee adduction moment from studies examining the effects of unloader knee braces. *: Effect size = (mean difference between the control and experimental condition)/(standard deviation of the control condition). †: Estimated data from figure. ‡: Insufficient data to calculate effect size. §: Data was not analyzed in the study.**

| Study | Experimental condition | Effect size* | |
|---|---|---|---|
| | | Walking speed | Knee adduction moment |
| Draganich, 2006 (19) | Off-the-shelf brace<br>Custom brace | -0.53<br>-0.60 | 0.16<br>0.53 |
| Esrafilian, 2012 (12) | | § | ‡ |
| Fantini Pagani, 2010 (13) | Neutral brace<br>4° valgus brace | § | 1st peak: 0.13, 2nd peak: 0.35, Impulse: 0.34<br>1st peak: -0.06, 2nd peak: 0.47, Impulse: 0.37 |
| Fantini Pagani, 2012 (14) | 4° valgus brace<br>8° valgus brace | § | 1st peak: 0.07, 2nd peak: 0.44, Impulse: 0.32<br>1st peak: 0.20, 2nd peak: 0.50, Impulse: 0.39 |
| Gaasbeek, 2007 (20) † | | 0.38 | 0.93 |
| Hewett, 1998 (21) | | ‡ | 0.00 |
| Hurley, 2012 (22) | | 0.18 | § |
| Jones, 2013 (23) | | 0.44 | Early: 0.29, Mid: 0.33, Late: 0.50, Impulse: 0.29 |
| Lindenfeld, 1997 (24) | | ‡ | 0.50 |
| Moyer, 2013 (25) | | 0.06 | 1st peak: 0.24, 2nd peak: 0.47, Impulse: 0.15 |
| Pollo, 2002 (26) | Normal valgus brace<br>4° valgus brace<br>4° tight valgus brace<br>8° valgus brace | -0.40<br>-0.40<br>-0.20<br>-0.30 | 0.03<br>0.15<br>0.23<br>0.19 |
| Schmalz, 2010 (15) | | ‡ | ‡ |
| Self, 2000 (16) | | § | 0.41 |
| Toriyama, 2011 (17) | | 0.32 | 1st peak: 0.30, 2nd peak: 0.00 |

term effect of knee braces was unclear. In addition, the effects of bracing depends on the type of the brace, such as 'off-the-shelf' or 'self-adjustable custom'[19], as well as its valgus setting[26]. Kutzner[30] stated an unloader brace with 8° valgus would likely be intolerable by the subject for a prolonged duration and therefore, medial load reductions of more than 25% could not be expected permanently. Because of this, appropriate dosage of valgus setting and patient comfort and compliance remain the challenges over the long term.

## Conclusion

On the basis of the studies reviewed, use of unloading knee bracing is effective management for decreasing knee adduction moment – particularly in 2nd peak – in the osteoarthritic knee. It is speculated that knee braces may not affect walking capacity such as walking speed and walking endurance; however, conclusive evidence cannot be stated due to the heterogeneity of trial interventions and the inherent effect on outcomes, as well as the poor quality of some studies. There still exists a need for randomized controlled trials concerning bracing for biomechanical changes and functional capacity in knee osteoarthritis.

## References

1.Felson DT, Zhang Y. An update on the epidemiology of knee and hip osteoarthritis with a view to prevention. Arthritis Rheum. 1998;41(8):1343-55.

2.Chang A, Hayes K, Dunlop D, Hurwitz D, Song J, Cahue S, et al. Thrust during ambulation and the progression of knee osteoarthritis. Arthritis Rheum. 2004;50(12):3897-903.

3.Brouwer RW, Jakma TS, Verhagen AP, Verhaar JA, Bierma-Zeinstra SM. Braces and orthoses for treating osteoarthritis of the knee. Cochrane Database Syst Rev. 2005(1):CD004020.

4.Raja K, Dewan N. Efficacy of knee braces and foot orthoses in conservative management of knee osteoarthritis: a systematic review. Am J Phys Med Rehabil. 2011;90(3):247-62.

5.Rannou F, Poiraudeau S, Beaudreuil J. Role of bracing in the management of knee osteoarthritis. Curr Opin Rheumatol. 2010;22(2):218-22.

6.Stratford PW, Kennedy DM, Woodhouse LJ. Performance measures provide assessments of pain and function in people with advanced osteoarthritis of the hip or knee.. Phys Ther 2006;86(11):1489-96.

7.Stratford PW, Kennedy DM. Performance measures were necessary to obtain a complete picture of osteoarthritic patients. J Clin Epidemiol. 2006;59(2):160-7.

8.Cohen J. A power primer. Psychol Bull. 1992;112(1):155-9.

9.Bryk FF, Jesus JF, Fukuda TY, Moreira EG, Marcondes FB, Santos MG. Immediate effect of the elastic knee sleeve use on individuals with osteoarthritis. Rev Bras Reumatol. 2011;51(5):440-6.

