Anew Shoe Decreases Pain and Fatigue in Ascending and Descending the stairs in patients with knee osteoarthritis

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Abstract: Osteoarthritis (OA) is a common painful and chronic condition that affects a large proportion of the older population. Patients with knee OA often present with decreased stair climbing performance, measured as time needed to ascend and descend a given number of stairs, and stair climbing performance is frequently used as a measure of function in this patient group. The aim of this study was to evaluate the effect of a new shoe on improving knee OA in ascending and descending the stairs in terms of pain and fatigue. Ninety-nine patients were divided into two group by gender and age adjustment. Group one consisted of forty nine patients, 44 (89.8%) female and 5 (10.2) male, mean age was 58.71±6.98 in this group. Group two was consisted of 50 patients 43 (86%) female and 7 (14%) male, mean age was 58.38±8.84 in this group. Visual analog scale (VAS) and fatigue score and duration of ascending and descending of stairs was studied in the patients with and without wearing the new shoe. VAS and fatigue score were lower in patients during wearing the designed shoe, although there was no significant difference in ascending and descending duration of stairs with or without shoe. Our experiment showed that a new designed shoe can improve OA patients in ascending or descending the stairs and improve their fatigue score, so it may be useful to improve their life quality through decreasing their pain in ascending and descending the stairs.
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1. Introduction

Osteoarthritis (OA) is a disease in which the joint cartilage breaks down, leading to joint changes (1) and chronic pain. Knee OA is a common painful and chronic condition that affects a large proportion of the older population [1]. Osteoarticular diseases reduce the rheological properties of synovial fluid in the various joints that increase the susceptibility of the articular cartilage to damage [2].

Estimated population prevalence varies from 4‑30% depending on the age, sex and disease definition. Knee OA is a multifactorial disease [3]. The cause of OA remains unknown, thought there is clear evidence for major risk factors, such as age, obesity, joint trauma, and heavy work load [3] The risk factors can be divided into systemic (for example age, gender, genetics and over weight) and local biomechanical factors, such as joint injury and mal alignment, over weight and muscle weakness[4]. Abnormal mechanical loading in various sport activities or during heavy work may activate the biochemical cascade that leads to joint degeneration and pain, but also even in normal mechanical loading if the cartilage is impaired.Of all the risk factors known, obesity is most strongly associated with development and progression of knee OA [5]. Although the pathogenesis of knee OA is not well understood, biomechanical stresses that affect the articular cartilage and subchondral bone have been implicated as important inciting factors [6,7]. Radin et al [8] postulated that the repetitive impulsive loading may first induce trabecular micro fractures in the subchondral bone. According to this theory, subsequent remodeling increases the stiffness and thickness of the subchondral bone in an attempt to dampen impact forces. As a consequence, the over lying cartilage may become overloaded an break down resulting in cartilage degeneration and loss [8]. The incidence of knee OA is estimated to increase because the proportion of elderly population continues to raise [9]. Knee OA has a substantial impact on activities of daily living treatment strategies for knee OA, so foot orthoses, knee braces and footwear, have been proposed to minimize the knee adduction moment, and consequently reduce the loading on the knee OA [9-10].One of the common complaints of an individual suffering from OA of the knee joint is pain while climbing stairs. Tibiofemoral joint weight loading is six times greater during stair descending comparing to level walking and thus frequently causes pain in patients with knee OA[11].

Patients with knee OA often present with decreased stair climbing performance, measured as time needed to ascend and descend a given number of stairs, and stair climbing performance is frequently used as a measure of function in this patient group[12,13]. The ability to ascend stairs is directly related to the function of the quadriceps femoris. It has been suggested that these patients lean their trunk forward to compensate for weakness in their quadriceps muscles [14]. Thus, as the severity of knee OA increases, it is likely that patients may also adopt compensatory strategies associated with a forward trunk lean [15].

In this study we used a kind of shoe to see if using this kind of shoe can help OA patients in ascending or descending the steps.

