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Effect of Cane on the Knee and Thorax Biomechanics in the Early Postoperative Period Following Total Knee Arthroplasty

Hidenori Tanikawa*[1], Ryo Ogawa[2], Kengo Harato[2], Yasuo Niki[2], Shu Kobayashi[2], Kazunari Okuma[3], Takeo Nagura[4]

[1]*Department of Orthopaedic Surgery, Saiseikai Yokohamashi Tobu Hospital, japan*

[2]*Department of Orthopaedic Surgery, Keio University School of Medicine, Japan*

[3]*Department of Orthopaedic Surgery, Saitama City Hospital, Japan*

[4]*Department of Clinical Biomechanics, Keio University School of Medicine, Japan*

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***Corresponding author:** Hidenori Tanikawa, Department of Orthopaedic Surgery, SaiseikaiYokohamashi Tobu Hospital, 3-6-1 Shimosueyoshi, Tsurumi, Yokohama, Kanagawa, Japan, Tel: 81455763000; Fax: 81455763525; Email: adriatic123sea@gmail.com

Abstract

Background: Although total knee arthroplasty (TKA) reliably reduces pain and improves knee function, several months are needed for the damaged quadriceps muscles to recover to preoperative strength. Patients with weak muscle strength often use a walking aid to prevent from falling after TKA. The aim of this study is to investigate the biomechanical effect of contralateral cane use on the knee and trunk movement in patients after TKA.

Methods: Twenty people with knee osteoarthritis scheduled to undergo unilateral TKA were enrolled in the study. The movements of knee joint and trunk were measured using three-dimensional motion analysis during walking. The kinematic and kinetic variables were statistically compared between aided walking and unaided walking using two-tailed paired t-tests.

Results: The peak knee adduction moment was significantly smaller in aided walking than in unaided walking. The peak trunk flexion angle and the peak trunk angle to the non-operated side were significantly smaller in aided walking than in unaided walking. The amount of coronal displacement of trunk in aided walking was significantly smaller than the unaided walking.

Conclusion: The use of a cane during walking decreases GRF by 5.6% and knee adduction moment by 15.8%. Also, the amount of coronal displacement of the trunk decreased with the use of a cane. Using a cane for walking during the initial rehabilitation period after TKA decrease the load on the knee joint, stabilize the movement of the trunk, and may useful for preventing patients from falls.

Keywords: Gait Analysis; Total Knee Arthroplasty; Biomechanics; Trunk; Cane

Abbreviations: TKA: Total Knee Arthroplasty; OA: Osteoarthritis; GRF: Ground Reaction Force

Introduction

Knee osteoarthritis (OA) is one of the leading causes of disability among elderly people over 65 years old. The incidence of knee OA increases with age and is characterized by joint instability, muscle weakness, joint deformity, pain and stiffness [1-3]. Total knee arthroplasty (TKA) is a common surgery for the management of severe pain in knee OA. TKA is a surgical intervention that eliminates pain and knee deformity and improves patient quality of life. Furthermore, TKA not only reduces pain in knee OA patients, but improves gait performance and balance function [4,5]. Elderly patients who have undergone TKA have been found to have some increased risk of falls. Older adults who undergo joint replacement surgery may have reduced proprioception, as well as a short-term increase in pain and reduction in muscle strength following surgery [6-8]. These deficits as well as the hospital admission itself may affect older adults who have less physical reserve and ability to compensate for these deficits than younger adults. Previous studies conducted with TKA patients have presented postoperative fall rate starting from 22% up to 40% [9-12].

According to the literature the intrinsic risk factors responsible for 39%-53% to falls in the elderly people are history of falls [12-

14], advanced age [15,16], gender [15,16], muscle weakness [17], reduced physical activity [17], mobility disorders and abnormal gait [18], and fear of falling [12,13,19]. Although TKA reliably reduces pain and improves knee function, several months are needed for the damaged quadriceps muscles to recover to preoperative strength. Quadriceps muscle weakness is most pronounced during the first month after surgery, and patients with weak muscle strength often use a walking aid to prevent from falling [20]. Previous biomechanical studies have found that patients frequently exhibit changes in gait biomechanics after TKA [21-25]. Patients after TKA exhibited a quadriceps avoidance gait pattern as the quadriceps muscles contribute less to the knee extension moment. A previous biomechanical study has revealed that, although there was a significant decrease in the contribution of the quadriceps muscles to the vertical acceleration and forward deceleration of the center of mass during walking, the patients with TKA compensated for this deficiency by leaning their trunks forward [21].

Furthermore the control of trunk movement was found to be critical to maintain balance and prevent falls [22-25]. The trunk constitutes two-thirds of the body weight; even slightly uncoordinated movement of the trunk may increase the risk of balance loss and falls after TKA. Until now, few studies have been performed on the variation of knee and trunk movement in TKA patients using a three-dimensional gait analysis system. The aim of this study is to investigate the biomechanical effect of cane use on the knee and trunk movement in patients after TKA. Our hypothesis was that using a cane in the early postoperative period following TKA affects the knee and trunk biomechanics in the way of decreasing knee joint load and increasing trunk balance during walking.