10.Collins A, Blackburn JT, Olcott C, Yu B, Weinhold P. The impact of stochastic resonance electrical stimulation and knee sleeve on impulsive loading and muscle co-

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contraction during gait in knee osteoarthritis. Clin Biomech (Bristol, Avon). 2011;26(8):853-8.
11.Davidson PL, Sanderson DJ, Loomer RL. Kinematics of valgus bracing for medial gonarthrosis: technical report. Clin Biomech (Bristol, Avon). 1998;13(6):414-9.
12.Esrafilian A, Karimi MT, Eshraghi A. Design and evaluation of a new type of knee orthosis to align the mediolateral angle of the knee joint with osteoarthritis. Adv Orthop. 2012;2012:104927.
13.Pagani CH, Bohle C, Potthast W, Bruggemann GP. Short-term effects of a dedicated knee orthosis on knee adduction moment, pain, and function in patients with osteoarthritis. Arch Phys Med Rehabil. 2010;91(12):1936-41.
14.Fantini Pagani CH, Hinrichs M, Bruggemann GP. Kinetic and kinematic changes with the use of valgus knee brace and lateral wedge insoles in patients with medial knee osteoarthritis. J Orthop Res. 2012;30(7):1125-32.
15.Schmalz T, Knopf E, Drewitz H, Blumentritt S. Analysis of biomechanical effectiveness of valgus-inducing knee brace for osteoarthritis of knee. J Rehabil Res Dev. 2010;47(5):419-29.
16.Self BP, Greenwald RM, Pflaster DS. A biomechanical analysis of a medial unloading brace for osteoarthritis in the knee. Arthritis Care Res. 2000;13(4):191-7.
17.Toriyama M, Deie M, Shimada N, Otani T, Shidahara H, Maejima H, et al. Effects of unloading bracing on knee and hip joints for patients with medial compartment knee osteoarthritis. Clin Biomech (Bristol, Avon). 2011;26(5):497-503.
18.Kirkley A, Webster-Bogaert S, Litchfield R, Amendola A, MacDonald S, McCalden R, et al. The effect of bracing on varus gonarthrosis. J Bone Joint Surg Am. 1999;81(4):539-48.
19.Draganich L, Reider B, Rimington T, Piotrowski G, Mallik K, Nasson S. The effectiveness of self-adjustable custom and off-the-shelf bracing in the treatment of varus gonarthrosis. J Bone Joint Surg Am. 2006;88(12):2645-52.
20.Gaasbeek RD, Groen BE, Hampsink B, van Heerwaarden RJ, Duysens J. Valgus bracing in patients with medial compartment osteoarthritis of the knee. A gait analysis study of a new brace. Gait Posture. 2007;26(1):3-10.
21.Hewett TE, Noyes FR, Barber-Westin SD, Heckmann TP. Decrease in knee joint pain and increase in function in patients with medial compartment arthrosis: a prospective analysis of valgus bracing. Orthopedics. 1998;21(2):131-8.
22.Hurley ST, Hatfield Murdock GL, Stanish WD, Hubley-Kozey CL. Is there a dose response for valgus unloader brace usage on knee pain, function, and muscle strength? Arch Phys Med Rehabil. 2012;93(3):496-502.
23.Jones RK, Nester CJ, Richards JD, Kim WY, Johnson DS, Jari S, et al. A comparison of the biomechanical effects of valgus knee braces and lateral wedged insoles in patients with knee osteoarthritis. Gait Posture. 2013;37(3):368-72.
24.Lindenfeld TN, Hewett TE, Andriacchi TP. Joint loading with valgus bracing in patients with varus gonarthrosis. Clin Orthop Relat Res 1997;344:290-7.
25.Moyer RF, Birmingham TB, Dombroski CE, Walsh RF, Leitch KM, Jenkyn TR, et al. Combined effects of a valgus knee brace and lateral wedge foot orthotic on the external knee adduction moment in patients with varus gonarthrosis. Arch Phys Med Rehabil. 2013;94(1):103-12.
26.Pollo FE, Otis JC, Backus SI, Warren RF, Wickiewicz TL. Reduction of medial compartment loads with valgus bracing of the osteoarthritic knee. Am J Sports Med. 2002;30(3):414-21.
27.Richards JD, Sanchez-Ballester J, Jones RK, Darke N, Livingstone BN. A comparison of knee braces during walking for the treatment of osteoarthritis of the medial compartment of the knee. J Bone Joint Surg Br. 2005;87(7):937-9.
28.Beaudreuil J, Bendaya S, Faucher M, Coudeyre E, Ribinik P, Revel M, et al. Clinical practice guidelines for rest orthosis, knee sleeves, and unloading knee braces in knee osteoarthritis. Joint Bone Spine. 2009;76(6):629-36.
29.Brouwer RW, van Raaij TM, Verhaar JA, Coene LN, Bierma-Zeinstra SM. Brace treatment for osteoarthritis of the knee: a prospective randomized multi-centre trial. Osteoarthritis Cartilage. 2006;14(8):777-83.
30.Kutzner I, Kuther S, Heinlein B, Dymke J, Bender A, Halder AM, et al. The effect of valgus braces on medial compartment load of the knee joint - in vivo load measurements in three subjects. J Biomech. 2011;44(7):1354-60.

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