The aim of this study was to evaluate the effect of a new shoe on improving knee OA in ascending and descending the stairs in terms of pain and fatigue. In brief by considering mathematical calculations, its clear that by decreasing stair height to half of its height, the torque force on knee joint decreases about 20% in ascending and descending the stairs, and this result in reduction of pain and accelerating of stair ascending and descending by patients. We did this by designing a shoe with half height of the stairs height. By this design during ascending the stairs, in each step, because of height of the shoe the patients have passed half height of the stairs before elevating his/her foot, and this result in torque force. This shoes are designed to use single step system of ascending and descending (in ascending, first foot without the shoe ascends and then foot wearing the shoe with put next to the other foot, in descending the action is reverse).

2. Material and Methods

Patients:

Ninety-nine patients were divided into two groups by gender and age adjustment. Group one consisted of forty nine patients, 44 (89.8%) female and 5 (10.2) male, mean age was 58.71±6.98 in this group. Group two was consisted of 50 patients 43 (86%) female and 7 (14%) male, mean age was 58.38±8.84 in this group.

Inclusion criteria:

(1): Fulfilling the diagnostic criteria of American college of rheumatology in cluding: age over 50 years of old, joint stiffness below thirty minutes and finally criptation by osteophyte. (2):The radiologic confirmation of knee OA. (3): Having bilateral knee OA having pain and disability in ascending or descending the stairs.

Exclusion criteria:

(1):Age under 50 years of old. (2):Underlying systemic diseases like congestive heart failure, COPD and etc.(3): Any disease causing imbalance and ataxia.4.Knee OA secondary to trauma, surgery, and etc.

Shoe:

The shoes were pair of shoes in which the right pair was 85 mm higher than the left pair (this height was the half height of each stair (170mm) that patients would ascend or descend on them). The shoes had strips to fasten the shoe and fit them to the foot (figure 1).

Figure 1. The shoes

Procedure:

After educating the patients about experiment procedure, visual analog scale (VAS) was explained to them and they were asked to score the scale before ascending the stairs (Pain intensity was assessed by a 100-mm visual analog scale (VAS)). Then they climbed a stairs consisted of nine steps by 170mm height in rehabilitation center of Imam Reza hospital, Tabriz, Iran. After climbing the steps they asked to score the VAS again. The score system includes 4 scores for both VAS and fatigue. 1: before ascending, 2:after ascending, 3:before descending, 4:after descending. There was a rest time of 20 minutes between the stages.

Ethics:

In this research patients considering inclusion and exclusion criteria were included in the research after informing them and explaining the experiment procedure. All participants provided written informed consent and were free to withdraw from the study at any time. The protocol was approved by local ethics committees.

Statistical Analysis

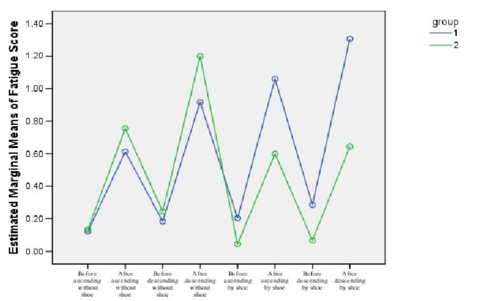
Differences in VAS and fatigue score between patients by shoe and control subjects were detected using analysis of variance (ANOVA; P<0.05). Tukey test applied for posthoc comparison between groups.The difference in ascending and descending duration between groups was analiaed by Student T test and (P<0.05) considered as significant level.

3. Results

3.1.VAS score:

The VAS score was significantly lower before ascending without shoe comparing to after ascending without shoe(P<0.0001). The VAS score was significantly higher after ascending without shoe, comparing to before ascending without shoe (P<0.0001), before ascending with shoe (P<0.0001) and after ascending with shoe (P=0.022) [Table 1, Figure2].

Figure (3).Fatigue score in before and after ascending and descending with and without shoe.