Materials and Methods

Subjects

Twenty female patients with knee osteoarthritis (OA) (mean (SD) age, 72.9 (5.2) years; height, 1.51 (0.059) m: mass, 57.6 (8.68kg) scheduled to undergo unilateral TKA were enrolled in the study. Patients who underwent hip joint arthroplasty or high tibial osteotomy, were diagnosed as rheumatoid arthritis, or could not walk without an assistive device, were excluded. The surgery was performed by a single surgeon using a standard medial trivector approach. A posterior stabilized type implant (Triathlon, Stryker, and Kalamazoo, MI) was used in all cases. All study protocols were approved by the Institutional Review Board of our institution, and informed consent was obtained from each patient prior to initiation of the study.

Gait Analysis

The measurements of patients were performed using eight optoelectronic cameras (Pro-reflex, Qualities) and four force plates (AM6110, Bertec) at synchronized frequencies of 120 Hz. Three-dimensional motion analysis was carried out using twenty-seven reflective markers placed on each segment of the lower extremities, pelvis, and trunk [26] The details of marker placement are showed in (Figure 1). Measurements were performed at three weeks after surgery, and the length of a cane was fit to each patient by one physiotherapist. Patients were instructed to walk with and without a cane at a comfortable self-selected speed. After a few practice trials, eight trials were recorded for each task, and successful trials with a clear hit on the force plate were selected for analysis. The analysis area was defined as from heel-touch to toe-off of each leg. Visual 3D software (C-Motion, Inc.) was used to calculate knee and trunk joint kinematics and kinetics in sagittal and frontal planes. All kinetic data were normalized to body mass. The variables, including peak ground reaction force (GRF), peak knee flexion angle, peak knee moments (flexion, extension, and adduction), peak trunk angle relative to the pelvis (flexion, extension, the operated side, and the non-operated side), and the amount of coronal displacement of the trunk were statistically compared between aided walking and unaided walking.

Figure 1: Twenty-seven retro reflective markers were placed on acromion, 7th cervical vertebla, 10th thoracic vertebla, 5th lumber vertebla, iliac crest, greater trochanter, thigh, medial and lateral epichondyles of a knee, shank, medial and lateral malleoli of an ankle, heads of 1st and 5th metatarsal bones, and calcaneus.

Statistical Analysis

Statistical differences in gait parameters (ground reaction force, average velocity of the center of pelvis, knee flexion angle, knee flexion, extension, and adduction moments, trunk flexion and extension angle, trunk angle to the operated side and to the non-operated side, and the amount of coronal displacement of the thorax) between aided walking and unaided walking were evaluated by two-tailed paired t-tests. Statistical analyses were performed using PASW software version 17.0 (SPSS Inc., Chicago, IL). The level of significance was set at P = 0.05.

Results

Kinematics and kinetics data of the knee joint and trunk are shown in (Table 1) and (Figure 2). There was no significant difference in the peak knee flexion angle, the peak knee flexion moment, and the peak knee extension moment between the aided and unaided walking, while the peak knee adduction moment was smaller in aided walking (Table 1). With respect to the biomechanics of the trunk movement, the peak flexion angle and the peak angle to the non-operated side were significantly smaller in aided walking than in unaided walking, while the peak extension angle and the peak angle to the operated side was significantly larger in unaided walking (Table 1) and (Figure 2). The amount of coronal displacement of the trunk in aided walking was significantly smaller than in unaided walking (Table 1). The peak GRF normalized to body mass (mean (SD), 0.84 (0.07) in aided walking, 0.89 (0.07) in unaided walking) and average velocity of the center of pelvis (mean (SD), 0.67 (0.15) m/s in aided walking, 0.71 (0.16) m/s in unaided walking) were significantly smaller in aided walking than unaided walking (P < 0.05).

Table 1: Mean (SD) values of the kinetics and kinematics of the knee joint and trunk.

Variables	Aided	Unaided	Mean difference (95%CI)	P
Knee flexion angle (degrees)	16.9(6.0)	17.4(6.4)	-0.36 (-1.34, 0.62)	0.45
Knee flexion moment (Nm/kg)	0.23(0.13)	0.25(0.11)	-0.03 (-0.07, 0.02)	0.99
Knee extension moment (Nm/kg)	0.25(0.10)	0.25(0.13)	0.00 (-0.45, 0.45)	0.21
Knee adduction moment (Nm/kg)	0.32(0.11)	0.38(0.12)	-0.06 (-0.08, -0.03)	<0.001
Trunk flexion angle (degrees)	2.85(8.15)	3.86(7.94)	-1.01 (-1.55, -0.48)	<0.001
Trunk extension angle (degrees)	-0.26(8.02)	-1.06(7.80)	0.80 (0.34, 1.26)	0.002
Trunk angle to the operated side (degrees)	3.74(3.11)	2.65(2.98)	1.08 (0.40, 1.77)	0.004
Trunk angle to the non-operated side (degrees)	0.77(3.88)	2.08(3.61)	-1.31 (-2.11, -0.51)	0.003
Amount of coronal displacement of the trunk (cm)	4.62(1.35)	5.26(1.29)	-0.63 (-1.26, 0.00)	0.005

