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Visual knee-kinetic biofeedback technique normalizes gait abnormalities during high-demand mobility after total knee arthroplasty☆,☆☆

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ABSTRACT

Background: Abnormal knee mechanics frequently follow total knee arthroplasty (TKA) surgery with these deficits amplifying as task demands increase. Knee-kinetic biofeedback could provide a means of attenuating gait abnormalities. The purposes of this study were as follows: (1) to describe the gait characteristic differences between patients with TKA and non-TKA adults during level (low-demand) and decline (high-demand) walking; and (2) where differences existed, to determine the impact of knee-kinetic biofeedback on normalizing these abnormalities.
Methods: Twenty participants six months following a primary TKA and 15 non-TKA peers underwent gait analysis testing during level and decline walking. Knee-kinetic biofeedback was implemented to patients with TKA to correct abnormal gait characteristics if observed.
Results: Patients with TKA had lower knee extensor angular impulse ($p < 0.001$), vGRF ($p = 0.001$) and knee flexion motion ($p = 0.005$) compared to the non-TKA group during decline walking without biofeedback. Patients with TKA normalized their knee extensor angular impulse ($p = 0.991$) and peak vGRF ($p = 0.299$) during decline walking when exposed to biofeedback. No between-group differences were observed during level walking. Groups were similar in age, gender, body mass index, physical activity level, pain interference and depression scores ($p > 0.05$).
Conclusion: Patients with TKA demonstrate abnormal gait characteristics during a high-demand walking task when compared to non-TKA peers. Our findings indicate that knee-kinetic biofeedback can induce immediate improvements in gait characteristics during a high-demand walking task. There may be a potential role for the use of visual knee-kinetic biofeedback techniques to improve gait abnormalities during high-demand tasks following TKA.

1. Introduction

Individuals who have undergone total knee arthroplasty (TKA) continue to report and display functional performance deficits, particularly during more physically demanding mobility tasks [1–3]. These findings are commonly observed, despite resolution in

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knee pain and improved patient-reported outcomes [4–6]. Challenges in restoring normal function of the knee are multifaceted though largely related to compensatory strategies developed by the arthritic process, the surgical intervention, reduced proprioceptive input from capsular/ligamentous tissues, lower limb weakness and kinematic alternations induced by the implant design [7–11].

Aberrant joint mechanics may be amendable to change through advancements in motor retraining techniques. Biofeedback modes include visual [12–16], haptic [17] or auditory [18–21] information to the patient that would otherwise be undetectable without the necessary technology. Biofeedback retraining has been understudied in the TKA population; however, recent studies incorporating visual weight-bearing retraining following surgery have shown improved gait characteristics to levels commensurate with non-TKA peers during low-demand level walking [22,23]. Joint mechanic deficiencies persist, despite weight-bearing biofeedback training when compared to tasks that require greater mechanical demand at the knee [22]. The mode of motor retraining may be important as abnormal knee-kinetics following surgery are consistently observed and a major contributor to functional limitations following surgery [4,24]. Lower sagittal plane knee extensor moments, relative to non-TKA peers, are one of the most common gait characteristic deficits reported in the literature [4,24]. Biofeedback used in altering foot angles, increasing medial knee thrust, weight-bearing corrections and trunk lean positions has also been shown advantageous in reducing abnormal stress to the knee; however, consensus on the optimal method still remains unknown [17,22,23]. Visual knee-kinetic biofeedback using sagittal plane internal knee extensor moments through computerized motion analysis has not been studied and can provide immediate assessment of compensatory patterns that may not otherwise be detected. This may offer a potential means of attenuating gait characteristic deficits during both low- (level walking) and high-demand (decline walking) mobility tasks [25]. To our knowledge, there are no peer-reviewed publications that have investigated knee-kinetic biofeedback during low- and high-demand walking tasks and its impact on normalizing gait characteristic strategies.

The purposes of this study were (1) to describe the gait characteristic differences between patients with TKA and healthy-matched non-TKA adults during both level (low-demand) and decline (high-demand) walking tasks; and (2) where differences existed, to determine the impact of knee-kinetic biofeedback on normalizing these gait characteristics.

2. Methods

2.1. Participants

After approval from the institutional review board and written consent obtained, a cross-sectional study was initiated using a convenient sampling of 20 participants (13 men; mean ± SD age, 63.5 ± 7.9 years; body mass index (BMI), 27.3 ± 4.7 kg/m^2) who underwent a primary unilateral TKA surgery between June 2015 and July 2017 and 15 healthy non-TKA peers (nine men; mean ± SD age, 65.3 ± 5.5 years; BMI, 26.4 ± 3.5 kg/m^2) matched a priori on age, gender, BMI and physical activity level (Table 1). All surgical procedures were performed by one of three fellowship trained joint reconstruction surgeons through a medial parapatellar approach. Implants included seven (35%) with a cruciate retaining design (Vanguard, Zimmer Biomet, Warsaw, IN, USA), seven (35%) with a bicruciate retaining implant (Vanguard XP, Zimmer Biomet, Warsaw, IN, USA) and six (30%) with a posterior-cruciate substituting implant (Triathalon PS, Stryker, Kalamazoo, MI, USA). All participants in this study met the following inclusion criteria: between 45 and 75 years of age; BMI less than 40; University of California, Los Angeles (UCLA) activity scale of greater than three; non-surgical knee pain less than or equal to four out of 10 on a visual analog scale for walking or stair climbing; no comorbidities that would have influenced balance or walking ability; no prior knee joint replacement procedure to either limb and no plans of undergoing a TKA on the contralateral limb within 12 months after the initial procedure. The non-TKA group had no confirmed diagnosis of knee arthritis; history of joint replacement or other lower-limb joint surgery that would interfere with their normal gait pattern. All TKA participants were recruited from the University of Utah, Orthopaedic Center (Salt Lake City, UT, USA) and non-TKA peers were recruited from the University of Utah, Center of Aging registry (Salt Lake City, UT, USA).

Table 1
Descriptive characteristics of participants by group.

Variable	TKA (n = 20)	non-TKA (n = 15)	p-Value
Age, y	63.5 (7.9)	65.3 (5.5)	0.452
Sex, n (% male)	13 (65.0)	9 (60.0)	0.762
Weight, kg	81.1 (13.7)	81.2 (15.3)	0.986
Height, m	1.72 (0.1)	1.74 (0.1)	0.399
BMI (kg/m^2)	27.3 (4.7)	26.4 (3.5)	0.528
UCLA Activity Scale, mean (range)	6.1 (4–9)	7.2 (5–9)	0.086
PF-CAT T-Score	47.6 (5.4)	52.8 (5.4)	0.009
PI-CAT T-Score	50.2 (8.6)	46.1 (7.9)	0.164
DEP-CAT T-Score	45.8 (8.3)	48.7 (5.2)	0.252

Note: Values represented as mean (SD), unless otherwise stated. Values for UCLA activity scale represented as mean (range). BMI, body mass index; UCLA, University of California Los Angeles; PF-CAT, physical function computerized adaptive testing; PI-CAT, pain interference computerized adaptive testing; DEP-CAT, depression computerized adaptive testing.

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