The VAS score was significantly lower before ascending with shoe comparing to after ascending without shoe (P<0.0001), and after ascending with shoe (P<0.0001). There was no significant difference in VAS score between before ascending without shoe and before ascending with shoe [Table 1, Figure 2].

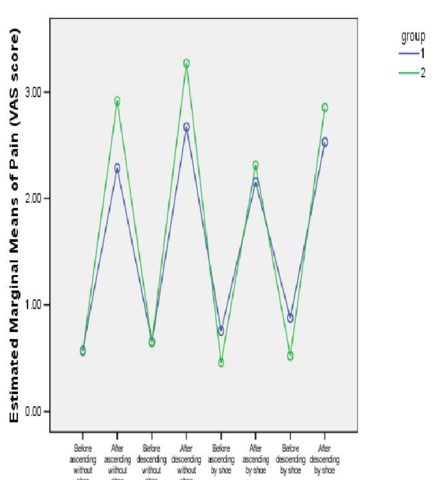
The VAS score is presented in all the groups, and wearing shoe improved vas score comparing to not wearing the shoe significantly.

The VAS score was significantly higher between after ascending with shoe and before ascending without shoe (P<0.0001) and before ascending with shoe (P<0.0001) but it was lower than, after ascending without shoe (P=0.022) [Table 1, Figure2]

Table (1).VAS score in before and after ascending and descending with and without shoe.

VAS	(1st : without shoe, 2nd :by shoe)	(1st :by shoe, 2nd :without shoe)
Before ascending without shoe	0.57±0.73	0.56±0.74
Before ascending by shoe	0.75±0.96	0.45± 0.68
After ascending without shoe	2.28±1.30	2.91±1.45
After ascending by shoe	2.15±1.28	2.31±1.55
Before descending without shoe	0.65±0.90	0.64±0.93
Before descending by shoe	0.87±1.12	0.52±0.79
After descending without shoe	2.67±1.50	3.27±1.72
After descending by shoe	2.53±1.69	2.85±1.68

Figure (2).VAS score in before and after ascending and descending with and without shoe.



The VAS score was significantly lower between before descending without shoe comparing to after descending without shoe (P<0.0001) and after descending with shoe (P<0.0001), but there was no significant difference in VAS score between before descending without shoe and before descending with shoe [Table 1,Figure2].

The VAS score was significantly higher between After descending without shoe and Before descending without shoe (P<0.0001), Before descending with shoe (P<0.0001) but there was no significant difference in VAS score between After descending without shoe and After descending with shoe(P=0. 376) [Table 1,Figure2].

The VAS score was significantly lower between before descending with shoe comparing to after descending without shoe (P<0.0001) and after descending with shoe (P<0.0001), but there was no significant difference in VAS score between before descending with shoe and before descending without shoe [Table 1, Figure2].

The VAS score was significantly higher between after descending with shoe and before descending without shoe (P<0.0001), before descending with shoe (P<0.0001), but there was no significant difference in VAS score between after descending with shoe and after descending without shoe(P=0. 376) [Table 1, Figure2].

3.2. Fatigue score

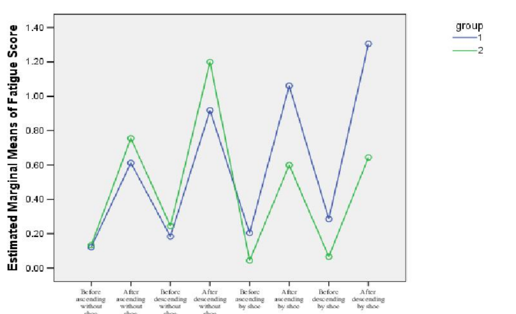
The fatigue score was significantly lower between before ascending without shoe than after ascending without shoe(P<0.0001) and after ascending with shoe (P<0.0001), but there was no significant difference in fatigue score between before ascending without shoe and before ascending with shoe [Table 2, Figure3].