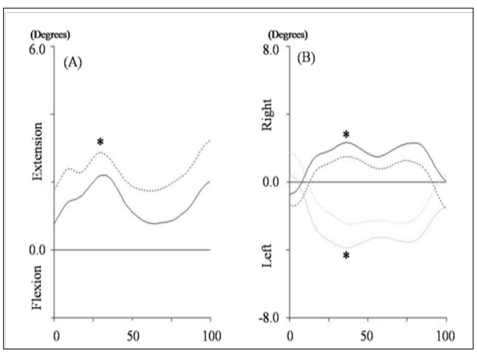

Figure 2: Trunk angle relative to the pelvis in sagittal plane (A) and coronal plane (B) are shown. Solid and dot lines indicate the aided and unaided walking, respectively. In the graph of the coronal plane (B), black and gray lines indicate the data of the patients who underwent TKA in his or her right and left knee, respectively.
*indicates significant difference (P<0.05).

Discussion

This is the first study that evaluated the biomechanical alteration in knee and trunk movement between aided walking and unaided waking after TKA. Using a cane during walking at the early postoperative period after TKA alters the kinematics and kinetics of knee joint and trunk. The use of a cane during walking decreases GRF by 5.6% and knee adduction moment by 15.8%. Our result is similar to previous studies that evaluated the effect of a cane in people with knee OA, which showed that the use of a cane decreased knee load by 10 % when using a cane in the contra lateral hand [27] Past reports documented that the strength of quadriceps and hamstring muscles declines to 50% of the preoperative level in the first four weeks after surgery [20]. Using a cane during the initial rehabilitation period may decrease the load on the operated knee and may be useful to avoid excess stress on the surgically invaded muscles. In regard with knee adduction moment, the use of a cane after TKA decreases knee adduction moment by 15.8%, which is in agreement with past gait studies following TKA which reported a peak knee adduction moment of between 2.5 and 3.0% (BW × Ht) [28-31].

In the current study, the thorax tends to tilt to the operated side relative to the pelvis during aided walking, resulting in a shift of the gravity center to the operated side, which may cause decrease of the knee adduction moment during aided walking. External knee adduction moment during gait is known to be a key variable in understanding frontal knee mechanics. Although, the clinical significance of a high knee adduction moment following TKA remains unclear, it has been proposed that there is a positive relationship between high knee flexion moment during gait and tibial component loosening [32]. Furthermore, a systematic review states a possible relationship between polyethylene wear in the medial tibia insert and postoperative knee adduction moment [33], but there is currently no study which clearly shows a direct relationship between greater knee adduction moment and mechanical failure following TKA.

Until now, few studies have been performed on the variation of trunk movement in knee OA patients pre- or post-TKA using a three-dimensional gait analysis system. The current study found that trunk tends to extend and tilt to the operated side relative to the pelvis with the use of a cane. Additionally, the amount of coronal displacement was decreased with the use of a cane, suggesting that thorax movement may be stabilized during walking. Our results are supported by the previous literature examining the alternation of trunk movement in patients with TKA, documenting that the maximal trunk speed to the non-arthroplasty side and the maximal trunk displacement to the arthroplasty side were both reduced in a medio-lateral direction after TKA [24]. As OA patients show weak muscle strength on the arthroplasty side, the reduction of trunk movement to the arthroplasty side with a cane has a beneficial effect on maintaining body balance and reducing falls. In regards with the sagittal plane of trunk movement, a previous biomechanical study has revealed that patients with TKA compensated for the deficiency of quadriceps muscles by leaning their trunks forward [21].

Another previous study has found the strong correlation between patients with kyphosis and falls after TKA [34]. It has been proposed that the trunk flexion has a biomechanical significance in that it may lead to falls [35], the use of a cane in the early period following TKA may be beneficial to prevent falls as it extend the trunk during walking. Our study has several limitations that need to be considered. Firstly, the study lacks a long-term follow-up. Functional recovery of the lower extremities and trunk movement after TKA is a long-term process, affected by many factors. Secondly, patients with unilateral knee OA may have some degenerative changes and slight pain at other joints of the lower extremities, and these may be factors limiting our results. Thirdly the small sample size could also affect the results.

Conclusion

Using a cane for walking during the early postoperative period following TKA alters the kinematics and kinetics of the knee and trunk, may decrease the load on knee joint, and stabilize the movement of trunk.

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