Table (2). Fatigue score in before and after ascending and descending with and without shoe

fatigue	(1st : without shoe, 2nd :by shoe)	(1st :by shoe, 2nd :without shoe)
Before ascending without shoe	0.12±0.33	0.13±0.34
Before ascending by shoe	0.20±0.53	0.04±0.20
After ascending without shoe	0.61±0.99	0.75±1.19
After ascending by shoe	1.06±1.40	0.60±1.07
Before descending without shoe	0.18±0.44	0.24±0.48
Before descending by shoe	0.28±0.61	0.06±0.25
After descending without shoe	0.91±1.09	1.20±1.42
After descending by shoe	1.30±1.44	0.64±0.98

The fatigue score is presented in all the groups, and wearing shoe improved vas score comparing to not wearing the shoe significantly.

Figure (3).Fatigue score in before and after ascending and descending with and without shoe.



The fatigue score was significantly higher in after ascending without shoe than before ascending without shoe (P<0.0001), before ascending with shoe (P<0.0001) but there was no significant relation between after ascending without shoe and after ascending with shoe [Table 2, Figure3].

The fatigue score was significantly lower between before ascending with shoe and after ascending without shoe (P<0.0001), after ascending with shoe (P<0.0001). There was no significant difference in fatigue score between before ascending without shoe and before ascending with shoe [Table 2, Figure3].

The fatigue score was significantly higher between after ascending with shoe and before ascending without shoe (P<0.0001) and before ascending with shoe (P<0.0001) but it was significant difference comparing to after ascending without shoe [Table 2, Figure3].

The fatigue score was significantly lower between before descending without shoe comparing to After descending without shoe (P<0.0001) and after descending with shoe (P<0.0001), but there was no significant difference in fatigue score between before descending without shoe and before descending with shoe [Table 2, Figure3].

The fatigue score was significantly higher between after descending without shoe and before descending without shoe (P<0.0001), before descending with shoe (P<0.0001) but there was no significant difference in fatigue score between after descending without shoe and after descending with shoe [Table 2, Figure3].

The fatigue score was significantly lower between before descending with shoe comparing to after descending without shoe (P<0.0001) and After descending with shoe (P<0.0001), but there was no significant difference in fatigue score between before descending with shoe and before descending without shoe [Table 2, Figure3].

The fatigue score was significantly higher between after descending with shoe and before descending without shoe (P<0.0001), before descending with shoe (P<0.0001) but there was no significant difference in fatigue score between after descending with shoe and after descending without shoe [Table 2, Figure3].

3.3. Ascending and descending duration:

The difference in time duration in (1st :without shoe, 2nd :by shoe) group for ascending by shoe and without shoe was not significant (P=0.62) [Table 3].

Table 3. Ascending and descending duration time.

	Ascending time (Seconds)	Descending time (Seconds)
Group (1st :without shoe, 2nd :by shoe)	39.73±13.04	40.89±13.16
Group (1st :without shoe, 2nd :by shoe)	22.24±27.75	22.44±12.52
Group (1st :by shoe, 2nd :without shoe)	38.72±13.02	37.24±13.66
Group (1st :by shoe, 2nd :without shoe)	21.16±9.80	23.56±12.63

There was no significant difference in time duration for ascending and descending the steps with or without shoe

The difference in time duration in(1st :without shoe, 2nd :by shoe) group for descending by shoe and without shoe was not significant (P=0.78) [Table 3].

The difference in time duration in (1st :shoe, 2nd :without shoe) group for ascending by shoe and without shoe was not significant (P=0.35) [Table 3].

The difference in time duration in (1st :shoe, 2nd :without shoe) group for descending by shoe and without shoe was not significant (P=0.41) [Table 3].

3.4. Data:

There was no significant difference in height, weight, hip flexion, hip extension, knee flexion and knee extension between two groups, Table 4.

Table 4. Demographic data of the patients

	Group (1st :by shoe, 2nd :without shoe)	Group (1st :without shoe, 2nd :by shoe)
Height	156.87±13.87	157.48±9.93
Weight	79.42±18.90	76.61±9.87
Hip flexion	118.57±9.24	121.00±8.45
Hip extension	25.06±26.75	20.06±3.28
Knee flexion	121.36±19.89	125.00±10.10
Knee extension	174.75±3.19	175.40±3.05

There was no difference in height, weight, hip flexion, hip extension, knee flexion and knee extension between two groups

4. Discussion:

Disability refers to persons impaired performance for socially defined life tasks that are expected in a typical sociocultural and physical environment of individual. Disability is a complex phenomon influenced by pain, obesity, co morbidity, low level of physical activity, social and psychological factors as well as local impairments in lower extremities [18]. These will interfere with object performance tests and physical function. However, in knee OA, the limitations in physical function or activities of daily living play a crucial role in the development of disability. Pain is obviously a centera factor in the physical function impairments via its direct effects on the function [18], but physiological [19] and social [20] factors contribute to the development of pain. The can be considered as mediators of pain and functional limitations.

The majority of patients with symptomatic knee OA do not attain satisfactory long-term relief, even with recent advances in pain relievers. Analgesic treatment may relieve the pain but does not improve biomechanics and may even aggravate OA. Although OA is complex and not completely understood, disease onset and progression are at least partly related to responses by bone and cartilage to biomechanical loading. Devices that promote pressure reduction from the medial knee may provide pain relief while simultaneously protecting the joint from further degeneration; one such device is a lateral wedge orthotic shoe insert. When worn during weight-bearing activity, these inserts have been shown to reduce loading of the medial compartment and may provide pain relief. There is controversial evidence regarding whether foot orthoses or knee braces improve pain and function in selected patients with OA. We asked whether a new shoe would reduce pain, enhance functional scores. Patients with knee OA frequently demonstrate difficulties in stair climbing [21] evaluated by the time required to ascend or descend a given number of stairs. Stair ambulation performance is often used as measure of function in OA patients [22].

Our data showed that also there was no significant difference in ascending and descending duration with or without shoe, but VAS score and fatigue score was better in using our shoe comparing to not using the shoe. Unfortunately, there are rather few papers available about stair ambulation during the gait analysis among patients with knee OA. Recently, Asay et al [23] investigated patients with moderate or severe knee OA and compared the results with healthy controls during stair climbing task. Patients with more severe OA (KL>3) demonstrated a greater peak trunk flexion angle, lower peak flexion moment and higher peak flexion moment than the controls. There was no difference in the knee flexion angle at the initial contact. Patients with one knee more severely affected than the other exhibited a decreased peak flexion moment on their more affected side compared to the contra lateral side. The authors concluded that the patients withsevere knee OA tried to reduce uaderatus femoris demanded by leaning their trunk forward during stair climbing [23].

Kaufman et al [24] found no differences in the maximum knee flexion during stair ascent and descent between the control subjects and patients with knee OA. The patients demonstrated lower maximum knee internal extension moments both during stair ascent and descent. Female OA subjects exhibited a greater peak knee extension moment as wel as more knee flexion Kaufman et al [24], again emphasizing the influence of gender. These results should be interpreted with caution, as the patients with knee OA were on average 27 years older walked at significantly slower speed and possessed different anthropometries compared to the controls. Hinman et al [25] reported that the patients with knee OA did not exhibit delayed temporal onset of VM muscle relatively to VL, in contrast to healthy controls, during stair climbing. Bennell et al [26] observed that the joint-position sense and QFM onset associated with the knee flexion angle at initial contact during stair descent, and further more, the Qfm strength correlated with the peak knee flexion angle occurring during the loading response. The authors concluded that the impaired sensorimotor function was not strongly associated with the altered joint kinematics in the knee OA patients during locomotion [26].

Kirkley et al. [27] described improvement on the Western Ontario and McMaster Universities (WOMAC) pain scale of 9% in 41 patients treated with an unloader valgus brace, which was better than a nonbraced control group. Brouwer et al. [28] noted a better knee function score (an improvement of 4 units of 100) after valgus bracing compared with nonbracing in a group of 95 patients with medial knee OA. A recent crossover RCT concluded wedged shoe insoles were not efficacious in patients with medial knee OA [29]. They compared laterally wedged insoles with neutral insoles, which may act as shock absorbers and relieve symptoms [30].

Hughes et al [31] reported that during both stair ascent and descent, the female subjects had a 6 to 8 degree greater peak knee flexion angle than males. The females also had a significantly greater peak knee flexion angle during level walking than men. The difference in peak knee flexion is most likely due to a significant difference in height between the female and male subjects. The female subjects had a mean height of 162 cm (±6) while the male subjects averaged 177 cm (±8).Similarly, the female subjects generated a greater maximum internal knee extension moment than men for all conditions, with only stair ascent demonstrating a significant difference.

5. Conclusion:

Society must prepare itself for an aging world, OA is the most common cause of reported disabilities. Hence, disability and participation restriction is becoming an important component to assess in defining public health strategies. Current treatment is aimed at minimizing pain, maintaining or improving joint mobility, and decreasing functional impairment. Our experiment showed that a new designed shoe can improve OA patients in ascending or descending the stairs and improve their fatigue score, so it may be useful to improve their life quality through decreasing their pain in ascending and descending the stairs.

References:

1.Woolf AD, Pfleger B. Burden of major musculoskeletal conditions. Bull World Health Organ. 2003;81:646–656.
2.Foti C, Cisari C, Carda S, Giordan N, Rocco A, Frizziero A, Della Bella G.A prospective observational study of the clinical efficacy and safety of intra-articular sodium hyaluronate in synovial joints with osteoarthritis.Eur J Phys Rehabil Med. 2011 Mar 15.
3-Arokoski J, Malmivaara A, Manninen M, Moilanen E, Ojala R, Paavolainen P, Ruuskanen J, Virolainen P, Virtapohja H, Vuolteenaho K, Osterman H.Duodecim. 2007;123(14):1759-60.
4-Arokoski JP, Lammi MJ, Hyttinen MM, Kiviranta I, Parkkinen JJ, Jurvelin JS, Tammi MI, Helminen HJ. Etiopathogenesis of osteoarthritis. Duodecim. 2001;117(16):1617-26; quiz 1626, 1679.
5-Nuki G, Salter D. The impact of mechanical stress on the pathophysiology of osteoarthritis. In: Sharma L, Berenbaum F, editors. Osteoarthritis: a companion to rheumatology. Philadelphia: Mosby; 2007. p. 33-52.
6.Jackson BD, Wluka AE, Teichtahl AJ, Morris ME, Cicuttini FM. Reviewing knee osteoarthritis-A biomechanical perspective. J Sci Med Sport. 2004;7(3):347-57.
7.Roemhildt ML, Coughlin KM, Peura GD, Badger GJ, Churchill D, Fleming BC, Beynnon BD. Effects of increased chronic loading on articular cartilage material properties in the Lapine tibio-femoral joint. J Biomech. 2010;43:2301–2308.
8-Radin EL, Paul IL, Rose RM.Role of mechanical factors in pathogenesis of primary osteoarthritis. Lancet. 1972 Mar 4;1(7749):519-22.
9-Nakajima K, Kakihana W, Nakagawa T, Mitomi H, Hikita A, Suzuki R, Akai M, Iwaya T, Nakamura

K, Fukui N. Addition of an arch support improves the biomechanical effect of a laterally wedged insole. Gait Posture. 2009;29:208–213.

10-Baker K, Goggins J, Xie H, Szumowski K, LaValley M, Hunter DJ, Felson DT. A randomized crossover trial of a wedged insole for treatment of knee osteoarthritis. Arthritis Rheum. 2007;56:1198–1203.

11. Andriacchi TP, Andersson GBJ, Fermier RW, et al. A study of lower-limb mechanics during stair-climbing. J Bone Joint Surg. 1980;62:749-757.

12-Mizner RL, Petterson SC, Snyder-Mackler L. Quadriceps strength and the time course of functional recovery after total knee arthroplasty. J Orthop Sports Phys Ther 2005, 35: 424–436.

13. Shrader MW, Draganich LF, Pottenger LA, et al. Effects of knee pain relief in osteoarthritis on gait and stair-stepping. Clin Orthop Relat Res 2004; 421:188–193.

14.Andriacchi TP, Galante JO, Draganich LF. Relationship between knee extensor mechanics and function following total knee replacement. In: Dorr L, editor. Proc 1st Ann Meet Knee Soc. Baltimore, MD: University Park Press 1985; 83–94.

15-Asay JL, Mündermann A, Andriacchi TP. Adaptive patterns of movement during stair climbing in patients with knee osteoarthritis.J Orthop Res. 2009 Mar;27(3):325-9.

18.Sharma L, Cahue S, Song J, Hayes K, Pai YC, Dunlop D.Physical functioning over three years in knee osteoarthritis: role of psychosocial, local mechanical, and neuromuscular factors. Arthritis Rheum. 2003 Dec;48(12):3359-70.

19.van Baar ME, Dekker J, Lemmens JA, Oostendorp RA, Bijlsma JWPain and disability in patients with osteoarthritis of hip or knee: the relationship with articular, kinesiological, and psychological characteristics. J Rheumatol. 1998 Jan;25(1):125-33

20.Ethgen O, Vanparijs P, Delhalle S, Rosant S, Bruyère O, Reginster JY.Social support and health-related quality of life in hip and knee osteoarthritis. Qual Life Res. 2004 Mar;13(2):321-30

21.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 Nov;86(11):1489-96.

22.Shrader MW, Draganich LF, Pottenger LA, Piotrowski GA.Effects of knee pain relief in osteoarthritis on gait and stair-stepping. Clin Orthop Relat Res. 2004 Apr;(421):188-93.

23.Asay JL, Mündermann A, Andriacchi TP.Adaptive patterns of movement during stair climbing in patients with knee osteoarthritis. J Orthop Res. 2009 Mar;27(3):325-9.

24.Kaufman KR, Hughes C, Morrey BF, Morrey M, An KN.Gait characteristics of patients with knee osteoarthritis. J Biomech. 2001 Jul;34(7):907-15.

25.Hinman RS, Bennell KL, Metcalf BR, Crossley KM.Temporal activity of vastus medialis obliquus and vastus lateralis in symptomatic knee osteoarthritis. Am J Phys Med Rehabil. 2002 Sep;81(9):684-90.

26.Bennell KL, Hinman RS, Metcalf BR.Association of sensorimotor function with knee joint kinematics during locomotion in knee osteoarthritis. Am J Phys Med Rehabil. 2004 Jun;83(6):455-63; quiz 464-6, 491.

27. Kirkley A, Webster-Bogaert S, Litchfield R, Amendola A, MacDonald S, McCalden R, Fowler P. The effect of bracing on varus gonarthrosis. J Bone Joint Surg Am. 1999;81:539–548.

28. Brouwer RW, Raaij TM, Verhaar JA, Coene LN, Bierma-Zienstra SM. Brace treatment for osteoarthritis of the knee: a prospective randomized multi-centre trial. Osteoarthritis Cartilage. 2006;14:777–783.

29. Baker K, Goggins J, Xie H, Szumowski K, LaValley M, Hunter DJ, Felson DT. A randomized crossover trial of a wedged insole for treatment of knee osteoarthritis. Arthritis Rheum. 2007;56:1198–1203.

30. Kemp G, Crossley KM, Wrigley TV, Metcalf BR, Hinman RS. Reducing joint loading in medial knee osteoarthritis: shoes and canes. Arthritis Rheum. 2008;59:609–614.

31. Hughes C. A., Kaufman K. R., Morrey B. F., Morrey M.A., K. N..Gender differences in knee kinematics and kinetics during stair climbing and level walking in adults with osteoarthritis of the knee.Myoclinic/Foundation,2000, http://www.asbweb.org/conferences/2000/pdf/085.pdf.

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